ORGANIC FARMING IN TROPICAL ISLANDS OF INDIA

Based on invited papers from faculty of ICAR Winter School
"Developments in Organic Farming in Tropical Islands in India" **is being organized by ICAR-CIARI, at Port Blair from 7-27th November, 2017.**

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Citation

B. Gangaiah, A. Kundu, K. Abirami, S. Swain, T. Subramani and S. K. Zamir Ahmed. 2017. Organic Farming in Tropical Islands of India, ICAR-Central Island Agricultural Research Institute, Port Blair, ***pp. 1-250.***

First Printed in: November, 2017

Number of Copies: 150

ISBN : 978-93-85418-30-3

Published by

The Director
ICAR- Central Island Agricultural Research Institute
Port Blair, 744 101

Printed at

Shri Vignesh Prints
65/33, Pudur 2nd Street,
Ashok Nagar, Chennai -600 083
Ph: 94449 36628, 94449 44196

FOREWORD
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ICAR-Central Agricultural Research Institute (ICAR-CARI) is working relentlessly since its inception on 23rd June, 1978 for the betterment of livelihoods of the farming community of Andaman & Nicobar Islands. After it's rechristening as Central Island Agricultural Research Institute (CIARI), its mandate has been extended to Lakshadweep Islands too. The island farming in both the islands has the innate adherence to ecosystem conservation and that is what the current organic farming tries to bring in. Agriculture is the most important pillar of island economy and source of livelihood for large section of population. Over the years, ICAR-CIARI has accepted full-fledged role for region specific research and imparting much needed technological backstopping & training to the front line extension officers, farmers, other stakeholders of not only islands but also beyond the islands. ICAR-CIARI has been closely working with administration to move the low profitable traditional farming into organic mode and to make it sustainable on long term basis. In this direction, the initiative of Government of India i.e. soil health card scheme in islands is duly supported by the CIARI. In this task of organic farming, CIARI has been entrusted with the responsibility of organizing a Brain storming session besides taking up the human resource development. In this direction, an ICAR sponsored winter school on "*Developments in Organic Farming in Tropical Islands in India"* is being organized by ICAR-CIARI, at Port Blair from 7-27th November, 2017.

The resource persons drawn from different parts of the country across specializations have come forward to share their knowledge with the trainees in the islands. They readily shared their knowledge in the form of a lecture notes that is being compiled as an edited book "*Organic Farming in Tropical Islands of India"* consisting of 42 chapters on almost all aspects of organic farming. I appreciate the editors and contributors of this compilation for their commendable efforts and hope that this will act as a reference material and also as a ready reckoner for all the extension scientist, development departments and policy makers. I take this opportunity to congratulate Dr. B. Gangaiah, Head, Natural Resource Management Division and his team for the work and bringing out this valuable publication.

27 November, 2017 **(A. Kundu)**

PREFACE

The two tropical islands of the country i.e. Andaman & Nicobar Islands and Lakshadweep Islands over which ICAR-CIARI has been mandated to work are known for traditional low external input homestead based farming systems. Marine fishing sector contribute enormously to the welfare of the farming (fishermen) community. Of late, there has been increasing emphasis on organic farming in light of plethora of opportunities emanating in this sector. To capitalize on the above scenario, the low external input farming of both the islands was contemplated to be transformed into organic one. This transformation is much easier in islands as compared to mainland as chemical input is either low or non-existent in some islands like Nicobar and Lakshadweep. With the integration of modern science, the traditional farming becomes organic, though it has several challenges. Lakshadweep Islands are ahead of Andaman in terms of certified organic acreage and is moving gradually towards completely organic. Lot of efforts are being made to make Andaman agriculture organic in phased manner. Significant information is generated by CIARI on organic farming.

To share this knowledge, an ICAR sponsored winter school on *"Developments in Organic Farming in Tropical Islands in India"* is being organized by ICAR-CIARI, at Port Blair from 7-27th November, 2017. The book "*Organic Farming in Tropical Islands of India"* is a compilation based on the lectures delivered by experts from different parts of the country including CIARI in the ICAR sponsored winter school. This book contains 43 chapters organized under 6 themes. In first theme: Organic Farming Concept, there are 4 chapters. In second theme: Organic Crop Management (Nutrition, Pests, Irrigation and Produce handling), there are 12 chapters. In third theme: Organic Livestock and Fish Production, there are 8 chapters. In fourth theme: Organic Crop Production, there are 8 chapters. In fifth theme: Organic Farming Impacts on farm Ecosystem, there are 8 chapters. In sixth and last theme: Organic Farming: Education and Socio-Economics, there are 3 chapters.

The editors are highly thankful to all the contributors for dedicating their valuable time in contributing their best information through their lecture notes that helped in creating this book for the benefit of not only trainees coming from various parts of the country and Islands, but also for the benefit of all stakeholders who are guiding the islands towards organic mode of farming. The help provided by Shri. Abbubaker (Senior Technician) Division of Natural Resource Management in typing, editing etc. tasks is duly acknowledged. The help rendered by all other staff of the Institute in one way or other in bringing out this publication are also appreciated. We hope the compilation will be useful to all those interested in promoting organic farming not only for these Islands but also in the main land India.

\27 November, 2017 **Editors**

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THEME I: ORGANIC FARMING CONCEPT

Organic Farming: Concept, Context, and implications to India and its tropical islands

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The use of term '*organic'* by human beings dates back to 1510s, originated from Latin *organicus*, *"serving as an organ or instrument,"* from Greek *organikos* "of or pertaining to an organ, serving as instruments or engines," from *organon* "instrument". Sense of "from organized living beings" is first recorded in 1778 (earlier this sense was in *organical*, mid-15c.). Organic may refer to: of or relating to an organism, a living entity. *Organic chemistry* is attested from 1831. The term '*organic'* was coined and used for the first time in agriculture by Jerome Irving Rodale in 1940 in his article published in Fact Digest. In context of organic farming it refer to: pertaining to, involving, or grown with fertilizers or pesticides of animal or vegetable origin, as distinguished from manufactured chemicals. Meaning "free from pesticides and fertilizers" first attested in 1942 (Encyclopaedia).

Organic farming has been defined / described by several persons and most important definitions are reproduced here in order of their time. As per the most comprehensive definition / description of organic farming given by Lampkin (1990), '*it is a production system that avoids / largely excludes the use of synthetic compounds (fertilizers, pesticides, growth regulators and livestock feed additives) while relying to a maximum extent on crop rotations, crop residues, animal manures, legumes, green manures, off farm organic wastes for nutrition and biological methods for pest control of crops. In livestock/ fish production, it entails use of organically produced fodders and feeds and non-chemical health management practices*'. Thus, it views soil as living system in which beneficial organism activities develops.

The Food and Agriculture Organization of the United Nations (FAO) defines organic agriculture as "a holistic production management system which promotes and enhances agro-ecosystem health, including biodiversity, biological cycles, and soil biological activity. It emphasizes the use of management practices in preference to the use of off-farm inputs, taking into account that regional conditions require locally adapted systems. This is accomplished by using, where possible, agronomic, biological, and mechanical methods, as opposed to using synthetic materials, to fulfil any specific function within the system." (FAO/ WHO, 1999).

The National Organic Standards Board, United States Department of Agriculture (USDA) (Lieberhardt, 2003) has defined organic as 'an ecological production management system that promotes and enhances biodiversity, biological cycles and soil biological activity. It is based on minimal use of off-farm inputs and on management practices that resource, maintain and enhance ecological harmony. This system of production focuses on soil conservation and soil building by largely excluding the use of synthetic chemicals and with maximum use of on-farm generated resources. USDA defined organic farming as "a system that is designed and maintained to produce agricultural products by the use of methods and substances that maintain the integrity of organic agricultural products until they reach the consumer. This is accomplished by using substances, to fulfil any specific fluctuation within the system so as to maintain long-term".

According to Scialabba (2007), organic farming is 'neo-traditional food system' that combines modern science with indigenous knowledge. The strongest benefits are its reliance on locally available resources that incur minimal agro-ecological stresses, cost-effective and fossil fuel independent.

IFOAM (2008) defines Organic Agriculture (OA), a production system that sustains the health of soils, ecosystems and people. It relies on ecological processes. Biodiversity and cycles adapted to local conditions, rather than the use of inputs with adverse effects. OA combines tradition, innovation and science to benefit the shared environment and promote fair relationships and a good quality of life for all involved.

Why renewed interest in organic farming

Organic farming is not new to the world. The ancient farming done till start of 19th century that is based on use of organic manure and human and animal (horses in the US and oxen in Asia) power is nothing but organic only. However, it has gradually paved way to new forms of agriculture (chemical) staring from developed world so as to support the needs of burgeoning population. The seeds of modern farming were sown with the invention of horse hoe by Henry Jethro William Tull in 1701 AD. It's upgradation as horse-drawn hoe and a seed drill in the early 19 th century resulted in start of agricultural revolution in England. It got further boost with development of *tractor* with an internal combustion engine in the US in 1910 (Rasmussen, 1973). With this, it became possible to till and operate large farms in developed world. With the start of *superphosphate* fertilizer manufacturing in England by middle of the 19th century, the inorganic farming made a beginning. At the same time, Fritz Haber, a German chemist has developed the process of ammonia synthesis that subsequently led to the manufacture of nitrogen fertilizer in Europe and the US. The cultivation of maize hybrids evolved in US through application of above N fertilizers developed has realized their attainable yields. The synthesis of Lindane {γ – hexa-chloro-cyclo-hexane also called as gammaxene or benzene hexa-chloride (BHC)} by Faraday in 1825 named after Dutch chemist 'Teunis van der Linden' for its isolation and description in 1912. Its pesticidal properties were established in 1942 and Imperial Chemical

Industries Limited (ICI) started its production and use in UK. Similarly the synthesis of DDT (2,2-bis (p-chlorophenyl), 1,1-trichloroethane) in 1874 and establishment of its insecticidal effectiveness in 1939 by P. Muller in Switzerland also paved way for use of pesticides in agriculture. The development of Nitrophenols (the first group of selective herbicides like rice herbicide fluorodifen and pesticide: parathion from precursor 4-nitrophenol) in 1933 followed by the development of growth regulator auxin based herbicides 2, 4-D and MCPA in 1940s (for broad leaved weed control). Thus, by the middle of the 20^{th} century, almost all components of modern agriculture entered into developed world agriculture. Independent India, traversed in the same path of developed world to address its growing food concerns quickly.

Over reliance on pesticides (more potent chemicals evolved over time) and their inefficient use has resulted in not only in killing of beneficial insects (predators, parasites and even pollinators) but also in accumulation of their residues in the food chain including water bodies above the permissible limits. The presence of pesticide residues even in breast milk of mothers and in the honey collected by honey bees shows the alarming situation. At this junction, Rachel Carson (USA) through her book '*Silent Spring'* in 1962 has highlighted the pesticide pollution concerns to the ecosystem including human beings. She termed pesticides as biocide and stated that chemical industry is giving misinformation (incomplete) about the impacts of chemicals and officials are accepting it unquestioningly. In India too such pesticide concerns arose with Endosulfan. Its aerial spray with helicopters in cashew plantations in Cheemeni estate, Kasargod (Kerala) from 1978 for containing the tea mosquito bug (*Helopeltis theivora)* menace has polluted not only the water bodies, but also people and animals drinking that water leading serious health problems. The health problems ranged from physical deformities, cancers, birth disorders and damages to brain and nervous system. The social movements emerged looking at sufferings of people that ran for many years have succeeded in banning endosulfon use in the region by 2003. On fertilizer front too, pollution problems have cropped up with the overuse of nitrogen (N). The water soluble fraction of fertilizer N as nitrate moving to water bodies enriched them. Drinking nitrate enriched water, infants (< 6 month age) developed *methaemoglobinemia* or *blue baby syndrome* (decreased oxygen carrying capacity of haemoglobin) disease. In nutrient enriched water bodies, algal bloom started that resulted in insufficient oxygen supply to biota leading to death of ecosystems (eutrophication). The ammonia and nitrous oxide from ammonification and denitrification processes of N cycle entering the atmosphere; have brought in the problems of acid rain and ozone layer depletion problems. Increased use of inputs (chemicals, ground water) have made soils saline and waterlogged making the farm lands less suitable or unsuitable for farming. The increased use of energy for agro-input manufacturing and farm mechanization etc. have contributed to green house gas emissions and thus to global warming that threatened the agriculture in many ways and also survival of human being on earth. Realizing and experiencing the above human health and ecosystem concerns with inorganic farming by developed world have renewed interest in organic farming (especially of food) that is devoid of fertilizer and pesticide use. The developing countries and even least developed countries of Africa have also evinced keen interest in organic farming for capitalizing on the organic market opportunities worldwide. Thus organic farming has gained prominence all over the world by now and is growing in leaps and bounds.

History / Evolution of organic farming (agriculture)

The organic agriculture that arose in early 20^{th} century has gone through the following three defined stages of evolution as adopted by the global organic movement (Arbenz *et al.,* 2015 and Niggli *et al.,* 2015) i.e. *Organic 1.0*: period of organic pioneers who developed the vision of organic agriculture; *Organic 2.0:* period of growth and marketing of organic in recent past and *Organic 3.0:* period for addressing the future challenges that aims at entering organic agriculture on the global stage.

Organic 1.0

The Organic 1.0 period was marked by the following important discoveries and events. The study on symbiosis between fungi and plant roots by Franciszek Kamienski between 1879-82 and naming this association as '*mycorrhiza*' by Albert Bernhard Frank in 1885 followed by the discovery of N - fixing bacteria by Hellriegel and Wilfarth (1888) and Beijerinck (1901) has enhanced the knowledge about biological aspects of soil fertility and the importance of soil fauna. The beneficial effects of FYM, green manure, compost, fermentation and minimum and non-inversion tillage on soil fertility were understood. The concepts and practices of farming (closed cycles, farms as organisms, holistic and spiritual thinking etc.) by 'Rudolf Steiner' in the form of lecture series that gave birth to bio-dynamic faming movement. Steiner in 1927 has introduced the trademark *'Demeter'* for food produced in biodynamic farming. Steiner's concepts were applied, verified and improved subsequently by scientists like E. Pfeiffer, L. Kolisko etc., transforming it into a robust system of biodynamic farming (Paull, 2011) on which research institutes were established in Järna (Sweden) and Darmstadt (Germany). Hans and Maria Müller, developed the organic-biological system in Switzerland based on practical experiences.

Lady Eve Balfour and Sir Albert Howard both from United Kingdom and Jerome Irvin Rodale and Rachel Carson of USA were the pioneers of organic agriculture. Lady Balfour in her Haughley Experiment, one of the first long-term studies started in 1939; compared organic with high external input conventional farming and tried to find out link between food quality and human health. She is a founder of IFOAM-Organics International at Bonn. Albert Howard, the Imperial Agronomist, has worked mainly on composting urban wastes, plant breeding, plant health and soil fertility in India at erstwhile Imperial Agricultural Research Institute, Pusa, Samastipur, Bihar. The Indore process of composting is his great contribution to organic farming. He promoted natural way of building soil and its fertility by use of deep rooted crops for recycling nutrients from sub soil, use of crop residues and green manures. He established the positive impacts of mycorrhiza on fruit trees. He wrote many prominent books like *The Waste Products of Agriculture: Their Utilization as Humus* (1931), *An Agricultural Testament* (1940) and *The Soil and Health* (1941) for furthering the cause of organic farming.

Rodale, using the term organic to indicate food grown without pesticides has built his concept of organic agriculture from the works of Louis Bromfield (Author of Malabar farm book), Dr. William Albrecht (Soils department, University of Missouri), Albert Howard and biodynamic farming movements. Rodale family establishing *Rodale Organic Gardening Experimental Farm* in 1940 and *Soil and Health Foundation* in 1947 has also started Rodale press which has its flagship publication magazine *Organic Farming and Gardening* (OFG) now renamed as *Organic Gardening*. He believed that healthy soil required compost and avoiding use of synthetic pesticides and fertilizers. Rachel Carson through her publication '*Silent Spring*' on 27 September, 1962 has documented the detrimental effects on the environment of the indiscriminate use of pesticides. Her demand has resulted in banning of DDT in the developed world.

In Italy, Alfonso Draghetti, working at Agricultural Research Station, Modena, published 'Principi di Fisiologia dell'Azienda Agraria' (Physiological Principles of the Farm) in 1948, in which he discussed how biological principles support the theory that the farm functions as a whole (Draghetti, 1948). Along with Francesco Garofalo, who founded the Associazione Suolo e Salute in Turin in 1969, and Ivo Totti, Draghetti is acknowledged as one of the fathers of organic farming research in Italy.

In Asia, Masanobu Fukuoka, a farmer who practised *do nothing* (no weeding, no ploughing, no fertilizer, no pesticides) method of natural farming in rice (summer) – Barley / rye (winter) system. Broadcasting mud pelleted seeds of crops in untilled soil, applied preceding crop straw, while clover cover cropping and sprinkling of poultry manure in lieu of fertilizers, allowed natural predators to take care of pests including weeds. His prominent books are: *The Natural way of Farming* and *The One Straw Revolution*.

In India, organic farming has its beginning with the evolution of Indore Method of aerobic composting by Sir Albert Howard (1929) and identification of role of mycorrhiza in fruit trees at IARI, Pusa, Bihar. Bangalore method of anaerobic composting by Archarya (1934) is also to be viewed as an important development in the field of organic farming in the country.

Organic 2.0:

The scientists have continued to encourage farmers to use organic methods of farming through the establishment of movement and founding of organic research institutes, associations and supporting groups. The first organic agriculture research institutions was founded privately by individuals viz., *Rodale Institute* in Pennsylvania, USA (1947); biodynamic research institute *'Forschungsring'* 1950 in Darmstadt, Germany (1950). The International Federation of Organic Agriculture Movements (IFOAM) was founded in 1972 at Bonn, Germany that gave the four basic principles: *Principle of fairness, Principle of care, Principle of health* and *Principle of ecology* (IFOAM 2005) are understood as inter-connected and formulated to inspire action. These principles offer guidance for research in organic agriculture. To date, most of these facilities and groups are located in western countries, but more recently, there has been increased organic establishment in developing countries. the Forschungsinstitut für biologischen Landbau (FiBL) i.e. *Research Institute of Organic Agriculture* which was established in 1974 in Oberwil, Switzerland. Its headquarters was moved to Frick, Switzerland, with branches in Frankfurt, Germany and Vienna, Austria; the Louis Bolk Institute in Driebergen, the Netherlands (1976); the Elm Farm Research Centre in Newbury, Great Britain (1982) and the Norwegian Centre for Organic Agriculture in Tingvoll, Norway (1986).

In India, Ministry of Agriculture, GOI has launched a National Project on Promotion of Organic Farming (NPOF) and to augment the research needs, a Network Project on Organic Farming (NPOF) under Project Directorate of Farming System Research (Now, IIFSR), Modipuram, Uttar Pradesh with 13 collaborating centres across the country was started. Also ICAR-National Organic Farming Research Institute (NOFRI) was established at Jadong, Gangtok, Sikkim (2016).

Publications in and funding for organic agriculture

For publication of scientific information related to organic agriculture, separate journals were started that includes *Biological Agriculture and Horticulture* (1982) and *The American Journal of Alternative Agriculture* (1986) renamed as *Renewable Agriculture and Food Systems*. In 2011, the International Society of Organic Agricultural Research (ISOFAR) journal *Organic Agriculture* was launched by Springer scientific publisher to meet the growing demand for scientific publications about organic agriculture research.

Organic agricultural research has received funding from private, NGO and public sources throughout the world, though its share is only 0.04% out of total agricultural research funding (40 billion US $ spent for conventional agricultural research) despite of accounting for 1% of purchases and farmland. Germany has the highest public spending of money on organic research i.e. 2% (87 m euros i.e 1.07 @ euro/ person) of the total spent on research during 2012 (Rahmann and Aksoy, 2014) as against its 4 billion euros (50 euros/ person) spending on conventional agriculture research. India has also increased its funding for promoting organic agriculture under various schemes like Paramparagat Krishi Vikas Yojana (PKVY) and also in North –East India since 2015.

Organic 3.0 : The base for Organic 3.0 research: future challenges of food and farming

Based on the insights and outcomes of organic agriculture till date, some key questions have been identified within the community (Rahmann *et al.*, 2016). Specifically, what is the future of organic agriculture and how can research help to solve future challenges for the food and farming sector with organic measures and strategies? What will be the role of science? The most important challenges for organic agriculture are to move from a purely agricultural perspective towards organic as an agri-food system view including the following: 1) Producing sufficient healthful, safe and affordable food for 9–11 billion 2) Reduction of pollution and greenhouse gas emissions derived from food production, processing, trading and consumption 3) Developing food chains driven by renewable energy and recycled nutrients 4) Adapting to climate change and mitigating greenhouse gas emissions 5) Protecting soils, water, air, biodiversity and landscapes and 6) Taking into account current and emerging ethics, food habits, lifestyles and consumer needs.

The strategy of organic 3.0 includes six main features, consistently promoting the diversity that lies at the heart of organic and recognizing there is ‘no-one-size-fits-all’ approach (IFOAM – Organics International and SOOAN. 2015) i.e. 1) *A culture of Innovation,* to attract greater farmer conversion, adoption of best practices and to increase overall productivity; 2) *Continuous improvement towards best practice,* at a localized and recognized level; 3) *Diverse ways to ensure transparent integrity,* to broaden the uptake of organic agriculture beyond third party assurance and certification; 4) *Inclusiveness of wider sustainability interests,* through alliance with many movements and organizations that have a complementary approaches to truly sustainable food and farming; 5) *Holistic empowerment from farm to final product,* to acknowledge the interdependence and real partnerships along value chains and also at the territorial level; and 6) *True value and fair pricing,* to internalize costs, encourage transparency for consumers and policy makers and to empower farmers as full partners.

What makes organic farming distinct from other farming systems?

The *traditional farming* of ancient times as well as the current times in regions (tribal areas, hilly terrains and regions like North-East India) where green revolution technologies have not reached even today due to various reasons, do meets the most important criteria of organic farming i.e. non-use of chemicals (fertilizers and pesticides) and genetically modified organisms (GMO), use of animal organic manures. However, the use of high yielding disease resistant crop varieties (including introduction of efficient green manures, cover crops, N fixing trees, and bio fertilizers) / livestock breeds; application of improved composting methods; use of microbial preparations for pest management and release / attraction of beneficial insects are there in organic farming only. Certification (of farm, produce, inputs etc) is another unique feature of organic farming.

Integrated farming (production) systems advocating the safe and integrated use of chemicals (fertilizers & pesticides) with other alternative options entails use of growth promoters, GMOs, use of growth promoters, unlimited fodder purchases. Thus it tries to address the ecosystem concerns (pollution) and thus is different from organic farming.

Organic farming also differs from *Sustainable Agriculture* (SA) systems like Low External Input Sustainable Agriculture

systems like LEISA are environmentally benign, economically viable (commercially competitive) and socially acceptable, (LEISA) as the later advocates the use agro-chemicals / external inputs to supplement local resources. Thus though SA can’t become organic farming systems.

Though the *biodynamic farming* (BD) of Austrian Philosopher, Rudolf Steiner is akin to organic farming, it has an additional feature of spiritual dimension (matter is never without spirit and spirit without matter). As per its belief, cosmic rhythm of constellation i.e. rhythm of sun, moon, planets and stars have strong influence on growth of crops, by using which a farmer have advantage. BD farming also has its own certification label *Demeter.*

Principles of organic farming

According to IFOAM (2005), Organic Agriculture (OA) is based on the following four principles

Principle of Health

OA is intended to sustain and enhance the health of soil, plant, animal, and human beings as one and indivisible. In view of this, it detests the use of fertilizers, pesticides, animal drugs and food additives that may have adverse health effects. Thus the principle of health aims at healthy soil, plants, animals, humans leading to a healthy planet.

Principle of Ecology

OA should be based on living ecological systems and cycles, work with them, emulate them, and help sustain them.

Principle of Fairness

OA should be built on the relationships that ensure fairness with regard to the common environment and life opportunities. Fairness is characterized by equity, respect, justice, and stewardship of the shared world, both among people and their relations to other beings. Ensure fairness to all levels and to all parties: farmers, workers, processors, distributors, traders, and consumers. The aim is to help provide everyone involved with a good quality of life, and contribute to food sovereignty and reduction of poverty.

Principle of Care

OA should be managed in a precautionary and responsible manner to protect the health and well-being of current and future generations and the environment. Practitioners of OA can enhance efficiency and increase productivity, but this should not be at the cost/risk of jeopardizing health and well-being.

Various forms of organic agriculture

The organic agriculture is practiced in different names though principles coalesce with each other. The different forms of organic farming are**:** *Biodynamic Agriculture; Panchgavya Krishi; Natural farming; Natueco Farming; Homa Farming and Effective microorganisms (EM) technology.* Details are given in other chapter of this compilation.

Where India stands on food security front

In Declaration of Human Rights in 1948, The United Nations has recognized the Right to Food and noted that it is vital for the enjoyment of all other rights. World Food Conference (1974) defined food security as "availability at all times of adequate world food supplies of basic food stuffs to sustain a steady expansion of food consumption and to offset fluctuations in production and prices". World Food Summit (1996) states food security exists when all people at all times, have physical and economic access to sufficient, safe and nutritious food to meet dietary needs and food preferences for an active and healthy life. FAO (2009) has emphasized that food security should be viewed from four dimensions: *availability*, *accessibility, utilization and stability*.

India through adoption of modern agriculture technologies that are based on yield enhancing (high yielding varieties / transgenic in cotton; fertilizers) and variability reducing technologies (irrigation, pesticides) has attained food security from *availability* point of view. This is evident from the highest food grain production achieved in 2016-17 i.e. 275.68 m t food grains (22.95 m t are pulses) as per 4th advance estimates released on 16th August, 2017 by DAC & FW, GOI. (http://eands. dacnet.nic.in/Advance_Estimate/3rd_Adv_ Estimates 2016-17_Eng.pdf). Similar attainments were also made by the country in horticulture (fruits: 90.18 m t; vegetables: 169.04 m t), animal husbandry (155.5 m t milk, 82.93 billion eggs) and fish production (10.80 m t) by 2015-16. In addition, the country has also emerged as a reliable exporter of several commodities like basmati rice, cotton, cashew nut, castor seed etc. in the world. The deficit of productions in commodities like pulses etc. is met through imports by the country. As per WTO's Trade Statistics, the share of India's agricultural exports and imports in the world agriculture trade in 2015 were 2.26% (Rs. 2, 13,556 crore) and 1.74%, respectively. The country is gearing itself to attain accessibility, utilization and stability dimensions of food security to each of its citizen at the earliest. Though the productions are in tune with the projected requirements of 2020-21 (Chand, 2007), meeting the 2050 projected population (1676 million; As per the NGO, People for Governance Report) demands is more challenging. This is because, GDP in the country between 2005-50 is expected an 11 fold increase (Foure *et al.,* 2010) which will drastically increase the purchasing power and thus increase the food demand (Alexandratos and Bruinsma, 2012) that is more oriented towards animal products (Figure 1). To ensure such food security we need to put question ourselves that *Can the current agriculture production ecosystem is able to meet such future demands of the country*?

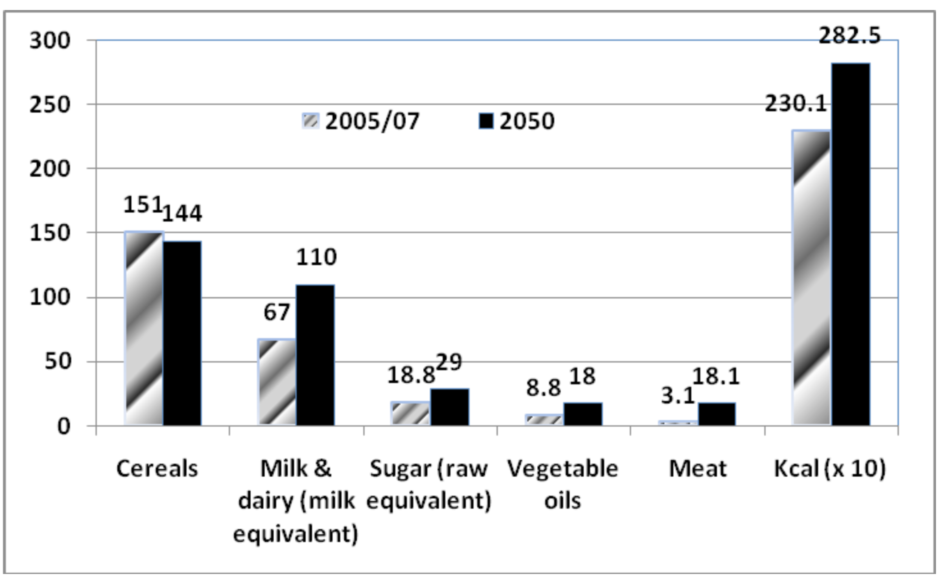

Fig. 1. India's food demand projections (kg/person/year) for base year 2005/07 and 2050 (Redrafted from original)

The current status of farming in the country indicates that net cultivated area is either static or decreasing year after year due to diversion of land to non-farming avocations (industry, service, housing) that are more remunerative and also partly due to soil degradation through salinity, water logging, multi-nutrient deficiency / toxicity problems. Between, 1960 and 2015, total fertilizer consumption (DOES, 2017) has increased over 91 times (0.292 vs 26.75 m t) and at present are consumed @ 130.66 kg/ha (84.84-34.08-11.73 kg/ha N-P-K). The bumper crops harvested under imbalanced fertilization (NPK) is leading to the emergence of new nutrient deficiencies (S, Fe, Zn, B, Cu, Mn Mo, etc.) in the soils. The pesticide consumption has reached 57,353 t (2014-15) while major irrigation potential has been tapped (95.77 m ha in 2013-14). The productivity of intensively farmed areas is either static or declining necessitating the country to concentrate on less intensively farmed areas for future growth. Initiatives like Bringing Green Revolution to Eastern India (BGERA) is one such initiative to produce more food in the country. Keeping aside such progress at country level, the meagre agricultural income of cultivators i.e. Rs. 1604 /month (NSS, 2012-13) and increasing indebtedness (35% cultivator households) are matter of grave concern to all. However, it seems pertinent and imminent for the country to travel in the path of modern agriculture (chemical) in future too. However, this chemical farming should be with orientation towards integrated concept. At this juncture, it is pertinent to ask *can India take any benefits from organic farming* for which world over there is an enormous emphasis.

India can definitely derive its share in the world organic farming without compromising its food security. The organic farming in India should be seen from the dimensions of (i) As an adjustment to ill effects of green revolution technologies; (ii) As an approach to tap the health conscious and elite consumers food and other agro-products market (both domestic and international; more international market) and (iii) As a way to ensure livelihood security by bringing in sustainable production in challenged areas of farming.

As an adjustment to ill effects of green revolution technologies

The modern agriculture practised since mid sixties in intensively farmed areas of the country have destroyed / depleted the very base of farming i.e. soil, water, air, biota. Over 14 m ha of intensively cultivated lands have registered a serious decrease in their soil fertility (Gardner, 1996). The emergence of multiple nutrient deficiencies especially that of micronutrients like manganese and copper in several parts of the country, limiting factor productivity of fertilizer nutrients is calling for addition of more and more nutrients.

The indiscriminate use of pesticides leaving behind their traces in crops beyond the maximum residue limits, particularly in crops like fruits, vegetables, spices etc. that are deleterious to human health and is therefore, a cause for public concern. Further, the use of non-genuine pesticides (accounting for > 40% of the pesticides sold in India in 2014) is not able to kill the pests or kill them efficiently. They also leave by-products which may significantly harm the soil and environment. The damage through such products is multifold. Apart from crop loss and damage to soil fertility, use of non-genuine products leads to loss of revenue to farmers, agrochemical companies and government. Thus adoption of organic way of production may prevent further deterioration of environment (by way of pollution and global warming also) and in long run may improve the same.

As an approach to tap the health conscious and elite stream of consumers

Sustainable consumption is one the millennium development goals, 2010, of United Nations. In this direction, consumers are showing great concern about their health, quality and nutritional value of food and the motivated and elite sections of the society prefer organic food. According to Organic Monitor, the global organic food and drink retail market was estimated at 80 billion US $ for 2014. Though the production and consumption of organic food was more popular in developed countries, it is rapidly getting acceptance in developing world as well. India is one such developing country of the world with largest area under organic management. Though export was the main force of organic production in India, in recent times domestic markets too are emerging big. If local productions are not arranged, the domestic consumers depend on imported products. Thus, enormous opportunities from elite consumers can be tapped for the advantage of stakeholders of farming in the country.

As a way to ensure livelihood security and sustainable production in challenged areas

The working group on organic and biodynamic farming, Planning Commission, Government of India have identified rain fed areas and regions of North-East as suitable niches for organic farming owing to their low or no input (especially chemical inputs) use (GOI, 2001). Rain fed production system spread over 60% of net cultivated area (141 m ha) of the country represents low input sustainable farming system with suitable integration of crops, pastures, trees, livestock etc. These low fertilizer consuming regions mostly growing pulses, oilseeds, cotton, minor millets can be easily brought under organic farming. In rain fed regions adoption of organic farming by way of large quantities of manure application will increase the water holding capacity of soils and result in more yields of crops. The better yields coupled with premium price of organic produce may enhance the profitability of farming in these regions.

Status of organic farming in India

Diverse agro-climates of the country with inherent traditional farming practices that are akin to organic farming made possible to produce a variety of organic products. The opportunity was explored fully by the country that is evident from the fact that the certified organic farming area grew over 17.2 times in the past decade (42,000 ha in 2003-04 to 7.20 lakh ha excluding forest area in 2014) that moved the country rapidly to 11th position in terms of world's organic agricultural land. Further, under forests and wild area for collections of minor forest produces, India has the 3rd highest acreage (4.22 m ha in 2015-16) in the world. India with 0.65 million registered organic producers in 2013-14 leads the world (Willer Helga and Julia Lernoud, 2016). India produced around 1.35 million tonnes (2015-16) of certified organic products (sugarcane, oil seeds, cereals & millets, cotton, pulses, medicinal plants, tea, fruits, spices, dry fruits, vegetables, coffee, cotton fibre, functional food products etc.) and organic food worth 298 million US$ (2,63,687 tonnes) were exported.

Programmes to promote organic agriculture in India

The Government of India in 2001 has launched the National Programme for Organic Production (NPOP) that involves the accreditation programme for Certification Bodies, standards for organic production, promotion of organic farming etc. The NPOP standards for production and accreditation system have been recognized by European Commission and Switzerland for unprocessed plant products as equivalent to their country standards. Similarly, USDA has recognized NPOP conformity assessment procedures of accreditation as equivalent to that of US. With these recognitions, Indian organic products duly certified by the accredited certification bodies of India are accepted by the importing countries.

Department of Agriculture & Cooperation (DAC) under the Ministry of Agriculture and Farm Welfare promotes various components of organic farming through its programmes viz. National Mission on Sustainable Agriculture (NMSA), Mission for Integrated Development of Horticulture (MIDH), Rasthtriya Krishi Vikas Yojana (RKVY) and 'Network Project on Organic Farming under ICAR'. National Project on Organic Farming (NPOF) which was started in the year 2004 has been concluded in March 2014. The existing components of organic farming have been put together under a programme called 'Paramparagat Krishi Vikas Yojana (PKVY)' to be implemented in a cluster mode from 2015-16, wherein it is proposed to increase certified area by 2 lakhs ha under organic farming (10000 clusters) within a period of 3 years. The financial assistance is provided (@ Rs. 50000/cluster) to clusters on components such as: 1) *Mobilization of farmers*: training of farmers and exposure visit by farmers 2) *Quality control*: soil sample analysis, process documentation, inspection of fields of cluster members, residue analysis, certification charges and administrative expenses for certification 3) *Conversion practices*: transition from current practices to organic farming, which includes procurement of organic inputs, organic seeds and traditional organic input production units and biological nitrogen harvest planting etc. 4) *Integrated manure management*: procurement of Liquid bio fertilizer consortia / Bio pesticides, neem cake, Phosphate rich organic manure and vermicompost 5) *Custom hiring centre charges*: to hire agricultural implements as per SMAM guidelines 6) *Labelling and packaging assistance & Transport assistance* and 7) *Marketing through organic fairs*.

Government has also made a budget announcement to develop commercial organic farming in the North Eastern States. This scheme is being implemented through Department of North Eastern Region. Further, easy certification through GGC and PGS are also considered. There are three components of organic farming under MIDH viz. adoption of organic farming, organic certification and establishment of vermi-compost units/organic input units.

In INM & Organic Farming component under NMSA, financial assistance is provided for: Setting up of mechanized Fruit/ Vegetable market waste/Agro waste compost production units; Setting up of State of art liquid/carrier; Setting up of Bio-fertiliser and Organic fertiliser testing laboratory or strengthening of existing laboratory under FCO; Promotion of Organic Inputs on farmer's fields; Support to research for development of organic package of practices specific to State and cropping system and Setting up of separate Organic Agriculture Research and Teaching Institute (against specific proposal).

To tap the North-East region potential in organic farming, a central sector scheme "mission Organic Value chain Development for North Eastern Region" (mOVcDNER) for implementation in the states of Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim and Tripura, was launched by GOI with a target area of 0.50 lakh ha to be covered under organic farming in 3 years (2015-16 to 2017-18) with an outlay of 400 crores. The scheme aims at development of certified organic production in a value chain mode to link growers with consumers and to support the development of entire value chain starting from inputs, seeds, certification, to the creation of facilities for collection, aggregation, processing, marketing and brand building initiative. The assistance is provided for cluster development, on/off farm input production, supply of seeds/ planting materials, setting up of functional infrastructure, establishment of integrated processing unit, refrigerated transportation, pre-cooling /cold stores chamber, branding labeling and packaging, hiring of space, land holdings, organic certification through third party, mobilization of farmers/processors etc. The progress reveals that during 2015-16 and 2016-17, Rs. 158.87 and 100 crore was allocated while Rs. 112.11 and 31.01 crore have been released to the states.

For easy certification, Participatory Guarantee System (PGS) as an alternative to third party certification was introduced. PGS are locally focussed quality assurance systems that are most appropriate for small farmers who can't afford certification costs. PGS certifies producers based on active participation of stakeholders and are built on a foundation of trust, social net works and knowledge exchange. India is the leading PGS beneficiary with 23317 producers involvement (21240 are certified producers).

Issues of organic farming

Organic farming is often seen as threat to food security of nation. The impact of conversion to organic mode of production must be looked from both food security of the nation and also from livelihood (income) security of the farming community. United Nations Conference on Trade and Development (UNCTAD) and United Nations Environment Programme (UNEP) reports indicate that organic farming as conducive for food security and sustainability in the long run. Studies of Paneerselvalm *et al.* (2015) in Tamil Nadu and Madhya Pradesh showed that large scale conversion to organic farming has improved the economic situation of farmers (5–40% in fertilizer subsidy scenario and 22–132% in no fertilizer subsidy scenario) although food production was reduced by 3–5% compared to the conventional system. It was also found that food production was higher under rain fed situations and lower in the irrigated situation with large-scale shift to organic farming. There is need of more research to understand the long-term impact of conversion to organic farming on food production, nutrient supply, food security and poverty reduction. The premium price obtained by organic produce owing to its preference by elite consumers may take away the food availability to other disadvantaged sections of the society. Organic farming is not advocated for adoption over entire country. In the event of blanket adoption of organic farming over the entire country, the available nutrient resources fall far short of the requirement. Same is the case with other agro-inputs (bio-pesticides etc). In light of this, the approach should be organic in selected pockets and integrated agriculture in rest of the country.

Though enormous opportunities are seen in organic farming, it do encounters plethora of challenges / constraints limiting its progress like i) Lack of awareness among stakeholders (farmers, consumers, researchers, planners), ii) Marketing problems: If premium price is not ensured at least during the period required to achieve the productivity levels of the conventional crop, it may not attract farmers acceptance, c) Shortage of manure: organic manure (biomass) availability is less than the required quantity also the available nutrient is less than the conventional manure. d) Less production: the production of organic farms is less than the conventional farms, e) High input cost: the costs of the organic inputs are much higher than the industrially produced chemical fertilizers and pesticides, etc. inputs used in the conventional farming system. f) Inadequate supporting infrastructure: lack of organic policies / credible mechanism to implement, inadequate accreditation and certifying agencies, educational and research needs of small-holders receive little attention.

Tropical Islands of India and their farming

Andaman & Nicobar Islands (ANI) and Lakshadweep Islands (LDI) are the two tropical islands of India (Fig 2). Andaman & Nicobar Islands are a group of 572 Islands (of which only 38 are inhabited) located in the Bay of Bengal between 6-14^0 N latitude and 92 - 94^0 E longitude as a long (North-South direction spanning over 700 km length) and narrow stretch (average and maximum width of 24 and 58 km) of landmass of rolling topography at about 1200 km away from (Chennai / Kolkota / Vizag) mainland. They are spread on ~0.825 m ha of geographical area. Lakshadweep Islands are a group of 36 islands (of which 11 are inhabited as per 2011 census) located in the Arabian sea between 8º - 12º 13" N latitude and 71º - 74º E longitude at about 220 - 440 km away from mainland (Kochi, Kerala) on a mere 32 km^2 geographical area.

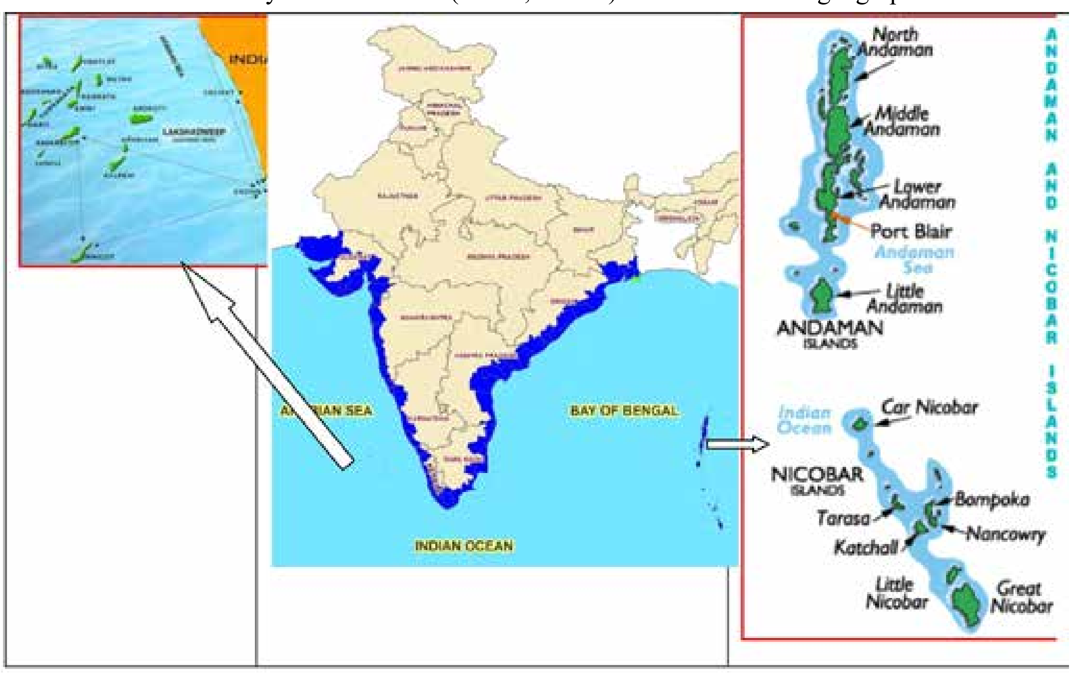

Fig.2.Tropical islands of India

The native Andamanes population was ~7000 in 1850s. With the increased contact with outside groups and arrival of settlers from the mainland (at first mostly prisoners and involuntary indentured labourers, later purposely recruited farmers), the population rose to 24,649 by 1901 and by 2011, they grew to 3, 79, 994. ANI has a very low population density (46 persons/km^2). Lakshadweep that has a population of 13882 in 1901 grew 64,473 in 2011 census (of the total population in 2011, 94.8% are Schedule Tribes). LDI have a very high population density (2013 persons/km^2).

History of Agriculture in Islands

History of agriculture in ANI reveals that native inhabitants of Andaman lived in isolation and depended for the food on forest products, fish and wild animals etc. for their survival and thus are unaware of crop culture. In Nicobar group of islands, the tribal's have been growing plantation crops like coconut and areca nut for centuries and used to exchange them for rice and cloth etc. with foreign shipper visiting these islands from China, Malaysia and Indonesia etc. For the first time, conventional agriculture in the islands was started with the establishment of small colony at Chatham Island in 1779 that was aimed to support the vegetables, tropical fruits etc. demands. However, due to aboriginal menace and diseases, this project was closed. The establishment of penal settlement during 1857 coupled with gradual increase of settlers by repatriation, land distribution was made in the islands, providing, each settler about 2 ha paddy land or 2 ha hilly land and 0.4 ha of homestead land. This marked the initiation of agriculture in these islands. By 1901, 10,198 ha of forest land were cleared of which 4,198 ha was put under cultivation. The expansion of agriculture by cutting forest ended with the Supreme Court ban order of 2003 on clearing forests even for logging industry for the sake of maintaining the ecological balance in the islands. Tsunami of 26 December, 2004 has resulted in loss of some cultivated area (6,000-7,000 ha) and at present 42, 839 ha (2013-14) is under cultivation. The land use pattern is dominated by plantation crops (coconut and areca nut with spices, fruit trees) in undulating lands and by rice in low lying areas in which vegetables do find a place (5,963 ha and 33,597 t during 2013-14). The crops are integrated suitably with livestock (cattle, buffalo, goat, poultry, pig etc.) rearing activities (68,713 households are involved in livestock rearing) and marine fisheries forms livelihood base of 14, 839 fisherman (36,426 t marine and 194 t fresh water fishes were sold in 2013-14).

The Department of Agriculture was established in 1945 to develop agriculture in ANI in a systematic manner. Up to 4th five year plan (1969-74) agricultural area expansion was emphasized. However, with the report of Mc Vean in 1976 on “Land use in the Andaman and Nicobar Islands”, which emphatically indicated these Islands as essentially forest terrains and not suitable for large scale agricultural settlement and agro-based enterprise, the thrust was diverted from area expansion to intensive agricultural practices in the existing area. Indian Council of Agricultural Research (ICAR) has started intervening in island agriculture development activities through establishment of regional stations of Indian Agricultural Research Institute (IARI), Indian Veterinary Research Institute (IVRI), Central Plantation Crops Research Institute (CPCRI) and Central Marine Fisheries Research Institute (CMFRI) for tackling specific problems. These stations were brought under an umbrella through establishment of Central Agricultural Research Institute (CARI) on 23rd June 1978 and was entrusted the mission of providing decent livelihood to farm youth from agriculture in a fragile island ecosystem on sustainable basis. For transfer of technologies, the Institute has three Krishi Vigyan Kendras (KVKs) situated at Sippighat (South Andaman Dt), Nimbudrea (North & Middle Andaman Dt) and Nicobar (Car Nicobar Dt).

In Lakshadweep, modern agricultural activities commenced in the year 1955 with the posting of an Agricultural Demonstrator at Agatti Island. During 1958, Agricultural Demonstration units were established in all inhabited islands and a separate department for Agriculture has come to existence under the UTL Administration. KVK was established under Lakshadweep administration in1998 at Kiltan Islands. With CARI rechristened as Central Island Agricultural Research Institute (CIARI) widening its sphere of activities to all island ecosystems of the country, KVK, Kiltan was taken over from Lakshadweep administration in August, 2016 that was relocated to Capital city, Kavaratti. Since, 1st April, 2017, CPCRI Regional station, Minicoy was also started functioning under administrative control of CIARI. Currently, the research work has been conducted under five divisions (Field Improvement and Protection, Natural Resource Management, Animal Science, Horticulture & Forestry and Fishery Science) and a section of Social Science.

Farming systems of tropical islands of India

Based on the *available natural resource base* **{**(land, water, grazing areas, forest; climate (including altitude); landscape (including slope) farm size, tenure and organization)} and *dominant pattern of farm activities and household livelihoods* (field crops, livestock, trees, aquaculture, processing and off-farm activities; and taking into account the main technologies used) farming systems in developing countries on a macro perspective are put under eight broad categories i.e. 1) *Irrigated farming systems*; 2) *Wetland rice based farming systems*; 3) *Rain fed farming systems in humid areas of high resource potential*; 4) *Rain fed farming systems in steep and highland areas*; 5) *Rain fed farming systems in dry or cold low potential areas*; 6) *Dualistic* (mixed large commercial and small holder) *farming systems*; **7)** *Urban based farming systems***;** and 8) *Coastal artisanal fishing mixed farming systems* (FAO, 2001).

Humid Tropical Coastal Artisanal mixed Fishing farming system of Andaman and Nicobar Islands and Lakshadweep

The coastal artisanal fishing mixed farming systems are estimated to be spread in developing world in over 70 m ha (11 m ha of cultivated land, of which 2 m ha is irrigated) and supporting 60 m agricultural population by FAO. In South Asia (Bangladesh, Maldives, India) coastal artisanal farming is adopted by ~18 m are agriculturists on 2.5 m ha of cultivated land (0.8 m ha is under irrigation) that supports 45 m population. In this estimate, Sri Lanka is not included though it falls in this farming system category. The island farming system of India is briefely mentioned below.

Andaman and Nicobar Islands: Islands are spread over 0.825 m ha geographical area supporting 0.38 million populations (2011 census) has a typical coastal artisanal fishing mixed farming system. The livelihoods are based on *artisanal fishing*. Artisanal fishing is a small-scale, low technology, low-capital, fishing practices undertaken by individual fishing households that are of coastal or island ethnic groups.They make short (rarely overnight) fishing trips close to shore, catch is usually not processed and is for local consumption. It uses traditional fishing techniques such as rod & tackle, fishing arrows and harpoons, cast nets, and small traditional fishing boats. It may be undertaken for both commercial and subsistence reasons. It contrasts with large-scale modern commercial fishing practices in that it is often less wasteful and less stressful on fish populations than modern industrial fishing. *Crop production* (often multi-storied coconut, areca nut plantations with spices, root crops as inter crops, cashew nut, oil palm, rubber are also seen in small scale and fruits; and rice and or vegetable cultivation) and *animal husbandry* activities (piggery, goatery, poultry, dairying; 68,713 households are connected with this activity in 2013-14) also forms major activities of farming. *Tourism* provides substantial gainful employment and income to the populace as a supplementary activity of farming or as an independent activity. The contribution of primary sector to GDP of islands is low (9.2% in 2013-14 of total 4220 crores). The objective of farming is not attaining self sufficiency (in wake of supplies from main land), but to produce the items that Islands is capable of and has a distinct advantage in the mainland or international market. The food grain and animal products production is done exclusively for the local consumption. There is a huge deficit in food grain production (only rice and small quantity of pulses are produced) that is met through shipments from mainland. Milk is also obtained from mainland to buffer the shortages but is in the form of milk powder. The plantation crops (especially coconut, areca nut), spices production and fishing (tuna) is done to cater to the needs of both local consumption as well as export to the main land. Tuna fish export is also done to international market to a small extent. The per caput income of islands (Rs. 89, 259/year in 2012-13) is comparable and better than many states of India that can be further improved if primary production problems are resolved.

In Lakshadweep Islands, the livelihoods are based on artisanal fishing and coconut production (on 2,751 ha by 10,285 farmers in 2011) and animal husbandry activities (goatery, poultry, dairying; 13,224 households are connected with this activity in 2012). Tourism provides substantial gainful employment and income to the populace as a supplementary activity of farming or as independent activity. The GDP of Lakshadweep islands was 370 crores and majority of it comes from farming. The objective of farming to produce coconut and coconut based products for local and mainland market. The animal products production (2.8 m litres of milk; 9.5 m eggs; 472.3 t broiler meat) is exclusively done for the local consumption. Nearly 90% of total households are rearing two to three goats for meat purposes and also to meet their daily requirement of milk to some extent. Chevon is the popular meat in Lakshadweep and people use it at all occasions especially marriages and religious functions. Due to scarcity of grazing lands, organized dairy farming is not encouraged. But household farming is being encouraged. There is a no food grain production in the islands and thus has to come from mainland (Kochi in Kerala and Mangalore in Karnataka) through ships. Fishing (tuna) is done to cater to the needs of both local consumption as well as to export to the main land. Of the total fish catch in Lakshadweep waters (12185 t in 2014-15), 92.2% is tuna only (CMFRI, 2015). The per caput income of Lakshadweep is Rs. 51,320/year in 2011.

Tropical Islands of India are ideal for organic farming

The islands are highly suitable for organic farming owing to the following reasons.

Physical isolation

Islands are separated from mainland by 200 (Lakshadweep) -1300 km (Port Blair) aerially and the agro-inputs of fertilizers and pesticides are to come from mainland through ships. The chemical inputs though reach to well connected capital cities (Port Blair, Andaman Nicobar and Kavaratti, Lakshadweep or even Minicoy) by ship / flight, their movement to other islands is more cumbersome and time taking. If the direct benefit transfer scheme for fertilizers is implemented in islands too, it may become more difficult to procure and use agro-inputs (due to poor dealer network) in coming times. This makes the farmers to either use low or no chemical inputs at all in farming. These small quantities of chemical inputs used can be easily met organically without reducing the productivity. Thus, it is easy to move in organic mode of production if all stakeholders unanimously decide to.

Low chemical input usage (below optimum) that can be easily replaced organically

The chemical-inputs (fertilizers and pesticides etc.) usage is one of the lowest in the country. In the island ecosystem (AEZ 20), farming (rain fed cultivation) is dominated by plantation crops that used 700 tonnes of fertilizer ($N+P_2O_5+K_2O$) in 2003-04 (FAO, 2005) at an average rate of 14.3 kg/ha (6.7+6.3+1.2 kg/ha, $N+P_2O_5+K_2O$) mostly in Andaman islands. The fertilizer consumption increased to 1091 t in 2014-15 in Andaman & Nicobar Islands (Table 1). In Lakshadweep, no fertilizers usage was reported and also permitted owing to the ecological considerations. Thus only 10% of the estimated fertilizer needs of crops in the Islands (10504 t NPK fertilizers i.e. 3100-2115-5288 tonnes of N-P-K) are used per annum (Table 2). The low fertilizer use coupled with inability to meet the nutrient demand through manures is primary cause of low productivities in crops. Pesticides are widely used in vegetable production only in the Andaman Islands especially in North & Middle Andaman district including Neil Island in South Andaman district (Neil Island was declared as organic now) and in coconut plantation of Lakshadweep (Table 3).

Table 1. Fertilizer use in Andaman & Nicobar Islands (2014-15)

Items	ANI	S. Andaman	N & M Andaman	Nicobar
Cultivated area (ha)	42359.6	9860.8	17843.7	14655
Fertilizer consumption (t)				
N	474.34	211.32	258.28	4.74
P	369.87	164.73	201.33	3.81
K	247.65	110.41	134.94	2.3
Total	1091.86	486.46	594.55	10.85
Application rate (kg/ha)	25.78	49.33	33.32	0.74

Table 2. Estimated fertilizer requirement of Islands (for 2014-15 ANI & 2011 LDI acreages)

Crops	Area (ha)	Recommended dose (kg/ ha)			Nutrient requirement (t/year)		
		N	P	K	N	P	K
Andaman & Nicobar islands							
Paddy	6435	90	60	40	579.2	386.1	257.4
Pulses	1575	20	60	40	31.5	94.5	63.0
Cashew nut	1133	150	50	150	170.0	56.7	170.0
Vegetables	5625	30	60	60	168.8	337.5	337.5
Areca nut	4670	120	50	160	560.4	233.5	747.2
Nutmeg, clove & cinnamon	231	200	100	200	46.2	23.1	46.2
Black Pepper	526	220	88	67	115.7	46.3	35.2
Ginger & turmeric	363	75	50	100	27.2	18.2	36.3
Coconut	21910	53	35	142	1161.2	766.9	3111.2
Fruits	3745	25	15	25	93.6	56.2	93.6
Total	**46213**				**2953.8**	**2018.8**	**4897.6**
Lakshadweep							
Coconut	2751	53	35	142	145.8	96.3	390.6
Total islands					**3099.6**	**2115.1**	**5288.3**

Table 3. Pesticide use in agriculture in islands and their districts (2013-14)

Item	Lakshadweep	ANI	S. Andaman	N & M Andaman	Nicobar
Pesticide: Dry (t)	**0**	8.6	2.6	5.5	0.5
Pesticide: Liquid (ltrs)	**700**	3719.1	1803.8	1776.05	139.25
Roban cake (t)	**0**	-	-	-	-
Fungicide : dry (t)	**0**	-	-	-	-
Fungicide : liquid type (t)	**335**	-	-	-	-

The currently used minimal quantity of fertilizers can be easily augmented through locally available organic resources. The annual waste generation from crops and livestock in ANI is 0.65 m t while that of Lakshadweep is 0.052 m t (Table 4). Assuming that all residues (crop and livestock) are recycled in farming systems through composting during which 60% weight of materials are reduced and the compost contains on an average of 0.75: 0.15:0.40 % N:P:K, could supply 3656 t of nutrients leaving a gap of 6538.2 t/annum (Table 5). The demand and supply gap by waste recycling was more in potassium followed by phosphorous and least in case of N. The N supply exceeds the demand in Lakshadweep islands. For meeting the balance nutrient requirement, vast forest litter is available in Andaman and Nicobar Islands that are spread on over 86.9% of its geographical area (7,17 069 ha). The forests which have a mean litter production of 3.13 t/ha/annum (Ravishankar and Gangaiah, 2016). Total litter availability from reserved and protected forests in Bay islands works out to 2.24 m t /annum. Inventory of the forest litter indicates the availability of 29, 7 and 6 kg of N,P and K /ha from forest litter. One tonne of forest litter contains around 0.0093, 0.0022 & 0.0019 t of N, P and K nutrients (Table 6). Reports indicates the critical C: N ratio of forest litter as 15:1 to 55:1 which makes that, nutrient can be made available to the crops from forest litter. It is re-estimated from the available data that, around 1,07,419 t of forest litter is required to meet the balance N requirement of 999 t (Ravishankar and Gangaiah, 2016). Similarly, 7,40,000 t and 19 23,684 t of litter are required to meet the P and K nutrient requirement (Table 7). As Andaman and Nicobar island soils are medium in available N, low in P & K, it is suggested that, 33% of forest litters from periphery may be collected for meeting the balance requirement of N and P. In respect of K, it is suggested that, from the 33% of litters, 1406 kg K requirement can be met and the balance of 2249 t needs to met through enrichment techniques.

There lies little scope for exploiting forests in Lakshadweep islands as they are non-existent. However, fish wastes could be ideal source for exploitation in promoting organic farming here. Poultry and goatery could also provide manures for promoting organic mode of farming.

Table 4. Availability of organic manures through plant / animal residues in Islands

Crop / Animal	Residue (t/ ha) / excreta production (t or kg/ animal/ year)	A & N Islands		Lakshadweep Islands	
		Crop Area (ha) / Livestock Population (no)	Total residue / excreta availability (t) / annum	Area (ha) / Population (no)	Total residue / excreta availability (t) / annum
Crop residues					
Rice	3	6435	19305	-	-
Pulses	5	1575	7875	-	-
Coconut	6.4	21910	140224	2751	17606
Areca nut	8.5	4670	39695	-	-
Vegetables	1.5	5625	8438	-	-
Fruits	1	3745	3745	-	
Sub total	**-**	***43960***	***219282***	***2751***	***17606***
Livestock wastes					
Cattle	7 t	45625	319375	3099	21693
Goat	185 kg	65321	12084	46497	8602
Buffalo	9.125 t	7863	71742	-	-
Poultry	25 kg	1165363	29134	164541	4114
Subtotal	**-**	***1284172***	***432335***	***214137***	***34409***
Total	**-**	**-**	**651617**	**-**	**52015**

Table 5. Balance sheet of nutrients

Nutrient	ANI			Lakshadweep		
	Require-ments (t)	Availability from plant residues / animal wastes (t)*	Balance requirement (t)	Require-ments (t)	Availability from plant residues / animal wastes (t)*	Balance requirement (t)
N	2954	1955	999	146	156	+10.0
P	2019	391	1628	96	31	65
K	4898	1043	3655	391	80.2	310.8
Total	**9871**	**3389**	**6482**	**633**	**267.2**	**365.8**

Table 6. Composition of nutrients from forest litter in ANI

Type	Litter fall (t/ha/year)	Total litter availability (t/ annum)	Nutrient content of litter (kg /ha)			Nutrient content (kg / t of litter)		
			N	P	K	N	P	K
Litter	3.13	2244426	29	7	6	9.3	2.2	1.9

Table 7. Litter requirement for meeting the balance nutrients in ANI

Nutrients	Nutrient Content (t /t)	Balance requirement (t)	Litter requirement (t)	Total litter availability (t/ annum)	% requirement of litter to meet the demand
N	0.0093	999	107419	2244426	4.79
P	0.0022	1628	740000		32.97
K	0.0019	3655	1923684.2		85.71

Islands need not be self reliant in production

Though food grains are produced in Andaman Islands (rice and pulses: mungbean, urdbean and pigeon pea) that is far behind their demand even in the largest area occupying filed crop of islands i.e. rice. In Lakshadweep and Nicobar Islands too no food grains are produced at all. There is a huge demand and supply gap for animal products (milk in both islands; egg, meat in Lakshadweep islands); vegetables (seasonally in Andaman and throughout the year in Lakshadweep islands) and fruits in both the islands. Even with concerted efforts, ANI can't be made self sufficient in production as no additional land is going to come under farming in light of Supreme Court ban on clearing additional forest land for any purpose including agriculture, while in Lakshadweep all available land is put under cultivation already. The production of coconut, marine fish (tuna) in both the islands and areca nut and spices in ANI far exceeds the local demand, hence traded in mainland India. Thus, the point of attention is that islands need not be self reliant in production of agricultural commodities as the deficits (lack) of production are met through shipping's from main land, India and this would be the biggest strength of the islands to resort to organic mode of production in commodities of surplus production or advantage. Coconut in both the islands and spices in ANI could be choice crop for organic farming and exploring the national and international markets.

Large biodiversity (especially forests) that can be tapped for organic farming both as source of organic manures, pesticides and wild collections in Andaman & Nicobar islands:

The Islands are bestowed with unique biodiversity that is a mix of both native (with similarities to Indo-Myanmar region in Andaman and Malaysia-Indonesian in Nicobar Islands) and introduced species from mainland India. This biodiversity could be exploited for keeping the pest induced losses at below economic threshold levels in both crops and livestock production systems done in organic mode. The vast forest lands could provide many wild collections (honey, underutilized fruits, tubers, vegetables and even medicines) that can be directly marketed as organic locally or in mainland. Pests (insect, diseases, and weeds) are the major threats to success of agriculture production and same holds true for livestock too (both in inorganic and organic mod of production and more loss causing in organic mode of production). Due to physical isolation, island crops are free from many dreaded diseases and pests as compared to mainland. In livestock, Haemorrhagic septicaemia (HS), Black quarter (BQ), Contagious bovine pleura-pneumonia (CBPP), Rinder pest, Anthrax, blue tongue, avian flu etc. diseases are not reported in the islands. This is same in case of fish too that has marine origin. Several plants with pesticidal and medicinal properties are available in the forests for control of crop/ animal pests (Abirami *et al.,* 2017).

Rain fed production system

Andaman & Nicobar Islands are bestowed with copious rainfall (3100 mm) year round. However, the rolling topography makes the rain water to find its way into oceans within an hour. Though small rivers are exploited for irrigation of small patches of vegetable crops, there lies little or no scope for creation of irrigation facilities for farming. In many places, water shortages are encountered even for drinking purposes. Moisture stress for cropping is seen during December- March/ April during which potential evapo-transpiration far exceeds the moisture availability. Non-exploitation of ground water owing to its saline nature further makes the system predominantly rain fed. This makes use of fertilizers limited. Thus many pollutants entering into agriculture production systems through ground water are curtailed. This is a boon to adoption of organic farming and exclusion of contaminates entering into food chain. In Lakshadweep, Fresh water resources of a durable nature are not available, thus affecting not only agricultural activity but also human life. These islands receive rainfall (1200-1600 mm) from South-West monsoons only with no storage facilities of rainwater in harvested structures for farming, prolonged moisture stress (October-April) is encountered by coconut. Low temperature desalinization of sea water and rain water harvesting from roof tops are resorted to for meeting human needs.

Majority of the Island farmers are small and marginal

Of the total 10285 holdings of Lakshadweep in 2010-11, 95.8 are marginal (<1 ha farm) and 2.6% are small (1-2 ha) holders and together operate 75.5% farm lands (Table 8). However in Andaman & Nicobar Islands, there are two times more numbers of farm holders, of which 42.2% are marginal and small holdings, but they operate only 11.8 farm lands. These farms with diversified enterprises can easily converted into organic farms.

Table. 8. Operational holdings and area farmed in Lakshadweep Islands and Andaman & Nicobar Islands (2010-11 census)

Farm size (ha)	Farmer category	Number of holdings	Area operated (ha)	Number of holdings	Area operated (ha)
		Lakshadweep Islands		Andaman & Nicobar Islands	
<1.0	Marginal	9854	1713	4626	2022
1.0-2.0	Small	267	364	4626	2022
2.0-4.0	Semi-medium	130	324	4830	6927
4.0-10.0	Medium	26	149	6274	16486
10-20	Large	8	192	1570	6727
Total		**10825**	**2751**	**21926**	**34182**

In light of above favourable conditions, islands can be targeted to become organic farm hubs. As on 2013-14, the certified organic area (ha) excluding forest area, in Islands is 1217.19 ha (321.28 and 895.91ha in Andaman & Nicobar Islands and Lakshadweep). If we add up forests also, large acreage will be under organic in ANI. The coconut and spices produced in large quantity in the Islands that are already traded in the mainland and foreign countries with low or no external input use can easily be shifted into organic mode that brings more income to the farmers. Cashew nut growing wildly or with low care could also be made organic easily.

How to proceed in organic way in Islands ?

Coconut homesteads conversion into organic mode of farming by integrating of nutrient enriching crops / cropping systems along with bio fertilizers and bio pesticides (local supplies to be arranged) addressing the nutrient and pest problems issues adequately required to be ensured. Integration of livestock breeds (local or improved with medium productivity) into homestead and utilizing their wastes (urine and dung) along with crop waste through vermicompost technology may come handy in furthering the organic farming promotion in islands. Besides tree spices, ginger and turmeric have immense scope for growing organically. Among fruits, pine apple as inert crop of coconuts can be targeted for organic production. Vast biodiversity from forests and fish wastes could widen the nutrition and pest management options in the islands. The medicinal plants wealth of the islands growing in their natural habitat could be explored for organic production. In this direction, the tribal forest dwellers and forest managers needs to be objectively engaged. Homestead farms being rain fed systems, use of manures are likely to enhance the water functions and thus may aid in offsetting the moisture stress induced production constraints over time. Back yard poultry could also be taken up in organic mode.

There are several challenges in path of becoming organic in Islands. Foremost one being optimization of local inputs to meet the nutrition and protection components from locally available organic resources. Setting of bio-fertilizer and bio-pesticide units may come handy in this direction. Input purchase and output marketing needs to be organized in cooperative mode. Output marketing must target the mainland and even foreign country customers as the local consumers may not be willing or able to bear the premium prices. Its volume is also small. Transport bottlenecks especially aggregation of organic produce (may be of small quantity) from distantly placed islands for marketing needs to be addressed. Local or centralized (better at UT capitals from where transport by air or ship to outside destinations) processing of organic produce (vegetable coconut oil, copra etc) may further the cause of organic farming. Decline in yields during conversion period may not be big in homesteads and thus no need to provide financial support to farmers. Certification (participatory guarantee mode) of organic produce and its branding needs to be attempted by stakeholders. Thus through concerted efforts of all the stakeholders, sustainability of livelihoods of farmers and their dependents can be brought in. Organic farming project initiation at CIARI under the aegis of AICRP mode from IIFSR, Modipuram, Uttar Pradesh may bring new leads to organic farming adoption in the islands. There is also need to contain the spurious organic market if any (not in Islands).

Conclusion

Organic farming is a way of life and can't be practiced as that of modern agriculture; continuous involvement of grower in the farm is essential to ensure production principles and requirements. If organized properly, it will bring rich dividends to coconut farming of Nicobar district and entire Lakshadweep islands instantly. In other parts of the Andaman & Nicobar Islands, it can be thought of after arrangement of proper logistics with willingness of all stakeholders only.

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Is organic produce nutritionally dense than conventional?

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Organic produce are defined as those foods that are grown without the use of synthetic fertilizers, sewage sludge, irradiation, genetic engineering, pesticides, or drugs. When talking about animals, organically raised animals are those raised with organic feed and kept free from growth hormones and antibiotics, as well as often times treated more humanely and given better areas to roam than their non-organic counterparts. Nowadays, food safety is receiving more attention than ever before by governments and policy makers, health professionals, the food industry, the biomedical community, and last but not least, the public also. Consumer concern, fuelled by several food scares has influenced food purchasing patterns, as well as several aspects of the political arena, international trade, and the farming industry. One such aspect has been the expansion of demand for organically grown food.

The preference for organic food has been associated with multiple factors that, in general, reflect an increased interest towards personal health, animal welfare, and environmental protection. Health-related issues seem to assume greater importance than other concerns, and notions about food safety are fundamental for purchasing organics. Consumers are questioning the ability of the modern food system to provide safe food, and perceive relatively high risks associated with the consumption of conventionally grown produce compared with other public health hazards. There is a widespread belief that organic food is substantially healthier and safer than conventional food, and consumers are willing to pay significant price premiums to obtain it. This perception is mainly due to the principles associated with organic food production. Organic farming is a production system that avoids or largely excludes the use of synthetic fertilizers, pesticides, growth regulators, and livestock feed additives. Information about the nutritional quality and health benefits of organic food crops would be of great interest to both consumers and producers. The National Organic Program (NOP) ensures that the production, processing and certification of organic foods match a comprehensive standard. Large farming or processing operations must be certified. Even smaller, uncertified organic operations must abide by certain labelling standards. Examples of more common labelling terms are as follows:

- ***100% organic:*** No synthetic ingredients are allowed by law.
- ***Organic:*** At least 95% of ingredients are organically produced.
- ***Made with organic ingredients:*** At least 70% of ingredients are organic and the other 30% are from a list approved by Government body.
- ***Natural or All Natural:*** Does not mean organic. These labels apply to meat and poultry products, which may not contain any artificial flavoring, colors, chemical preservatives, or synthetic ingredients. These food items must only by minimally processed (e.g., roasted, frozen) or if there is a physical process it is to simply separate the item (e.g., grind, separating eggs, and juicing fruit) and cannot be separated by chemicals or other unnatural means.

In general researchers found that organic produce had a 30% lower risk of pesticide contamination than conventionally grown fruits and vegetables.

Pesticide residue, heavy metal, nitrate and toxin in organic food crops

Pesticide residue

One of the major concerns of people buying organic food is pesticide residues. As organic farming prohibits use of synthetic fertilizers and chemical pesticides, there are growing evidences about lower level of pesticide residue. Some of these can travel in the air and remain for a very long time in the environment. These chemicals are just as likely to be present in conventional and organic systems that have been under conventional production previously. Some pesticides which are now prohibited (DDT, organochlorines) and environmental pollutants such as dioxins, furans, PCB's, and PAH compounds are found equally in organic and conventional fat and oil-containing foods (Kumpulainen, 2001). An American study found detectable levels of DDT in 17% of carrots tested twenty years after this pesticide was banned (Heaton, 2001). Pesticides can, however, reduce exposure to toxins when used to control mycotoxin contamination.

Heavy metals

High concentrations of heavy metals are another major concern among people who buy organic food. Lead, mercury and cadmium are often measured when considering food quality. The main sources of heavy metals are fertilizers and pesticides. Lead and mercury do not differ significantly between organic and conventional production because these heavy metals are normally found in very low concentrations in mineral fertilisers. These heavy metals are also not taken up by plants readily. No difference in lead and mercury were detected between organically and conventionally grown potatoes and carrots (Kumpulainen, 2001). Studies indicated that cadmium levels vary greatly between different areas and soil types. The main sources of cadmium contamination are aerial deposition, phosphate fertilizer and sewage sludge. There are a number of studies showing higher contents of heavy metals and especially cadmium from conventional grown products than from organic one (Zaccone et al., 2010). A few studies also report on higher cadmium (Cd) and lead (Pb) levels in organic tomatoes, but lower levels of Cu as compared to conventional ones (Rossi et al., 2008), and higher levels of nickel, Pb and zinc (Zn) in organic wheat, as compared to conventional. One explanation for higher levels of heavy metals in conventional than organic crops and crops based food might be the higher levels of Cd, copper and Zn in inorganic fertilizers that commonly have been used, although presence of heavy metals in conventional fertilizers has been reduced during recent years.

Nitrates

Forty-one studies reviewed by Woese *et al.* (1997) have addressed the nitrate content in vegetables from different cultivation systems. These studies presents no general findings confirming a lower nitrate content in vegetables from organic cultivation or vegetables grown with organic fertilisers. Mineral fertilisers seem to have a larger effect on nitrate content of potatoes than farmyard manure. Similar results were found in a study by (Warman and Harvard, 1998) where the only difference that could be observed in potato quality between systems using compost and inorganic fertiliser was tissue nitrogen, which was lower in organic potatoes. Not all vegetables and fruits are affected to the same level by the amount and type of fertiliser. Higher nitrate contents in conventional vegetables were mainly found in leaf, root, and tuber vegetables. These plants are nitrophilic, meaning that they tend to accumulate nitrogen quite easily compared to fruit, seed and bulb vegetables. These plants have lower nitrate-accumulating potential, and in most studies, have either equal or slightly lower nitrate contents in organically grown plants. One of the important elements effecting the nitrate contents of plants is weather. Leaching and volatilization can reduce the concentration of nitrates in crop fields and increase the contamination of the surrounding environment.

Microbiological toxins

Microbial infections are far more common than toxic substance problems with fruits and vegetable consumption (Williams *et al.*, 2000). They can arise from industrial processing in handling or microbes in soil or animal manures used for growing crops. Microbiological health hazards are more important than toxicological dangers, and may be more likely to occur in organic than in conventional farming because of the frequent use of organic fertilisers. However, Williams *et al.* (2000) state that there is currently no reliable data that can prove organic food is more likely to be contaminated with harmful microbiota. It has been suggested that organically produced food has higher levels of mycotoxin contamination because organic farming prohibits the use of fungicides. The comparison of the contaminant content in organic and conventionally grown raw materials showed no conclusive evidence whether conventional products are more or less safe than organic ones (Heaton, 2001). In fact organic farmers would contend that their crops are less prone to fungal diseases because high doses of nitrogen increase the growth rate of crops leading to a thinning of the plant cell walls making the crop more vulnerable to fungal attack.

Mineral and nutrient profile in organic crops vs conventional crops

It is too early to affirm that organic food is better than a conventional one, as regards safety and nutritional quality. Based on availability of research findings (LeClerc et al.,1991 etc), in organic farming with difference in management practices, various minerals presented in crops are presented in fig. 1 below. In organic farming, management of soil fertility affect soil dynamics and plant metabolism, which result in differences in plant composition and nutritional quality. Soil that has been managed organically has more microorganisms that produce many compounds to the benefit of plants, including substances such as citrate and lactate that combine with soil minerals and make them more available to plant roots. Nitrogen from any kind of fertilizer affects the amounts of vitamin C and nitrates as well as the quantity and quality of protein produced by plants. When a plant is presented with a lot of nitrogen, it increases protein production and reduces carbohydrate production. Because vitamin C is made from carbohydrates, the synthesis of vitamin C is reduced also. Moreover, the increased protein that is produced in response to high nitrogen levels contains lower amounts of certain essential amino acids such as lysine and consequently has a lower quality in terms of human and animal nutrition. If there is more nitrogen than the plant can handle through increased protein production, the excess is accumulated as nitrates and stored predominately in the green leafy part of the plant. Because organically managed soils generally present plants with lower amounts of nitrogen than chemically fertilized soils, it would be expected that organic crops would have more vitamin C, less nitrates and less protein but of a higher quality than comparable conventional crops. Potassium fertilizer can reduce the magnesium content and indirectly the phosphorus content of at least some plants. When potassium is added to soil, the amount of magnesium absorbed by plants decreases. Because phosphorus absorption depends on magnesium, less phosphorus is absorbed as well. Potassium is presented to plants differently by organic and conventional systems. Conventional potassium fertilizers dissolve readily in soil water presenting plants with large quantities of potassium while organically managed soils hold moderate quantities of both potassium and magnesium in the root zone of the plant. Given the plant responses just described, it would be expected that the organic crops would contain larger amounts of magnesium (27.8%) and phosphorus (14.3%) than comparable conventional crops (Fig. 1).

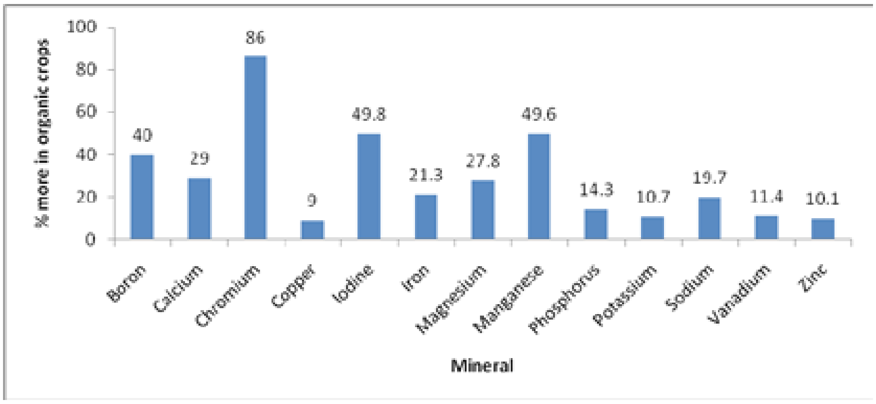

Fig. 1 Mean percent additional mineral content in organic compared to conventional crops.

Several kinds of fertilizers contain toxic heavy metals that enter the soil and are absorbed by plants. Phosphate fertilizers often are contaminated by cadmium. Also, trace mineral fertilizers and liming materials derived from industrial waste can contain a number of heavy metals. These heavy metals build up in the soil when these fertilizers are used year after year. As the soil becomes more contaminated, the crops grown on these soils also become more contaminated. When chemical nitrogen fertilizers are added to these soils, plants may absorb even more toxic heavy metals. As a consequence, it might be expected that organic crops would contain lower amounts of toxic heavy metals. Table 1 shows organic crops have a higher nutrient content in more than half of the comparisons. For the one toxic compound, nitrates, the organic crop had a lower content the majority of the time.

Table 1. Nutrient content of organic versus conventional crops: mean percent difference, level of significance, number of comparisons, and number of studies for statistically significant nutrients

Nutrient	Mean % difference*	Level of significance	Range	Organic higher	Organic lower	No difference	No. of studies
Vitamin C	+27	<0.001	2100%–507%	83	38	11	20
Iron	+21.1	<0.001	273%–1240%	51	30	2	16
Magnesium	+29.3	<0.001	235%–1206%	59	31	12	17
Phosphorus	+13.6	<0.01	244%–1240%	55	37	10	18
Nitrates	-15.1	<0.0001	297%–1819%	43	127	6	18

*Plus and minus signs refer to conventional crops as the baseline for comparison. For example, vitamin C is 27.0% more abundant in the organic crop (conventional 100%, organic 127%).

Table 2. Differences in nutritional content between organic and conventional vegetables

Vegetable	Nutrient*			
	Vitamin C	Iron	Magnesium	Phosphorus
Lettuce	+17	+17	+29	+14
Spinach	+52	+25	-13	+14
Carrot	-6	+12	+69	+13
Potato	+22	+21	+5	0
Cabbage	+43	+41	+40	+22

*Plus and minus signs refer to conventional crops as the baseline for comparison. For example, vitamin C is 17.0% more abundant in organic lettuce (conventional 100%, organic 117%).

This distribution of results is also evident when the results are compiled by study rather than by individual comparisons. Organic crop on average has a higher content of the four significant nutrients and less of the toxic nitrates. For example, the vitamin C content of an organic fruit or vegetable is 27% more, on average, than a comparable conventionally grown fruit or vegetable. Table 2 shows the results for the five most studied vegetables. Because there are fewer studies and a smaller number of comparisons for individual vegetables than there are for the whole data set, these results reflect more of the variability that is characteristic of agricultural data. Overall, the results for individual vegetables are similar to those for the entire data set.

Ngereza and Pawelzik (2016) found that the fructose, glucose content was higher in conventional mango and pine apple cultivars. However, manganese, calcium and magnesium contents were 33, 18 and 12% in organic than conventionally grown pineapple fruit. Organic mango cultivars were shown to have higher contents of phosphorus and potassium by 17 and 6%. Some researches, dealing with the characterisation of vegetables from organic production, showed that in some plants (mustard greens, lettuce and tomato), no significant differences in the content of β-carotene and ascorbic acid, in comparison with samples produced conventionally, were observed (Ismail and Fun, 2003). Other works, for example the six year study of Fjelkner-Modig et al. (2000), did not show significant differences in vitamin C content, expressed as dry matter, in parts of vegetables grown under organic or conventional mode. Obviously, especially when the substance under analysis is characterised by low stability, such as ascorbic acid or polyphenols, care should be paid to experimental conditions during sample preparation and analysis: the drying conditions could negatively affect easily oxidisable substances in the sample. It has to noticed that an irrigation deficit can constitute a powerful tool to improve food nutritional value, because of a reduced amount of water available to the fruit; thus, the dry matter content and concentration of nutrients in the fruit will increase. The content of other vitamins, or vitamin precursors, in real samples was observed to depend on the cultivation procedure.

Leclerc et al. (1991) found that organic fertilisation yielded higher β-carotene and vitamin B_1 contents in carrots. Moreover, other works showed no difference in lycopene content when comparing the effect of the cultivation system (Juroszek et al., 2009). Hunter et al. (2011) reported higher micronutrients in organically produced vegetables and legumes. On the other hand, a study by Laursen et al. (2011) making multielement fingerprinting of potatoes, fava bean, wheat and barley reported no systematic difference between organic and conventional crops or factors such as year and location in the content of essential plant mineral elements. Pires et al., (2015) studied nutritional characterization of organically and conventionally grown mango, Acerola and pineapple of different origins. For mango, significant differences ($P < 0.05$) between the two farming systems were only observed for Mg, K and Cr, with a higher Mg and K content in organic mango and a higher Cr content in conventional mango (Table 3). The latter finding might be explained by the use of chemical fertilizers containing Cr. Conventional acerola contained higher amounts of Ca, Fe, Mn and Mo than organic acerola ($P < 0.05$). Clark *et al.* (1998) showed that soil supply of C, P, K, Ca and Mg was higher in organic farming systems as a result of the type of fertilization and cultivation practices. An increased micronutrient content of organic foods is reported in different studies, but this small difference does not seem to have implications for consumer health.

Table 3. Mean concentration of minerals and trace elements in the edible portion on organic and conventional grown fruits

Nutrients	Mango		Acerola		Strawberry	
	Organic	Conventional	Organic	Conventional	Organic	Conventional
K	113.07*	67.28*	147.96	147.31	104.78	107.53
P	7.85*	6.71	20.30	24.28	22.82	20.82
Ca	5.48	7.01	14.12*	27.87*	13.50	13.61
Mg	8.39*	6.83*	15.71	17.62	11.64	11.65
Na	0.35	0.30	0.53	0.69	0.45	0.48
Mn	0.12	0.23	0.03	0.06*	0.13	0.15
Fe	0.01	0.12	0.18	0.27*	0.22	0.26
Zn	0.045	0.048	0.102	0.131	0.089	0.076
Cu	0.081	0.052	0.069	0.081	0.042	0.041
Se	0.016	0.013	0.004	0.004	0.007	0.007
Mo	0.006	0.005	0.005 *	0.011 *	0.011*	0.007*

*Significant difference between organic and conventional farming for each fruit and element ($P < 0.05$, Student *t*-test)

Sugar, starch, acid and dry matter

Woese *et al.* (1997) found no differences for both for the proportion of monosaccharides in total sugar and total sugar content itself. In studies on spinach, beetroot, carrots, celery and leeks, no difference was found in organic acids (malic, citric, oxalic, and total acid) (Woese *et al.*, 1997). Dry matter content seems to differ between production methods for some produce. In general, the dry matter content of above-ground (leaf) vegetables (studies done on spinach, chard, and savoy and white cabbage) was higher in organic crops, whereas no difference was detected in the dry matter and starch content of belowground (root and tuber) vegetables (Woese *et al.*, 1997). Also, no differences were observed either in dry matter content and sensory properties between organic and conventional fruits in experiments done by Lairon et al. (1983). Higher dry matter content in organic products can be explained by the fact that fertilisation is generally less intense in organic agriculture, and therefore organic fruit and vegetables are smaller and thus contain less water. The content of acids, sugars and dry matter is variable between fruit grown under the same production system. These variables are influenced by microclimate, maturity and other factors, making it difficult to differentiate based on production system alone. There does, however, seem to be a significant difference in dry matter content for some produce, between organic and conventional production.

Livestock Products

General statements on the quality of egg, meat, milk and dairy products from animals from different livestock farming practices is difficult, since despite specific organic guidelines, organic livestock production itself is characterized by heterogeneous farming conditions that allow for huge differences in the variability of nutrient resources, the implementation of feeding regimes, the use of genotypes, which all affects the nutritional quality of the livestock products. Organic and conventional meat production methods vary greatly, i.e. in animal material, composition and nutrient density in feed, livestock farming system, fattening period, final weight etc. Several studies and reviews focus on the meat quality in relation to sensory properties, technological factors and on hygiene and toxicological factors. Fat content and fatty acid composition are important aspects of nutritional quality. In general, it appears that the fatty acid composition of milk and dairy products is influenced by agricultural practice and studies (Anka et al. 2011) have shown that organic dairy products in general contain higher amounts of conjugated linoleic acid (CLA) and omega-3 fatty-acids than conventional dairy products. In addition, a study by Hermansen et al. (2005) showed a difference in several major and trace element levels in cow milk, due to agricultural practice. Again recent reviews on the topic are contradictory. Dangour et al.(2009) reviewed on nutritional quality of organic produce, found only nine satisfactory quality-livestock-product studies and found that it was only possible to do statistics on two parameters (fats and ash) and no differences were found. Smith-Spangler et al. (2012) reported that organic milk and chicken meat contain more omega-3 fatty acids than conventional products. In addition, a study by Angood et al. (2008) showed a difference in the fatty acid composition of lamb meat, due to organic and conventional production methods. However, factors such as season and brand of milk have also been shown to affect the fatty acid composition of dairy products and disrupt the cultivation system effect.

Phytochemicals in organically grown crops

Fruits and vegetables are rich source of phytochemicals with antioxidant properties. They contains wide array of phenolic compounds, carotenoids, vit-C and vit-E etc. Therefore, consumption of fruits and vegetables is thought to reduce the risk of many diseases, promote overall health. The amounts and types of phytochemicals in a plant are determined by a number of factors, including genotype, ontogeny, plant tissue, fruit size, stage of development and ripening, soil conditions, Irrigation, fertilizer consumption, season, location, and climatic conditions. The merit of the findings for comparison of organic vs conventional practice lies in careful control over above factors.

The content of the secondary substances from the phenolic compound group in plant products is therefore of great interest, and has led to more scientific studies comparing their contents in organic and conventional produce.

Examing evidence of improved phytochemical content in oraganically grown crops

The lack of consistent difference in vitamin and mineral between organically and conventionally grown crops has led to an increased interest often recommended. Due to various cofounding factor it is difficult to attribute difference between whole systems to specifics effects. It is not clear which variables in organic farming systems might have the greatest effect on the phytochemical content of crops. It has been postulated that the absence of pesticides, or the nutrient availability in the organic systems, induces or promotes production of phytochemicals in organically grown plants.

Ren et al. (2001) reported that organically grown onion, green pepper, and leafy greens showed 1.3 to 10.4 times higher quercetin concentration and possessed higher antioxidant and antimutagenic activities, compared with conventional crops from a nearby farm. Sousa et al. (2005) reported that organic cabbage tended to have higher total phenolic content in leaves than did conventional. Input of the chemical fertilizers and/ or pesticides in conventional farming systems might interfere with the biosynthesis of phenolic compounds in plants. Young et al.(2005) found no differences between organic and conventional lettuce, collards and pac choi for most flavonoids and phenolic acids evaluated, but did find significantly higher total phenolics inorganic pac choi. Pereira et al. (2016) studied the antioxidant activity of organic and conventional carrot, green pepper lettuce. The result indicated higher DDPH (1,1- diphenyl-2-picryl- hydrazyl) activity in organic samples. Salanandan et al (2009) reported choice of melon cultivar using conventional and organic production, respectively, enabled a 1.7- and 1.6-fold gain in total phenolics, a 2.6- and 4.2-fold gain in radical scavenging capacity determined by ABTS method, and a 1.8- and 2.4-fold gain determined by DPPH assay. Ngereza et al. (2016) reported antioxidant capacity and carotenoid content of 17 and 22% higher in organic mango compared to conventional one.

For vegetables, the results were variable and less clear. In some studies vegetables grown in organic production systems have higher content of some nutrients and secondary plant metabolites with antioxidant activity, while in other studies there was no effect of the growing system on the nutrients analysed. Also, the level of nitrate in some studies was lower and in other studies higher in organic compared to conventionally grown vegetables. Therefore, it is not possible to draw a clear conclusion on the effect of production system on nutrients and nitrate contents in vegetables. Therefore, it is not possible to draw a clear conclusion on the effect of production system on nutrients and nitrate contents in vegetables.

The majority of studies comparing the polyphenol content in plant products from different farm systems indicated a significant advantage of organic fruits and vegetables (Young et al., 2005). However, some authors have found a lower or similar level of phenolic compounds in organically grown vegetables and fruits are mentioned in table 4 below.

Table 4. The content of polyphenols in fruits and vegetables from organic and conventional production

Fruit/ Produce	Higher/lower/similar content in organic fruit or vegetable compared to conventional
Peach	Higher in organic
Pear	Higher in organic
Marionberry	Higher in organic
Frozen strawberry	Higher in organic
Frozen corn	Higher in organic
Orange peel	Higher in organic
Papaya peel	Higher in organic
Chinese cabbage Pac Choi	Higher in organic
Yellow plum	Lower in organic
Tomato	Lower in organic
Pear	Similar content
Lettuce	Similar content

The data show that organically grown fruits, and, to a lesser extent, vegetables, contain higher levels of secondary metabolites known as antioxidants and polyphenolics than conventionally grown fruits and vegetables. This information may enhance consumer confidence that organically grown food is better for one's health. Interestingly, many articles reviewed for this chapter link secondary metabolite synthesis to cultural production methods, namely, biotic and abiotic stresses (Young et al., 2005). With regard to biotic stresses, Anttonen et al. (2006) noted a relationship between increased disease pressure due to a lack of pesticide use and elevated levels of polyphenolics in organically grown foods. With regards to abiotic stresses, fertilization may be a key component of secondary plant metabolism. According to Stracke et al. (2009), organic fertilizers contain higher amounts of available phosphorous (a nutrient linked to increased photosynthetic activity) and less-available forms of nitrogen. Finally, conventional herbicides may decrease a plant's ability to perform carbon fixation (in effect, decreasing secondary metabolite synthesis. Further research is needed into how these stresses may translate into a biological benefit to humans in the area of disease prevention and maintenance.

Within the framework of "organics," crop genotype and organic management practices, as well as season and location, deserve systematic study. There are many organic production conditions, and they can significantly vary both within and among farms and regions. Without an understanding of the key components of organic farming in comparison with conventional production, it will be difficult to control the specific elements in organic systems correlated with improved phytochemical contents.

Testing of organic food for health benefits

Organically produced diets that had higher contents of quercetin and keampferol resulted in higher urinary excretion of quercetin and keampferol than conventionally produced diets, but the proportion of flavonoid excretion to the intake, as well as most biomarkers of antioxidative defense, did not differ between the two diets (Grinder-Pedersen et al., 2003). In another study comparing consumption of organic vs. conventional wines, no significant difference was found in terms of low density lipoprotein oxidation in human blood samples (Akcay et al., 2004). To assess thoroughly the potential for and benefits of phytochemical improvement in organic systems require interdisciplinary collaboration involving horticulturists and other including food scientists, nutritionists, entomologists, plant pathologists, biochemists. It is difficult to draw any definitive conclusions, although it seems that organic farming might have some potential for producing phytochemical enriched fruit and vegetables. Whether consistent differences will be found, and the extent to which biotic and abiotic stresses, and other factors, such as soil biology, contribute to those differences remains to be determined. Very likely, consumer demand for organically grown produce will continue to increase. Both consumers and producers will be well served by a clearer understanding of the benefits that might be expected from consumption of organically grown foods and of the production techniques that may be used to enhance crop nutritional value.

Contribution of organic foods to human health

Both animal studies and *in vitro* studies clearly indicate the benefits of consumption of organically produced food instead of that conventionally produced. Investigations on humans are scarce and only few of those performed can confirm positive public health benefits while consuming organic food. However, animal experiments are today routinely used to assess impact on humans in various other aspects and thus, the positive effects on animal from consumption of organically produced food can be regarded as an indication of positive effects also on humans. The reasons why organically produced food contributes to public health are unclear, as specific high amounts of nutritionally high value compounds with high antioxidant capacity do not seem to be the key for improved public health from organic food consumption. Instead synergistic effects of several constituents might be the back-ground for the possible positive effects of organic food, as well as absence of pesticide residues. The present review also did not find higher contents of nutritional beneficial compounds, with the exception of phenolic compounds, as an answer to increased amounts of pathogens, in organically cultivated crops than in conventionally cultivated ones. Some previous studies have indicated a higher vitamin C content in organically produced crops as compared to conventionally ones (Asami et al., 2003), as a response to increased amounts of pathogens. Vitamin C might be part of the synergistic constituents contributing to prevention against oxidation of other compounds although vitamin C in itself was not found to protect against proliferation of cancer cells. Extremely large variation of nutritional beneficial compounds was found in crops due to various reasons, and parameters contributing to the variation were: genotypes, farming conditions, environment, harvest time, crop part and genetic modifications of the crop. The highest values of specific nutritional compound were seen in specific genotypes and high increases were seen for genetically modified crops. These crops with very high values of certain compounds could be of relevance for cultivation and production of food in areas with a large deficit in that specific compound in the diet. For a general improvement in public health, it however, seems more relevant to focus on combining a "right" genotype with a "right" farming system, where organic farming could be an alternative. The low amounts of pesticide residues and heavy metals reported in organically produced crops might be one part of the reported bases for an anticancer effect of organic food. Table 5 lists the most recent studies, arranged according to the aforementioned three study types, e.g. in vitro/ex vivo studies, animal models and human in nutritional research.

Table 5. Effects of agricultural practice on health-related biomarkers in in vitro/ex vivo, animal and human studies

Study design type	Study design and exposure	Main effects of agricultural system
In vitro and *ex vivo*	Antioxidant effectiveness of organically or non-organically grown red orange extracts on Caco-2 cells	Higher phytochemical content and intracellular antioxidant activity in organic than non-organically red oranges
	Activity of apple extracts from organically or integrated systems on Caco-2 cells	Cultivation system had no effect on antioxidant, cytoprotective and antiproliferative activity
	Activity of organically or conventionally grown strawberry extracts on inhibition of cancer cell proliferation	Higher anti-proliferative activity of extracts from organically produced strawberries
Animal	Mice fed Danish or Italian carrots grown organically or conventionally in two consecutive years	Eating organic carrots induced some changes in the lymphocyte populations and lead to immune stimulation
	Rats fed complete diets composed of potatoes, barley, wheat, fava beans and rapeseed oil from three cultivation systems	Cultivation system had an impact on the nutritional quality, affecting amino-acids and fatty acid composition.
	Rats fed diets consisting of 40 % carrots grown under three cultivation systems	Cultivation system had no clear impact on carrot nutritional quality or the measured health-biomarkers
	Two-generation chicken study with feeds composed of six ingredients, grown either conventionally or organically	Jejunal gene expression (49 genes) was affected by the diets, including genes involved in the cholesterol biosynthesis and immunological processes
	Two-generation chicken study with feeds composed of six ingredients, grown either conventionally or organically	Chickens fed conventional diets had a higher weight gain, while those fed organic diets showed an increased immune reactivity, a stronger reaction to an immune challenge and subsequent stronger catch-up growth
	Rats fed complete diets of vegetables and fruit from three cultivation systems	Health biomarkers; α-tocopherol, IgG, daytime activity, liver metabolic function and liver lipid peroxidation were affected by cultivation strategies
	Rats fed diets containing conventional or organic wheat	Lymphocyte function was affected by cultivation system
Human	Intervention study: 18 subjects given complete diets, based on food products from three cultivation systems in two consecutive years	Growth system had no effect on the carotenoid content of the carrots or the plasma carotenoid concentrations in the humans
	Epidemiological study: Lactating women (310) with a conventional or alternative lifestyle	Lower 9(*trans*)18 : 1/11(*trans*)18 : 1-ratio in breast milk from women consuming organic meat and dairy products
	Epidemiological study: children at 2 years of age with a conventional or alternative lifestyle	Consumption of organic dairy products was associated with lower eczema risk. No effect of organic meat, fruit, vegetables or eggs

	Intervention study: 36 subjects given diets supplemented with blanched carrots of different cultivation systems	Cultivation system did not affect carotenoid content of the carrots or antioxidant, antigenotoxic and immunological effects.
	Epidemiological study: lactating women (312) with a conventional or alternative lifestyle	Higher level of CLA and TVA in the breast milk of women eating diets containing organic dairy and meat products, than in those eating conventional
	Intervention study: six subjects given organically or conventionally	No effect on antioxidant capacity

Organic dairy products and health

Breast milk serves as the primary/only nutrient source during the first period of life and in many cultures animal milk and dairy products contributes to the daily food intake lifelong. Most studies on health-related effects of consuming livestock products from different agricultural practices are related to dairy products and comprise human epidemiological studies, where the immune system and allergy has been the primary focus point (Table 5). Kummeling et al. (2008) showed that consumption of organic dairy products was associated with a lower risk of eczema in children at the age of two years. At the same time, results from the birth study found that mothers consuming organic dairy products had altered trans fatty acid (TFA) ratios (Mueller et al ., 2010) and higher CLA levels (Rist et al., 2007) in their breast milk, which coincides with studies (Anka et al., 2011) showing that organic dairy products in general contain higher amounts of CLA and omega-3 fatty-acids which are known immune-modulators. Omega-3 fatty acids are known to affect the immune system and a possible link between the fatty acid composition of the food intake and development of atopic diseases has been suggested. So, apart from eating organic diets and consuming organic dairy products there might be other aspects of consumer lifestyle that should be taken into consideration, such as dietary pattern and food quality when evaluating the epidemiological data.

Furthermore, it is reasonable to ask how the observed differences in nutrient content might affect a person's nutrient intake and health. Estimates of the nutrient content of organic and conventional daily vegetable intake were made, and the organic vegetables had higher amounts of all nutrients (Table 6). However, the health effects that might accrue from these differences in nutrient content have not been assessed to any extent. Animal studies suggest that such functions as reproduction and resistance to infection might be adversely affected by conventionally produced foods as compared to organically produced ones. The one existing human study reported that the percentage of normal sperm increased as the percentage of organic food in men's diets increased. Although preliminary, these findings are consistent with the results of the animal studies. Moreover, it should be noted that some of the animal studies included no pesticide usage at all so that the poorer outcome of the conventionally fed animals cannot be entirely attributed to pesticide residues. Soil factors appear to have an effect as well. In summary, this analysis found more iron, magnesium, phosphorus, and vitamin C and less nitrates in organic crops as compared to conventional crops. In addition, there were several trends showing less protein but of a better quality, more nutritionally significant minerals, and lower amounts of some heavy metals in organic crops compared to conventional ones.

Table 6. Nutrient content of an organic and Conventional diet: mg of vitamin C, Iron, magnesium, and phosphorus in one Day's vegetable intake

Diet	Vitamin C(mg)	Fe (mg)	Mg	P
Organic	89.2	3.7	80.0	124.0
Conventional	67.9	3.0	68.6	111.8

Many studies that have compared the taste and organoleptic quality of organic and conventional foods report no consistent or significant differences between organic and conventional fruits and vegetables. But among the well-designed studies that have found differences, the vast majority favour organic produce. The more intense flavors in organic fruits and vegetables probably stem from two factors: somewhat higher average levels of antioxidants, and somewhat lower average crop yields. Yield levels and the availability of nitrogen to crops clearly can alter both nutritional and organoleptic quality. The high yields achieved today in some fruit and vegetable crops have likely come at the expense of crop nutritional and organoleptic quality. Organic produce tends to store better and has longer shelf life, probably because of lower levels of nitrates and higher average levels of antioxidants. The former can accelerate food spoilage, while antioxidants help preserve the integrity of cells and some are natural antibiotics. More research is needed to refine methods for comparing the organoleptic quality of food and to establish reliable linkages between organic farming practices and enhanced quality. Progress in tracing the roots of food quality to core farm management practices will no doubt point the way toward farming systems that consistently deliver both good nutrition and great taste.

Conclusions

Even though researchers found that organic produce had a 30% lower risk of pesticide contamination than conventional fruits and vegetables, organic foods are not necessarily 100% free of pesticides. Organic crops have more minerals, vitamin C, less nitrates and less protein but of a higher quality than comparable conventional crops. It is a difficult task to compare conventional and organic agriculture in terms of nutritional quality of food, due to the sources of variability, complexity of study design and the multipart definition of the term 'health'. However, some systematic differences in the nutritional content, i.e. nitrogen, protein, vitamin C, phosphorous and phenolic compounds of plant products grown under different cultivation systems have been observed. The influence of these nutritional differences on the nutritional quality of the food and health is questionable and future studies should look beyond the generally measured nutrient components and maybe look for new interesting compounds such as secondary metabolites. A way to improve comparative researches on nutritional value of organic food is to unify the methodologies applied and to better consider the various factors influencing nutrients content of agricultural food. More research is needed both to verify these findings and to discover relevant mechanisms in both plants and soil. Either choice, organic or conventionally grown foods, eating fruits and vegetables along with lean proteins have health benefits that will help you and your family for years to come.

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National and International Status of Organic Farming and Policy Issues

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Organic Farming has emerged as global interest with significant benefits on social, economic and environmental issues. It has shown positive effects on climate change mitigation especially by enhancing the soil carbon sequestration. Similarly, it is also considered ecosystem-friendly because of its emphasis on minimum tillage and reduced use of pesticides, herbicides and synthetic fertilizers. Organic agriculture is considered to play a major role in fighting against desertification, preserving biodiversity, contributing to sustainable development and promoting animal and plant health. The growing interest of consumers and markets worldwide in organic products has also opened new trade opportunities for developing countries, through internationally recognized certification.

The national fortitude was so intense that all the attention was focused on the increase in agriculture production, resulted in increased in food grain production but later it was realized that this has been achieved at the cost of the nature and environment, which support the human life itself. This modern system of farming or chemical farming which is characterized by mono-cropping of some selected high yielding varieties, heavy use of chemical fertilizers, insecticides, herbicides etc. is becoming unsustainable or self-destructive as evidenced by declining crop productivities, loss of biodiversity, damage to environment, chemical contaminations, *etc*. Hence, there is an urgent need for an alternative agriculture method which can function in a friendly eco-system while sustaining and increasing the crop productivity.

Organic farming is thought of as the best alternative to avoid the ill effects of conventional chemical farming. Furthermore, organic farming reduces the vulnerability of the farmers to climate change and variability by comprising highly diverse farming systems and thus, increases the diversity of income sources and the flexibility to cope with adverse effects of climate change and variability, such as changed rainfall patterns. This leads to higher economic and ecological stability through optimized ecological balance and risk-splitting and by low-risk farming strategy with reduced input costs and, therefore, lower risks with partial or total crop failure due to extreme weather events or changed conditions in the wake of climate change and variability.

Organic agriculture offers the most sustainable solution for developing the agricultural sector and provides food security with least negative impacts on the environment and also offers solutions for sound rural development, provides healthy food and creates jobs. The demand for organic produce is very high, hence, cost of organic products is 2–3 times higher than the conventional ones depending on the products and area. Organic agriculture avoids nutrient exploitation and increases soil organic matter content. Consequently, soils under organic farming capture and store more water than soils under conventional cultivation. Crops and crop varieties used in organic farming are usually well adapted to the local environment. Naturally, organic agriculture (OA) is an adaptation strategy that can be targeted at improving the livelihoods of rural populations and those parts of societies that are especially vulnerable to the adverse effects of climate change and variability. Very rough estimates for the global mitigation potential of OA amount to 3.5-4.8 Gt CO_2 from carbon sequestration (around 55-80 per cent of total global greenhouse gas emissions from agriculture) and reduction of N_2O by two-thirds (Niggli *et al.* 2009). An organic production system is thus mainly designed to:

- Enhance biological diversity within the whole system;
- Increase biological activity in soil;
- Maintain long-term soil fertility;
- Recycle wastes of plant and animal origin in order to return nutrients to the land, thus minimizing the use of non-renewable resources;
- Rely on renewable resources in locally organized agricultural systems;
- Promote the healthy use of soil, water and air as well as minimize all forms of pollution, thereto, that may result from agricultural practices; and
- Handle agricultural products with emphasis on careful processing methods in order to maintain the organic integrity and vital qualities of the product at all stages (Preface, Codex Guidelines).

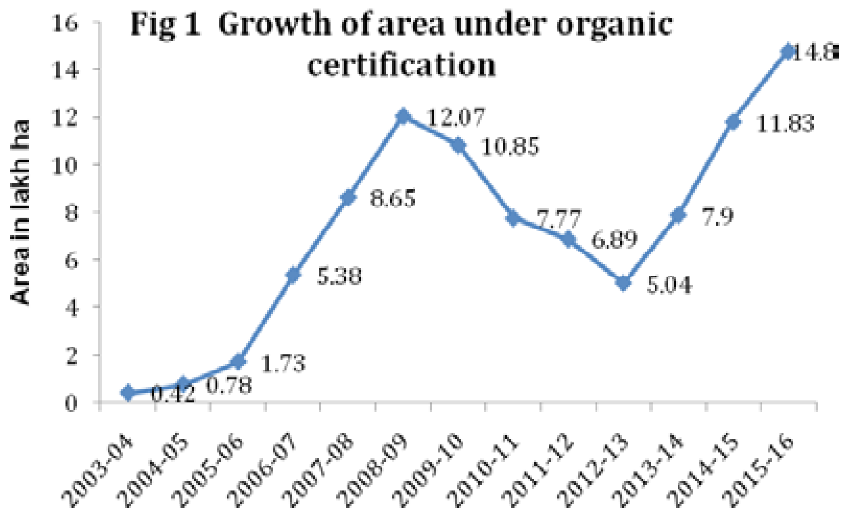
What is Organic Farming?

Organic agriculture is holistic production management system which promotes and enhances agro-ecosystem health, including biodiversity, biological cycles, and soil biological activity. Organic production systems are based on specific and precise standards of production which aim at achieving optimal agro-ecosystems which are socially, ecologically and economically sustainable. IFOAM defines “organic agriculture” as: “*a production system that sustains the health of soils, ecosystems and people. It relies on ecological processes, biodiversity and cycles adapted to local conditions, rather than the use of inputs with adverse effects. Organic agriculture combines tradition, innovation and science to benefit the shared environment and promote fair relationships and a good quality of life for all involved.”*

The World of Organic Agriculture

As per the statistics compiled by the IFOAM and FiBL (Anonymous 2016) world over 43.7 million ha land (1% of total agricultural land) is being managed organically by 2 million producers in 172 countries. Besides, there is another 37.6 million ha being certified for wild harvest collection. Global sales for organic products have reached 80 billion US$ with US and Europe being the largest consumers.

As on March 2016, India has brought 57.0 lakh ha area under organic certification process, which includes 14.8 lakh ha cultivated agricultural land and 42.2 lakh ha of wild harvest collection area in forests. Growth of cultivated farm area under organic farming during different years is presented in Fig. 1. Reduction in the area during the period from 2009-10 to 2012-13 was attributed to the loss of area under cotton due to introduction of BT cotton.



During 2015-16, India exported 2.64 lakh MT of organic products belonging to 135 commodities valuing at US$ 285 million (approximately INR 1900 crore). Domestic market is also growing at an annual growth rate of 15-25%. The major share of exports was oilseeds, cereals and millets and processed foods with a combined share of around 91%. In the oilseeds category, soybean with exports of 1.26 lakh tons during 2015-16 had a share of about 95%. In cereals and millets category, rice, maize, wheat and coarse millets are being exported. In the rice category the quantity of basmati rice exported was around 10300 tons. As per the survey conducted by ICCOA, Bangalore domestic market during the year 2012-13 was worth INR 600 crore which has now grown to more than 1000 crore during 2014-15.

Status of organic farming in India

Indian agriculture should be able not only to maintain but also must strive to increase the production of food grains. Organic agriculture started in India in 1900 by Sir Albert Howard, a British agronomist in North India. Development of Indore Method of aerobic compost (Howard, 1929), Bangalore method of anaerobic compost (Archarya, 1934), and NADEP Compost (ND Pandari Panda, Yeotmal, 1980) initiated organic agriculture in India. Nevertheless, India is bestowed with lot of potential to produce all varieties of organic products due to its varied agro-climatic regions. This holds promise for the organic producers to tap the market which is growing steadily in the domestic market related to the global export market. India can emerge as global leader due to the presence of large number of organic producers (almost 7 lakh producers). As regards the availability of major organic nutritional inputs (NPK) in India, the estimate of National Centre of Organic Farming, Ghaziabad is given in Table 1.

Table 1: Availability of organic nutritional input in India

Organic nutrient input	Quantity
Crop residue	3.865 million tonnes
Animal dung	3.854 million tonnes
Green manure	0.223 million tonnes
Bio-fertilizer	0.370 million tonnes

As per the available statistics, India's rank in terms of World's Organic Agricultural land was 15 as per 2013 data (FIBL & IFOAM Year Book 2015). The total area under organic certification is 5.71 million hectare (2015-16). This includes 26% cultivable area with 1.49 million hectare and rest 74% (4.22 million hectare) forest and wild area for collection of minor forest produces. Area under organic management in India is continuously increasing. India produced around 1.35 million tonnes (2015-16) of certified organic products. During 2012-13, India exported 1,65,262 MT of 135 varieties of organic products valued at EU € 268.58 million (INR 2074.78 crores). In the same period, the domestic market grew annually at

15-25%. A survey conducted by ICCOA (www.iccoa.org) found the domestic market in 2012-13 to be worth INR 600 crores. Tea is currently the most common product produced by means of organic farming in India. The most common organic products being exported from India are organic tea and spices. Vegetables and fruits are the major organic products desired by the Indian customers (Org-Marg, 2002).

India has the potential to produce range of organic products due to its agro climatic variability. In several parts of the country, the inherited tradition of organic farming is an added advantage. This holds promise for the organic producers to tap the market which is growing steadily in the domestic market related to the export market. The Government of India has implemented the National Programme for Organic Production (NPOP). The National Programme involves the accreditation programme for Certification Bodies, standards for organic production, promotion of organic farming *etc*. The NPOP standards for production and accreditation system have been recognized by European Commission and Switzerland as equivalent to their country standards. Similarly, USDA has recognized NPOP conformity assessment procedures of accreditation as equivalent to that of US. With these recognitions, Indian organic products duly certified by the accredited Certification Bodies of India are accepted by the importing countries. With regards to production, India produced around 1.24 mt of certified organic products which includes namely sugarcane, cotton, oilseeds, basmati rice, pulses, spices, tea, fruits, dry fruits, vegetables, coffee and their value added products. The production is not limited to the edible sector but also produces organic cotton fiber, functional food products *etc.* Among all the states, Madhya Pradesh has covered largest area under organic certification followed by Himachal Pradesh and Rajasthan. The state wise area under organic farming during 2013-14 is given in Table 2.

Table 2. State-wise area under certification process and state-wise certified organic production available for sale as organic commodities (production excludes quantity sold locally or for home consumption)

S No.	State Name	Organic Area (in ha)	In Conversion area (in ha)	Total area (in ha)	Total production available for sale
1	Andhra Pradesh	7710.127	10541.459	18251.586	6565.491
2	Arunachal Pradesh	221.250	3964.010	4185.26	0
3	Assam	5092.332	23340.912	28433.244	9543.558
4	Bihar	0.000	91.700	91.7	0
5	Chhattisgarh	1930.214	8654.725	10584.939	5847.675
6	Goa	15377.853	1579.740	16957.593	4815.761
7	Gujarat	46498.560	30314.504	76813.064	55466.237
8	Haryana	4469.581	399.467	4869.048	5133.963
9	Himachal Pradesh	4590.531	8168.594	12759.125	1329.243
10	Jammu & Kashmir	6599.795	18915.215	25515.01	15784.198
11	Jharkhand	100.706	30263.027	30363.733	0
12	Karnataka	26438.320	67525.020	93963.34	280935.789
13	Kerala	12350.178	13549.217	25899.395	10574.544
14	Lakshadweep	895.332	0.189	895.521	42.180
15	Madhya Pradesh	198460.263	263314.463	461774.726	364088.178
16	Maharashtra	74100.761	124251.528	198352.289	361565.693
17	Manipur	0.000	251.400	251.4	0
18	Meghalaya	1410.882	3198.540	4609.422	772.293
19	Mizoram	0.000	213.800	213.8	906.087
20	Nagaland	991.660	5195.274	6186.934	40788.120
21	New Delhi	10.800	12.230	23.03	0
22	Odisha	38614.932	57282.049	95896.981	0
23	Pondicherry	0.000	2.835	2.835	0
24	Punjab	500.398	460.805	961.203	107.300
25	Rajasthan	56106.747	98913.526	155020.273	51629.983

26	Sikkim	42605.547	33245.664	75851.211	109.263
27	Tamil Nadu	7773.220	6683.280	14456.5	14392.022
28	Telangana	2934.651	7420.936	10355.587	796.708
29	Tripura	203.560	0.000	203.56	309.197
30	Uttar Pradesh	29972.525	31109.303	61081.828	51399.651
31	Uttarakhand	20597.850	16623.537	37221.387	20464.387
32	West Bengal	14728.264	3162.148	17890.412	12411.647
Total		**621286.839**	**868649.097**	**1489935.936**	**1315779.168**

Table 3. Category wise production (2015-16)

Crop category	Production in tonnes		
	Organic	**In-conversion**	**Total Certified**
Cereals and millets	199448.640	9254.095	208702.735
Dry fruits	8613.647	0.675	8614.322
Fiber crops	156361.635	7248.192	163609.827
Fodder crops	19.527	0	19.527
Fresh Fruits	24636.401	94.513	24730.914
Medicinal/herbal/aromatic plants	34819.252	124.45	34943.702
Ornamental plants/ flowers	1922.938	0	1922.938
Plantation crops	37656.668	2.00	37658.668
Processed foods (wheat)	0	117.200	117.2
Pulses	36438.7299	16.04	36454.7699
Oil seeds/ oil crops	251978.625	0	251978.625
Spices and condiments	22484.636	1494.64	23979.276
Sugar crops and Cocoa	530749.303	1697.00	532446.303
Tuber crops	1471.751	0	1471.751
Vegetables	8692.742	0	8692.742
Others	485.068	1.8	486.868
Total	1315779.5629	3193.44	1335830.1679

Or say 1.34 million tons

Export of organic product

India exported 135 products last year (2013–14) with the total volume of 1,94,088 MT including 16,322 MT organic textiles. The organic agri export realization was around US $ 403 million including US $ 183 million organic textiles registering 7.73% growth over the previous year. Organic products are exported to US, European Union, Canada, Switzerland, Australia, New Zealand, South East Asian countries, Middle East, South Africa *etc*.

Table 4. Category wise Export (2015-16)

S. No.	Category	Quantity in MT
1.	Oil seeds	131981.589
2.	Cereals and millets	44113.941
3.	Processed foods	67108.239
4.	Tea	5403.843
5.	Pulses	4817.645
6.	Dry fruits	2464.871
7.	Spices and condiments	3085.505
8.	Medicinal/ herbal/ aromatic products	2242.067
9.	Coffee	2004.067
10.	Others	464.87
	Total	263686.637

Contribution of different commodities in India to total organic exports

Soybean (70%) leads among the products exported followed by cereals and millets other than basmati (6%), processed food products (5%), basmati rice (4%), sugar (3%), tea (2%), pulses (1%), dry fruits (1%), spices (1%) and others (www.apeda.org). The Government of India has implemented the National Programme for Organic Production (NPOP) in the year 2001. States like; Uttarakhand, Karnataka, Madhya Pradesh, Maharashtra, Gujarat, Rajasthan, Tamil Nadu, Kerala, Nagaland, Mizoram, Sikkim have been promoting organic farming. State-wise major crops grown under organic farming is given in Table 5.

Table 5. State-wise major crops grown under organic farming in India

Arunachal Pradesh	Maize/sorghum, Pulses, oilseeds, tea / coffee, herbal / medicinal plants
Andhra Pradesh	Cotton, maize, pulses, oilseeds, fruits and vegetables
Assam	Tea/coffee, fruits and vegetables
Chhattisgarh	Rice, wheat, vegetables
Delhi	Wheat, vegetables
Goa	Fruits, vegetables
Gujarat	Cotton, pulses, oilseeds, vegetables
Haryana	Basmati rice, wheat, maize, vegetables
Himachal Pradesh	Wheat, fruits, vegetables
Jammu and Kashmir	Spices, fruits and vegetables
Karnataka	Cotton, rainfed wheat, maize, sorghum, pulses, oilseeds, vegetables
Kerala	Spices, vegetables, herbals
Manipur	Spices, vegetables, herbals
Maharashtra	Cotton, rice, wheat, pulses, oilseeds, spices, vegetables
Madhya Pradesh	Soybean, wheat, vegetables
Meghalaya	Spices, vegetables
Punjab	Basmati rice, wheat, vegetables
Sikkim	Maize, Rice, Buckwheat, Finger millet, vegetables, spices, herbs
Rajasthan	Cotton, wheat, seed spices, vegetables
Tamil Nadu	Tea, herbs, spices
Uttar Pradesh	Rice, wheat, maize, vegetables
Uttarakhand	Basmati rice, vegetables, maize, sorghum, herbs, spices
West Bengal	Tea and vegetables

Constraints of organic farming

Lack of awareness

- Lack of skill about improved methods of compost making
- Lack of awareness about the concentration, time and method of manures and biofertilizer application
- Lack of proper training about organic farming
- Inadequate knowledge of field functionaries about organic farming
- Lack of knowledge in farmers about different bio pesticides
- Farmers think that chemical fertilizers are more effective than manures and biofertilizers
- Low credibility of source for purchasing compost and biofertilizers

Marketing problems: It is found that before the beginning of the cultivation of organic crops, their marketability and that too at a premium over the conventional produce has to be assured. Inability to obtain a premium price, at least during the period required to achieve the productivity levels of the conventional crop will be a setback.

Shortage of biomass: The small and marginal cultivators have difficulties in getting the organic manures compared to the chemical fertilizers, which can be bought easily, of course if they have the financial ability. But they have to either produce the organic manures by utilizing the bio-mass they have or they have to be collected from the locality with a minimum effort and cost. Increasing pressure of population and the disappearance of the common lands including the wastes and government lands make the task difficult (Narayanan, 2005). Besides, very high volume of organic materials required to meet the nutrient demand. [eg. Average application of 234 kg N/ha/year for a system, this requires either 46 t of raw FYM (0.5 % N) or 15.5 t vermicompost (1.5 % N)].

Inadequate supporting infrastructure: The certifying agencies are inadequate, the recognized green markets are non-existent, the trade channels are yet to be formed and the infrastructure facilities for verification leading to certification of the farms are inadequate.

Absence of an appropriate agriculture policy: Promotion of organic agriculture both for export and domestic consumption, the requirements of food security for millions of the poor, national self-sufficiency in food production, product and input supplies, etc. are vital issues which will have to be dealt with an appropriate agriculture policy of India.

Inability to meet the export demand: The market survey done by the International Trade Centre (ITC) during 2000 indicates that the demand for organic products is growing rapidly in many of the world markets while the supply is unable to match it. India is known in the world organic market as a tea supplier and there is a good potential to export coffee, vegetables, sugar, herbs, spices and vanilla. In spite of the several initiatives to produce and export organic produces from the country, the aggregate production for export came to only about 14000 tonnes. This also includes the production of organic spices in about 1000 ha under certification. The country could export almost 85 per cent of the production indicating that demand is not a constraint in the international markets for organic products. (Narayanan, 2005).

Risk associated with organic farming

Some of the risks associated with organic farming are as follows:

1. Risks of contamination of organic crops by genetically modified organisms (GMOs)
2. Shortages of particular inputs such as certified organic seeds and biological pesticides
3. Access to capital, because banks are sometimes unfamiliar with organic production systems
4. Instability of organic price premiums; and
5. Some crops in organic rotations do not benefit from USDA commodity program price and income protection (Hansen *et al.*, 2004).

Prospects of Organic Farming

The interest in organic agriculture in developing countries is growing because it requires less financial input and places more reliance on the natural and human resources available. It is indicated from the study that organic agriculture offers a comparative advantage in areas with less rainfall and relatively low natural soil fertility levels. Labour realizes a good return and this is very important where paid labour is almost nonexistent. Agricultural policies should revise their food supply strategies and valorise local production. Organic agriculture does not need costly investments in irrigation, energy and external inputs but rather substantial investments in capacity-building through research and training. Pro-poor organic agricultural policies have the potential to improve local food security, especially in marginal areas.

Policy Support to Organic Agriculture

Strong policy support is essential for promotion and success of organic farming. Government of India has ambitious programme ahead for the spread of organic farming in India but the programme will benefit greatly with an appropriate organic policy support from the federal and the state governments with agriculture being largely a state subject.

Organic Farming Policy 2005

The Government of India's Policy on Organic Farming, 2005 based on the recommendations of Task Force under the Chairmanship of Dr. Kunwarjibhai Jadhav had the following salient points:

"The Policy of Ministry of Agriculture, Government of India on organic farming will seek to promote technically sound, economically viable, environmentally non-degrading, and socially acceptable use of natural resources in favour of organic agriculture. The Policy seeks to actualize the area and crop potential for organic farming, sustaining soil fertility, conserving bio-resources, strengthening rural economy, promoting value addition, accelerating the growth of agro-business and securing a fair standard of living for the farmers and agricultural workers and their families".

Based on the above, the **objectives of the Policy on organic farming** were determined as follows:

(a) Maintenance of soil fertility by encouraging and enhancing the biological cycle within farming systems involving micro-organisms, soil flora and fauna, plants and animals; (b) Identification of areas and crops suitable for organic farming; (c) Development of organic package of practices; (d) Setting up of model organic farms for getting seed material for organic cultivation; (e) Assurance of production and supply of quality organic input; (f) Adoption of biological methods for pest and disease control; (g) Adoption of biological and mechanical methods for weed management; (h) Harnessing of traditional and indigenous knowledge relating to organic farming; (i) Creation of awareness among farmers towards organic agriculture; (j) Development of domestic market for organic produce; (k) Improvement of farmers' income through production of quality produce; (l)Generation of rural employment opportunity; (m) Simplification of certification system and recognition of adequate certification agencies, especially for domestic market; (n) Promotion of group certification; (o) Maintaining a diversity of plant and animal species as a basis for ecological balance and economic stability; (p) Improvement in condition of livestock that allow them to perform all aspects of their innate behavior; (q) Development of regulatory mechanism for various organic input and organic produce.

The Policy adopted an area approach, and areas having very low levels of fertilizer consumption, namely dry land / rain fed areas, hilly areas and north eastern states were classified as most suitable for conversion to organic farming. The dry land / rain fed agriculture which constitutes about 60% of the net sown area could play an important role for organic farming as average fertilizer use in these areas is very low, the policy stated. Similarly, hill agriculture is by and large natural farming except in valleys and high value crops.

Further, **3 priority zones for organic farming were identified**:

Category-I: Those areas which are rain fed and mostly under monocrop and traditionally no chemical input has ever been used. They can easily be classified as organic produce areas. Broadly, these areas exist in the States of N.E. Region, Jharkhand, Uttaranchal and Rajasthan;

Category-II: Those areas primarily under rainfedfarming having little irrigation support. These are normally under single season cropping rarely under double cropping. Broadly the States of Orissa, HP, J&K, MP, Chattisgarh and Gujarat and also parts of Maharashtra and Karnataka will fall under this category;

Category-III: Those areas which have moderate to heavy use of chemical fertilizers as well as pesticides. These areas are mostly under multiple cropping. The conversion of these areas into organic farming will initially cause some loss of productivity. For these areas, balanced and conjunctive use of biomass, organic and inorganic fertilizers and controlled use of chemicals through integrated nutrient and pest management (INM&IPM) will be promoted to achieve the sustainable increases in agricultural production.

In terms of identification of crops, the policy sought to give **thrust on the following crops to be grown organically**:

i. Major horticultural crops including vegetables. It will include mainly grapes, banana, mango, papaya, pineapple, guava, passion fruits, mausambi, orange, cashewnut, walnut and fresh vegetables.
ii. Export oriented cereals like basmati rice, and few others like sorghum and pearl millet.
iii. All pulses, soybean, groundnut and cotton.
iv. Chillies, garlic, turmeric, coriander, ginger.

The policy gave importance to Rural Income Generation, and sought to encourage **on-farm production** of organic manure, compost, vermi-compost, azolla, blue green algae by farmers. Local manufacturing means no packing or transport cost. Therefore it will save the money of the farmer. It noted that organic beekeeping as well as organic honey has growing demand and it may generate rural income sufficiently. Similarly, organic produce gets high premium and this will increase farm income. The policy promised to encourage farmers for generating higher income with organic produce.

Under Market Development and Domestic Certification, developing Organic Bazaar was emphasized as a local marketing programme which will provide assured organic products, fair prices for producers and consumers and opportunities for new relationship between producers and consumers. Simultaneously, it was envisaged that the product of organic producer will be linked with Agri Export Zone. This policy acknowledged that the existing certification system is alien to Indian farmers, and said that approach should be made to develop 'Participatory Guarantee System' for domestic certification purpose where there will be interactive participation of small farmers, enterprises, traders and consumers. The policy also encouraged group certification processes. Emphasizing bio-diversity as a key factor for successful organic farming, the policy promised that agri-horti-silvi-pastoral-fodder system would be encouraged on individual farm.

Some examples of policy support worldwide are cited below.

- European Union (EU) has supported organic agriculture for long time.
- In 2016, Sri Lanka launched the 'Toxin Free Nation Program', a 3-year plan that lays down 10 areas of action to phase out toxic chemicals from Sri Lankan agriculture through a step-by-step process.
- In India, the Federal government launched the PKVY program that allocated Rs. 300 crores in organic support measures. The Ministry of Agriculture continues to support PGS through their national PGS India program with

an impressive 150,000 farmers. Third party certification is also being supported with significant funds allocated to State Governments for setting up public organic certification bodies and obtaining accreditation.

- Support to organic agriculture in the Philippines is in full swing, measures such as subsidies for certification, organic input development and provision, or support to research and capacity building.
- In Armenia, the government started the 'Organic Agriculture Support Initiative'. This EU-funded project combines a range of support measures to boost national capacities and policies in favor of organic agriculture.
- Capacity development in organic agriculture is also on the agenda in China. The government plans to invest around € 187 million in 2016-2020 in new farmers training, with a focus on organic and sustainable agriculture.
- In April 2016, the city of São Paulo decided that by 2026, 100% of the two million school meals offered in the city every year should be organic.

The Government objective has to develop a national strategy for organic agriculture (policy framework) to encourage the sector growth with a view to use natural resources sustainably and improve the quality of life of farmers and consumers.

Conclusion

Organic farming offers the most sustainable solution for developing the agricultural sector and provides food security with least negative impacts on the environment. Hence, promotion of organic farming identifying the niche crop and area based promotion for sound rural development, besides provides healthy food, more ecosystem services and creating more jobs opportunities. Similarly, a market driven organic agriculture policy has to be created that target the food security.

Organic Farming in India: Production issues and strategies

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Organic farming systems are very much native to Indian Agriculture. As of now also, in more than 85% of the farm-households, crop + livestock farming system is prevailing. Nevertheless, during pre-green revolution period (up to 1960s) the rate of national agricultural growth was not able to keep pace with population growth and virtually 'ship to mouth' situation prevailed. This was the major factor for introduction and large-scale popularization of the high yielding varieties (HYVs) of crops, which were highly responsive to the chemical fertilizers and water use. As a result, the total food grain production increased phenomenally – from mere 50.82 million tonnes (m t) in 1950-51 to 264 m t in 2013-14 – indicating a 5-times increase. This increase can be primarily attributed to large-scale adoption of HYVs, combined with other green revolution technologies (GRTs) in cereal crops, expansion of gross irrigated area (22.56 m ha in 1950-51 to 89.36 m ha in 2010-11) and increase in fertilizer consumption (0.07 m t in 1950-51 to 25.54 m t in 2012-13). All of them put together have led to substantial increase in the productivity of crops, especially food grains (from 522 kg/ha in 1950-51 to 2125 kg/ha in 2012-13) culminating into the change in the status of India from a food importer to net food exporter in many commodities.

However, total factor productivity growth score prepared by National Institute of Agricultural Economics and Policy Research has revealed that technology-driven growth has been highest in Punjab and lowest in Himachal Pradesh. It implies that some of the states like Himachal Pradesh, Uttarakhand, Madhya Pradesh, Rajasthan, Jharkhand and north-eastern region of India have not been influenced much by the modern inputs of agriculture like chemical fertilizers and pesticides. India's average fertilizer and pesticide consumption stands at 128.3 kg/ha and 0.31 kg a.i./ha, respectively. Moreover, despite all technological advancements, the nutrient use efficiency is on lower side (33% for N, 15% for P and 20% for K and micronutrients). On the other hand, it has been proved scientifically and convincingly that integrated use of organic manures with chemical fertilizers improves the use efficiencies of the latter owing to concurrent improvement of soil physical, chemical and biological properties. The water holding capacity of the soil also gets improved on account of regular use of organic manures. It is estimated that various organic resources having the total nutrient potential of 32.41 m t will be available for use in 2025. Out of these organic resources, considerable tapable potential of nutrients ($N + P_2O_5 + K_2O$) from human excreta, livestock dung and crop residues have been worked out to be only 7.75 m t.

Area under organic farming, production and export

With increasing health consciousness and concern for environment, organic farming systems have been drawing attention of the people all over the world almost for past three decades or so. As a result, there is widespread organic movement. Demand for organic products, especially in developed countries, has been increasing by leaps and bounds. Organic agriculture is practiced in 179 countries and 50.9 m ha of land are managed organically by 2.4 m farm households. The global sales of organic food and drink reached 62.9 billion US dollors in 2011. The regions with the largest areas of organically managed agricultural land are Oceania (12.1 m ha of 33 per cent of the global organic farmland), Europe (10.6 m ha or 29 per cent of the global organic farmland) and Latin America (6.8 m ha or 23 per cent). On a global level, the organic agricultural land area increased by 14.7 per cent compared with 2014. The countries with the most organic agricultural land are Australia (22.7 m ha), Argentina (3.1 m ha) and the United States (2.0+ m ha). The countries with the highest numbers of producers are India, Ethiopia and Mexico. The number of organic producers has increased by 7.2 per cent compared with 2014.

In Asia, land under organic management reached 3.6 m ha for 2009 up from just under 3.4 m ha reported for 2008 and under 2.9 m ha for 2007. The expansion of over 0.2 m ha, a growth rate of close to 6 per cent comes on top of a 17 per cent growth from 2007 to 2008. It maintains an upward trend albeit a slower pace of conversion. The main contributor of the expansion of cultivated acreage is India. The Agriculture and Processed Food Product Export Development Authority (APEDA), competent authority of India's National Programme for Organic Production (NPOP), reported cultivated area grew from close to 1.02 m ha in 2008 to 1.49 m ha in 2015. Forest area reached 4.22 m ha up from 2.79 m ha. Other countries reporting large increases in cultivated organic acreage are Philippines (+36'751 ha), Saudi Arabia (+16'635 ha), Thailand (7'361 ha), and Indonesia (+10'000 ha). It is the 3rd consecutive large annual increase for Saudi Arabia. Myanmar reported for the first time at 555 ha. The number of producers took a giant leap from just under 405'000 to 725'000. This is mainly due to the phenomenal increase in the number of producers in India, which almost doubled from the 340'000 reported in 2008 to 677'000 in 2009. The majority of production in the region (except for China) is organized and certified under grower group schemes. Wild collection takes place in 12 out of the 35 places covered within the region. Organic livestock production is not developed in most parts. Organic animal products are only available in some places (e.g., Japan, South Korea, Taiwan, and China). The majority of production and export in the region continue to be primary products except for Japan, South Korea, and Taiwan.

India has traditionally been a country of organic agriculture, but the growth of modern scientific, input intensive agriculture has pushed it to wall. But with the increasing awareness about the safety and quality of foods, long term sustainability of the system and accumulating evidences of being equally productive, the organic farming has emerged as an alternative system of farming which not only addresses the quality and sustainability concerns, but also ensures a profitable livelihood option. Emerging from 42,000 ha under certified organic farming during 2003-04, the organic agriculture has grown almost 29 fold during the last 5 years. By 2015-16, India has brought more than 5.71 m ha area under organic certification process. Out of this cultivated area accounts for 1.49 m ha while remaining 4.22 m ha is wild forest harvest collection area. In India Madhya Pradesh has highest area under organic farming followed by Maharastra and Rajasthan besides these states Meghalaya has committed to have 2 lakh ha of certified land by 2020 and Sikkim is the first organic state of the country.

Concept and Principles organic farming

Historically, the concept of organic farming in India and China is based on following principles:

- Nature is the best role model for farming, since it does not use any inputs nor demand unreasonable quantities of water.
- The entire system is based on intimate understanding of nature's ways. The system does not believe in mining of the soil of its nutrients and do not degrade it in any way.
- The soil in this system is a living entity and the soil's living population of microbes and other organisms are significant contributors to its fertility on a sustained basis and must be protected and nurtured at all cost.
- The total environment of the soil, from soil structure to soil cover is more important.
- In its simplistic form, organic agriculture may be defined as "a kind of diversified agriculture wherein crops and livestock are managed through use of integrated technologies with preference to depend on resources available either at farm or locally". Other benefits of organic agriculture are its reliance on fossil fuel independent, locally available resources that incur minimal agro-ecological stresses and are cost-effective. The organic community has adopted four basic principles, and broadly speaking, any system using the methods of organic agriculture and being based on these principles, may be classified as organic agriculture:
- **The principle of health:** Organic Agriculture should sustain and enhance the health of soil, plant, animal, human and planet as one and indivisible.
- **The principle of ecology:** Organic Agriculture should be based on living ecological systems and cycles, work with them, emulate them and help sustain them.
- **The principle of fairness:** Organic Agriculture should build on relationships that ensure fairness with regard to the common environment and life opportunities.
- **The principle of care:** Organic Agriculture should be managed in a precautionary and responsible manner to protect the health and wellbeing of current and future generations and the environment.

Components of organic farming

Essential components of organic farming are keeping the soil alive through effective management of natural resources. They are as follows

- *Enrichment of soil:* Abandon use of chemicals, use crop residue as mulch, use organic and biological fertilizers, adopt crop rotation and multiple cropping, avoid excessive tilling and keep soil covered with green cover or biological mulch.
- *Management of temperature:* Keep soil covered, plant trees and bushes on bund
- *Conservation of soil and rain water:* Dig percolation tanks, maintain contour bunds in sloppy land & adopt contour row cultivation, dig farm ponds, maintain low height plantation on bunds.
- *Harvesting of sun energy:* Maintain green stand throughout the year through combination of different crops and plantation schedules.
- *Self-reliance in inputs:* Develop your own seed, on-farm production of compost, vermicompost, vermiwash, liquid manures and botanical extracts.
- *Maintenance of life forms:* Develop habitat for sustenance of life forms, never use pesticides and create enough diversity.
- *Integration of animals:* Animals are important components of organic management and not only provide animal products but also provide enough dung and urine for use in soil.
- *Use of renewable energy:* Use solar energy, bio-gas and other eco-friendly machines.

Different forms of organic agriculture

Rishi Krishi: Drawn from Vedas, the Rishi Krishi method of natural farming has been mastered by farmers of Maharashtra and Madhya Pradesh. In this method, all on-farm sources of nutrients including composts, cattle dung manure, green leaf manure and crop biomass for mulching are exploited to their best potential with continuous soil enrichment through the use of Rishi Krishi formulations known as "*Amritpani*" and virgin soil.

Panchgavya Krishi: Panchgavya is a special bio-enhancer prepared from five products obtained from cow; dung, uine, milk, curd and sometimes ghee. Panchgavya contains many useful microorganisms such as fungi, bacteria, actinomycetes and various micronutrients. The formulation act as tonic to enrich the soil, induce plant vigour with quality production.

Natural farming: Natural farming emphasizes on efficient use of on-farm biological resources and enrichment of soil with the use of Jivamruta to ensure high soil biological activity. Use of Bijamruta for seed/ planting material treatment and Jivamruta for soil treatment and foliar spray are important components.

Natueco Farming: Natueco Farming emphasizes `Neighborhood Resource Enrichment' by `Additive Regeneration' rather than through dependence on external, commercial inputs. The three relevant aspects of Natueco Farming are: *Soil* **-** Enrichment of soil by recycling of the biomass by establishing a proper energy chain; *Roots* **-** Development and maintenance of white feeder root zones for efficient absorption of nutrients and *Canopy* **-** Harvesting the sun through proper canopy management for efficient photosynthesis.

Homa Farming: Homa farming has its origin from vedas and is based on the principle that "you heal the atmosphere and the healed atmosphere will heal you" The practitioners and propagators of homa farming call it a "revealed science". It is an entirely spiritual practice that dates from the Vedic period. The basic aspect of homa farming is the chanting of Sanskrit mantras (Agnihotra puja) at specific times in the day before a holy fire.

Biodynamic Agriculture: Method of farming that aims to treat the farm as a living system which interacts the environment, to build healthy, living soil and to produce food that nourishes and vitalizes and helps to develop mankind. The underlying principle of biodynamics is making life-giving compost out of dead material. The methods are derived from the teachings of Rudolf Stainer and subsequent practitioners. The important components of biodynamic farming are turning in plant materials such as green crops and straw, not using chemical fertilizers and pesticides, avoiding soil compaction by machinery or animals, particularly in wet weather, keeping soil covered by pasture, crops or mulch not destroying the soil structure by poor farming practices such as excessive use of rotary hoe or cultivation in unsuitable weather (too wet or too dry), fallowing the land by planting deep-rooting permanent pasture species or using green crops, use of preparations BD-500 and BD-501, compost made with preparations BD-502 – BD-507, liquid manure made with preparations BD-502 – BD-507 and cowpat pit manure made with preparations BD-502 – BD-507. Till now, 9 biodynamic preparations have been developed, named as formulation 500 to 508. Out of these, formulation-500 (cow horn compost) and formulation- 501 (horn-silica) are very popular and are being used by large number of organic farmers. Formulations-502 to 507 are compost enrichers and promoters, while formulation 508 is of prophylactic in nature and helps in control of fungal diseases.

Organic and towards organic agriculture

Organic is more of a description of the agricultural methods used on a farm, rather than food itself and those methods combine tradition, innovation and science. Organic agriculture, in simple terms, requires a shift from intensive use of synthetic chemical fertilizers, insecticides, fungicides, herbicides, PGRs, genetically engineered plants to extensive use of animal manures, beneficial soil microbes, bio-pesticides, bio-agents and indigenous technological knowledge, based on scientific principles of agricultural systems. Scientific evidences clearly establish that conversion of high intensive agriculture areas to organic systems lead to reduction in crop yields considerably (up to 25-30%), especially during initial 3-4 years; before soil system regains and crop yields come to comparable level. In this scenario, if all the cultivated areas are brought into organic production systems, the national food production system may get jeopardized; hence a phased approach may be desirable. Considering this fact on one hand and looking into global scenario of organic agriculture, working group on Horticulture, Plantation Crops and Organic Farming for the XI-Five-Year Plan suggested a spread of organic farming on 1-5 per cent area in the high productive zones and larger spread in the less exploited areas, such as, rainfed and hill areas. Nevertheless, integrated approach of crop management – including integrated nutrient management and inter/ mixed cropping – is also considered as *"towards organic"* approach; and at the same time has been found to increase the use efficiency of all costly inputs especially fertilizers and water, it would be appropriate to adopt it in the food bowl areas contributing major share to the food basket. This approach will also contribute to *'more crop per drop and less land, less resource/ time and more production'* strategies of the government.

Towards organic approach (integrated crop management) in wheat (Source: NPOF centre, Bhopal)

Further, India has a sizable cropped area in different states, which is more prone to weather vagaries; especially those located in rain fed, dry land and hilly areas. Increasing the agricultural productivity and income of the farmers as well as sustaining soil resource in these agricultural systems has always been a challenging task for researchers and policy planners. Presently, in these areas use of fertilizers and pesticides is minimal and much below the national average. At first instance, these are the areas which need to be targeted for organic production by devising proper strategies and identifying niche crops (crops which yield higher under organic production systems and have adequate market demand). The domestic and export markets must be exploited for increasing the income of the farmers, as it is important to note that 78% of Indian organic consumers prefer Indian brand of organic and many other countries also require diversified organic foods of tropical fruits, vegetables, essential oils, flowers, herbs, spices and organic cotton from India. In addition, large-scale adoption of organic agriculture in such areas will not only help in conserving the environmentally fragile ecosystems but also help in supplementing overall food production of the country. This can be clearly brought out by the example of Sikkim – an agriculturally weak state located in north-eastern hills region of the country. During 2002-03 (before Sikkim Organic Mission) fertilizer consumption was the highest (21.5 kg/ha), the productivity of rice was 1.43 t/ha but 11 years later, i.e., during 2013-14, it increased to 1.81 t/ha, and more interestingly, no yield reduction was observed during conversion period. Productivity increase in other crops was also noted to the tune of 11%, 17% and 24% in maize, finger millet and buckwheat, respectively.

Practical production issues and strategies for success

Although several issues exist for organic growers, practically there are three major issues which constraints the productivity of crops under organic farming compared to conventional farming. These issues are

1. **Supply of sufficient nutrient through organic management:** Crop needs nitrogen, phosphorus, potassium and several other secondary and micro nutrients for assimilation and better biomass output. These nutrients need to be supplied in a form which does not have synthetics and environmental degradation. Organic farming discussion starts with the question that how to meet the nutrient requirement of crops through organic manures and where it is available?
2. **Insect and disease management:** Another important issue which directly related to crop productivity and environment. Is it possible to manage the pests and diseases without using synthetics?
3. **Weed management:** It is the major issue for many of the organic growers as it has been observed that under organic management, weeds grow intensively if manures from outside the farm are used?

Strategies for success

A. **Supply of sufficient nutrient through organic management**

Enough scope for production of sufficient organic inputs exists in India and it works out to 7 m t in terms of nutrients. Among different sources, livestock accounts for major share (nearly 40 per cent). It is followed by crop residues (30 per cent) and other sources (15 %). Other sources include the rural compost, vermi-compost and agricultural wastes. Further, concept of promoting organic farming in individual crops should be done away and it should be practiced in cropping/farming systems. The issue of sufficient nutrient supply under organic systems can be addressed through following measures.

Integrated Organic Farming System (IOFS) model established at Umiam (Source: NPOF centre, Umiam)

1. **Practice through farming system:** Organic farming is considered incomplete without livestock as livestock alone contributes nearly 40 % of total organic manures in the country. Crop + dairy are the pre-dominant farming system practiced traditionally by Indian farmers over the centuries. Analysis of farming systems practiced by 732 marginal households across the 30 NARP zones indicated existence of 38 types of farming systems. Out of this, 47 % of households have the integration of crop + dairy, 11 % have crop + dairy + goat and 9 % households have crop + dairy + poultry systems. Hence, natural strength exists in the country for promotion of organic and towards organic agriculture. Integrated Organic Farming Systems (IOFS)**:** Integrated organic farming system models established at Coimbatore (Tamil Nadu) and Umiam (Meghalaya) under Network Project on Organic Farming (NPOF) could improve the net returns by 3 to 7 times compared to existing systems (Table 1) and meet up to 90 % of seeds/planting materials, nutrients, bio-pesticides and other inputs with in the farm in the two years of establishment.

Table 1. Performance of integrated organic farming system models

Components	Area (ha)	Total cost (Rs/year)	Net returns (Rs/year)				
			Crop	Livestock	Others	Total	Existing system
Coimbatore (Tamil Nadu)							
Crop (Okra, cotton, desmanthus) + dairy (1 milch animal, 1 heifer & 1 bull calf) + vermicompost + boundary plantation	0.40	1,10,109	64,500 (87 %)	8,216 (11 %)	1,600 (2 %)	74,316	27,200*
Umiam (Meghalaya)							
Crops (Cereals + pulses + vegetables +fruits + fodder) + Dairy (1 cow + 1 calf) + Fishery + Vermicompost	0.43	68,255	33,531 (57 %)	13,252 (22 %)	11,538 (21 %)	58,321	8,618**

* fingermillet – cotton - sorghum, ** rice-fallow

2. **Multiple cropping and crop rotation:** Mixed cropping is the outstanding feature of organic farming in which variety of crops are grown simultaneously or at different time on the same land. In every year, care should be taken to maintain legume cropping at least 40%. In selecting crop combinations, it is also to be kept in mind that plants also have their feelings, likes and dislike e.g. maize gets along well with beans and cucumber, tomatoes go well with onions and marigold. On the other hand beans and onions do not go well with each other. Entire farm should have at least 8-10 types of crops at all the times. Each field/ plot should have at least 2-4 types of crops out of which one should be legume. In case if only one crop is taken in one plot then adjacent plots should have different crops. For maintenance of diversity and pest control, vegetable seedlings can be planted randomly @ 50-150/acre which can be used for home consumption and 100 plants/acre of marigold in all crop fields. Crop rotation is the succession of different crops cultivated on same land. Follow 3-4 years rotation plan. All high nutrient demanding crops should precede and follow legume dominated crop combination. Rotation of pest host and non pest host crops helps in controlling soil borne diseases and pest. It also helps in controlling weeds. It is better for improving productivity and fertility of soil. Crop rotations help in improving soil structure through different types of root system. Legumes should be used frequently in rotation with cereal and vegetable crops. Green manure crops should also find place in planning rotations. Principles with examples for selecting the crops and varieties for organic farming are given below.

Direct seeded rice + soybean under organic management (Source: NPOF centre, Pantnagar)

- Non–leguminous crops should be followed by leguminous crops and vice-versa, eg. green gram – wheat / maize. If preceding crops are legume or non-legume grown as intercrops or mixed crops, the succeeding crop may be legume or non-legume or both.
- Restorative crops should be followed by exhaustive or non-restorative crops.eg. sesame – cowpea / green gram / black gram / groundnut
- Leaf shedding crop should be followed by non-leaf shedding or less exhaustive crops.eg. pulses / cotton – wheat / rice
- Green manuring crop should be followed by grain crops.eg. dhaincha - rice, green gram/ cowpea – wheat / maize.
- Highly fertilized crops should be followed by less-fertilized crop.eg. maize - black gram/gourds.
- Perennial or long duration crops should be followed by seasonal /restorative crops. eg. napier / sugarcane - groundnut /cowpea /green gram.
- Fodder crops should be followed by field or vegetable crops. eg. maize + cowpea-wheat/potato/cabbage/onion.
- Multicut crops should be succeeded by the seed crops. eg. green gram/maize.
- Ratoon crops should be followed by deep rooted restorative crops. eg. Sugarcane /jowar-pigeonpea / Lucerne / cowpea.

- Deep rooted crops should be succeeded by shallow rooted crops. eg. cotton/ castor/ pigeonpea – potato / lentil / green gram etc.
- Deep tillage crops should be followed by zero or minimal tillage crops. eg. potato / radish / sweet potato/sugarcane - black gram/green gram/green manuring crops.

3. **Green manures:** Green manures are the principal supplementary means of adding organic matter to the soil. The green-manure crop supplies organic matter as well as additional nitrogen, particularly if it is a legume crop, due to its ability to fix nitrogen from the air with the help of its root nodule bacteria. The green-manure crops also exercise a protective action against erosion and leaching. Green manure to be incorporated in soil before flowering stage because they are grown for their green leafy material, which is high in nutrients and protects the soil. Green manures will not break down in to the soil so quickly, but gradually, add some nutrients to the soil for the next crop. Green manure crops can also be inter cropped and incorporated which will have dual advantage of managing weeds and soil fertility. Popularly grown green manures are *Sesbania aculeate* (Dhaincha), *S. rostrata*, sunhemp etc.

4. **Combination of organic nutrient sources:** Combining more than one organic source for supplying nutrients to crops has been found to be very effective as meeting the nutrient requirement by single source is not possible. For example, rice-wheat system requires around 30 t FYM/year to meet its nutrient demand. This can be very easily managed by adopting strategies of cropping systems involving green manures, legumes and combined application of FYM + vermicompost and neem cake. This type of management also helps in reducing the insect/disease incidences as incorporation of neem cake in soil has been found to much effective. FYM (partially composed dung, urine, bedding and straw), edible and non-edible oil cakes, enriched composts and effective microorganisms are some of the combinations which can be used for meeting the nutrient demand of crops. FYM contains approximately 5 - 6 kg nitrogen, 1.2 - 2.0 kg phosphorus and 5 - 6 kg potash per tonne. Though FYM is the most common organic manure in India, the farmer, in general, do not give adequate attention to the proper conservation and efficient use of the resource. For preparing better quality FYM, the use of pit method for areas with less than 1000 mm precipitation and heap method for other places is recommended. Some of the non-edible oilcakes such as castor and neem cakes are having the insecticidal properties also. Among the edible oil cakes, coconut, groundnut, niger, rapeseed and sesame cakes have higher nutrients (N ranging from 3 to 7.3 %; P_2O_5 ranging from 1.5 – 2 % and K_2O ranging from 1.2 to 1.8 %). In case of non-edible oil cakes such as castor, cotton, karanj, mahua, neem and safflower cakes, neem cake is having higher N (5.2 %), while castor and Mahua cake is having higher P_2O_5 (1.8 %) and K_2O (1.8 %) respectively. Depending upon the nature and quantity of raw material available with the farmer, any one or combination of composting methods such as Indore method, NADEP compost, NADEP phospho compost, IBS rapid compost, coirpith, sugarcane trash, pressmud composts, poultry waste compost using paddy straw, vermicompost, pitcher khad and bio-gas slurry can be adopted to make compost within the farm. Effective microorganism is a consortium culture of different effective microbes commonly occurring in nature. Most important among them are : N_2-fixers, P-solubilizers, photosynthetic microorganisms, lactic acid bacteria, yeasts, plant growth promoting rhizobacteria and various fungi and actinomycetes. In this consortium, each microorganism has its own beneficial role in nutrient cycling, plant protection and soil health and fertility enrichment. Identified nutrient management packages for various cropping systems are given in Table 2.

Intercropping of dhaincha in rice and incorporation through cono weeder

Table 2. Identified nutrient management packages for cropping systems at different locations

Location (State)	Cropping System (s)	Sources to meet nutrients
Coimbatore (Tamil Nadu)	Cotton-maize-green manure (GM) Chillies-sunflower-greenmanure	Farm Yard Manure (FYM) + Non Edible Oil Cakes (NEOC) + Panchagavya (PG)
Raipur (Chhatisgarh)	Rice-chickpea	Enriched compost (EC) + FYM + NEOC + Bio dynamic (BD)+PG
Dharwad (Karnataka)	Groundnut-sorghum Maize-chickpea	EC + VC + Green leaf manure (GLM) + biodynamic and PG spray
Ludhiana (Punjab)	Maize-wheat-summer greengram	FYM + PG + BD in maize, FYM +PG in wheat and FYM alone in moong
Bhopal (Madhya Pradesh)	Soybean-wheat Soybean-chickpea Soybean-maize	FYM+PG + BD
Pantnagar (Uttarakhand)	Basmati rice-wheat-greenmanure Basmati rice-chickpea Basmati rice-vegetable pea	FYM + VC + NC + EC + BD + PG
Ranchi (Jharkhand)	Rice-wheat-greenmanure	VC+ Karanj cake + BD+ PG

B. **Insect and disease management**

In general, the incidence of pests and diseases are comparatively low under organic production system compared to inorganic systems due to several factors such as application of oil cakes having insecticidal properties, use of green leaf manures such as calotrophis and slightly higher content of phenols in plant parts under organic management. Further, organic management also increases the natural enemies in the farm. Natural enemies of crop pests and diseases such as Coccinellids, syrphids, spiders, Micromus, Chrysopa and campoletis were higher under organic management compared to integrated and inorganic management. Coccinellids, which naturally reduce the hoppers and leaf folders was found to be two to three times higher under organic management in cotton, groundnut, soybean, potato and maize crop fields (Table 3). Similarly, spiders which also control the pests are found to be twice higher under organic management compared to inorganic management. The diversity of arthropod population in soil viz., Collembola, dipluran, pseudoscorpians, cryptostigmatids and other mites population was also found to be higher under organic management compared to integrated and chemical management.

Table 3. Changes in *Coccinelids* and other natural enemy population in various crops under organic and chemical management practices

Crops	*Coccinelids*		Other natural enemies (*Syrphids, Micromus, Chrysopa, spiders*)		Cumulative % reduction of natural enemies/year under chemical management
	Chemical	Organic	Chemical	Organic	
Maize (nos/m)	0.80	2.65	0.50	1.53	68
Groundnut(nos/m)	0.69	2.58	0.76	2.15	69
Soybean (nos/m)	0.35	1.35	-	-	74
Cotton (nos/plant)	1.60	4.15	0.88	2.67	63
Potato (nos/m)	0.30	1.25	0.09	0.30	74

Products collected from the local farm, animals, plants and micro-organisms and prepared at the farm are allowed for control of pests and diseases. (eq. Neem Seed Kernel Extract, cow urine spray). The products that are permitted for control of pest & diseases are neem oil and other neem preparations like Neem Seed Kernel Extract, pheromone traps, mechanical traps, plant based repellants, Soft soap and clay. Identified pest & disease management packages for various cropping systems are given Table 4.

Table 4. Identified pest and disease management packages at various locations for different cropping systems

Location (State)	Cropping System	Pest/disease	Recommended practice
Modipuram (Uttar Pradesh)	Basmati rice-chickpea	Soil borne pests and diseases	Summer ploughing + green manure incorporation
Calicut (Kerala)	Ginger	Shoot borer	Seed treatment with Ginger Endophytic Bacteria 17 & 18, Ginger Rhizobacteria 57
Bajaura (Himachal Pradesh)	Cauliflower-peas-tomato	Fruit borer & fruit rot	Karvi (*Roylea cinerea*) @ 10% aqueous leaf extract + cow urine (3%) + tween-80 (0.05%) as emulsifier
Umiam (Meghalaya)	Maize + Soybean	Monolapta Mylloceros Ephilechma Leaf folder	Derisom (3 ml/l) + Panchagavyya @ 10% and cow urine 3% Anomin 3 ml/litre or Panchagavyya @ 3%.
		Rust	Panchagavyya @ 3% + lantana @ 10% + vermiwash @ 10%

A popular natural pest repellent paste mixture prepared by Tamil Nadu farmers containing each 1kg leaves of *Vitex nigunda*, *Agave cantala* , *Datura metha*, *Calotropis* and neem seeds and dissolved in 5 litres of cow urine are kept in plastic or earthen ware. After 15 days of fermentation, 100 liters of water are added and the filtrate is sprayed in the field. It has been observed by farmers that most of the insect pests are repelled from the treated area.

X. **Weed Management**

Weeds are major problem under organic management and almost 43 % of organic growers expressed; low and no cost weed management techniques should be identified for successful practicing of organic farming. Slash weeding is to be done between the plants. Weeds under the base of the plants can be cleaned and put as mulch around the plant base. The weeded materials should be applied as mulch in the ground itself. Stale seed beds, hand and mechanical weeding are the other options available for managing weeds under organic management. Further, effective crop rotation, mixed and intercropping is also essential for reducing the weeds. Few identified weed management practices for various locations and cropping systems are given in Table 5.

Table 5. Identified weed management packages for various locations and cropping systems

Location (State)	Cropping System	Recommended practice
Raipur (Chhatisgarh)	Rice-mustard	Conoweeder with square planting for rice Stale seed bed for mustard
Coimbatore (Tamil Nadu)	Rice-blackgram-greenmanure	2 hand weeding + spray of aqueous leaf extract at 3-4 leaf stage of weeds
Dharwad (Karnataka)	Groundnut	Spray of *cassia* and *Prosopis juliflora* as post emergent
Ludhiana (Punjab)	Basmati rice-wheat-greenmanure	High density planting + hand weeding at 25-30 DAT
Pantnagar (Uttarakhand)	Basmati rice-wheat-*greenmanure*	one hand weeding at 25-30 DAT during *kharif* and 2 hand weeding at 25-30 and 45-50 DAS during *rabi*
Umiam (Meghalaya)	Maize (green cob)-mustard	Mulching with fresh eupatorium/ambrosia @ 10 t/ha (after earthing up)

The other important practical constraints faced by organic growers are incidence of termites and rats. Some of the Indigenous Technical Knowledge (ITKs) practiced for termite management include application of dye prepared from Noni (*Morinda citrifolia*) mixed with garlic extract on trees, application of tank silt in sandy wetlands, *use of alotropis* plant material (8-10 kg) soaked in sufficient quantity of water for 24 hr and filtered and poured on termite infested soil and application of sheared human hair obtained from barber's shop, applied on live mounds and along the infested pathways.. ITKs used for rat management include pieces of cotton or thermocole, dipped in jaggery solution, made into small packets and spread in field / orchard and partly cooked sorghum grains coated with cement or white cement and packed into small packets and spread in the field, and

Crop productivity and economics under organic management

Available records on grain yield of paddy under traditional farming practices indicates yield up to 2.95 t/ha (2605 lbs/acre) in the first crop (*Kuruvai*) and 2.81 t/ha (2484 lbs/acre) in the second crop (*Thaladi*) [1925-26] has been recorded by Lalgudi Sivagnanam Co-operative Agricultural Society in the Madras Presidency.. Similarly in case of wheat, yield of 2.41 t/ha has been reported from West Bengal during 1970-71. Analysis of yield recorded at various locations under organic management over inorganic indicated many crops (Table 6) responded positively to yield higher under organic systems. Sustainable yield index of basmati rice, rice, cotton, soybean, sunflower, groundnut, lentil, cabbage and French bean are higher under organic management compared to integrated and inorganic management systems. Long-term results of organic management clearly establishes that the scientific Package of Practices (PoP's) for organic production of crops in cropping systems perspective should be adopted for keeping the crop productivity at comparable or higher level than chemical farming. Under ICAR-Network Project on Organic Farming (NPOF), location specific package of practices for organic production of crops in cropping systems (42 no's) suitable to 11 states have been developed which can be practiced for getting optimum productivity under organic management. Among the pulses, green gram, chickpea and cowpea responds better.

Table 6. Number of data entries, averages and ranges (%) of relative yields between organic over inorganic for selected crops in India

Crops	n[a]	Organic over inorganic		Crops	n[a]	Organic over inorganic	
		Mean	Range			Mean	Range
Basmati rice	67	104	88-121	Okra	10	118	90-142
Rice	52	100	89-122	Chilli	12	109	107-112
Maize	37	110	62-137	Onion	13	107	87-127
Sorghum	17	114	89-132	Garlic	9	104	86-121
Greengram	12	107	96-122	Cauliflower	12	104	90-117
Chickpea	24	100	65-114	Cabbage	5	111	81-142
Soybean	54	104	96-123	Tomato	11	106	83-130
Groundnut	16	103	83-116	Ginger	12	120	108-129

[a]n= the number of yield entries

Cost of production per unit area is comparable or less under organic agriculture than inorganic management when on-farm organic inputs are used. However, if organic inputs from outside the farm are purchased and utilized, the cost of production increases by about 13 %. Therefore, organic agriculture should naturally depend on on-farm generation of inputs including mixed cropping, crop rotation, residue recycling, composting etc.

Environment saviour: Continuous practice of raising the crops organically has good potential to sequester the C (up to 63 % higher C stock in 10 years), higher soil organic carbon (22 % increase in 6 years), reduction in energy requirement (by about 10-15 %) and increase in water holding capacity (by 15-20 %), thereby promoting climate resilience farming.

Summary

It can be concluded that scientific organic farming packages with ecological perspective needs to be maintained for obtaining comparable or higher yield of crops and income with that of chemical farming. Further, accelerated adoption of **"towards organic"** (integrated crop management) approach in intensive agricultural areas (food hubs) and **"certified organic farming"** with combination of tradition, innovation and science in the de-facto organic areas (hills) and rainfed/ dryland regions can contribute towards safe food security and climate resilience, besides increased income of farm households. This approach will also positively contribute to the cause of human, livestock and eco-system health, the basic objective of organic agriculture.

THEME II:
ORGANIC CROP MANAGEMENT (NUTRITION, PESTS, IRRIGATION AND PRODUCE HANDLING)

Technology for Composting of Agricultural Waste and Crop Residue

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Agriculture is the first invention done by human. In developing country like India, the economy depends on success and failure of agriculture. India has already enjoyed four decades of post green revolution. Although, extensive use of chemical fertilizer created several problems which deteriorated the soil and environment health, causes health hazard and insecurity of quality food, energy crisis, higher fertilizer cost. Such issues related to sustainability in agri-production system and ecological stability are renewed the interest of farmers and research workers in non-chemical sources of plant nutrients like biofertilizers, farmyard manure, green manure, composts etc. Human beings and cattle were also adversely affected due to the residues of these agrochemicals in food products (Kumar and Bohra, 2006). The organic manures like compost and vermicompost can improve food quality without compromising with food safety (Ersahin, 2011). Composts not only reduce the dependence on chemical fertilizers by supplying essential macronutrients, but also improve the soil organic matter, microbial biomass carbon (Sarangi and Lama, 2013), soil microbial activity (Dadhich *et al.,* 2012), inactivate the soil borne pathogen (Lodha and Buramn, 2000), thereby encourage the growth, quality of crop, as well as sustain higher productivity (Sangeetha *et al.,* 2013).

With the increased agricultural production due to green revolution, a huge amount of agro waste is also produced in the country. Disposal of such organic wastes from various sources like domestic, agriculture and industries has caused serious environmental hazards and economic problems. Generally, waste from the fruit and vegetable market is collected and dumped into the municipal landfills, causing a nuisance because of high biodegradability (Bouallagui *et al.,* 2004). This result in loss of potentially valuable nutrients (Baffi *et al.,* 2005). In India most common practices of waste processing are uncontrolled dumping which causes mainly water and soil pollution (Bouallagui *et al.,* 2004), whereas air pollution is caused due to burning of crop residue in the field. It leads to emission of GHGs and loss of valuable plant nutrient in the atmosphere (Jain *et al.,* 2014), that can be processed into fertilizer. In this context, recycling of agro-waste through composting and vermicomposting represents the key technology for the production of organic manures and their use as nutrient supplements in soil to partially replace the chemical fertilizers or integrated use of both organic and inorganic sources of nutrients.

What is agricultural waste?

Waste generated from agricultural activities like farming of cereals and pulses, horticulture, floriculture, animal husbandry etc which may or may not be biodegradable (ENVIS Newsletter, 2008). There are several types of agricultural waste like crop waste, food processing waste, animal waste and hazardous and toxic waste. Agro waste utilization pattern in India given in Table 1.

Table 1. Agro waste utilization pattern in India

Agro waste	**Utilization**
Rice husk ash and charcoal	Additive in cement mixes, glass manufacture, active carbon
Rice husk	Electricity generation
Banana peel and sugar fiber	Paper making pulp
Oil empty fruit bunch	Mulching and organic fertilizer
Oil palm stems, rubber wood	Soft wood furniture
Onion skin, G.N. husk	Heavy metal removal
Husk, Bagasse	Mushroom cultivation
Bagasse, banana fruit reject	Ethanol production, animal feed
Husk, straw, cow dung	Biogas production, electricity
Animal waste	Compost, fertilizer

There are many economical uses of agro-waste available in India other than composting. So we cannot say strongly that we can use such agro-waste for compost making only but under certain circumstances we can use this waste for compost making. The status of crop residue generated and is given in Table 2. A large proportion of this residue has been burnt. Burning of rice residue is very common in north Indian states. Residue of other crops also subjected to burning but magnitude of rice residue burning is very high. This burning pollutes and badly affects the soil and environment.

Table 2. Status of crop residue generated and residue burning (million tonnes/year) in India

Crop	*Dry residue generated*	*% residue burning*	**Burned residue*
Paddy	192.82	40	77.13
Wheat	120.7	22	26.55
Maize	26.75	3	0.80
Jute	31.51	3	0.95
Cotton	90.86	8	7.27
Groundnut	11.44	1	0.11
sugarcane	107.5	20	21.50
Rap. and mustard	17.28	1	0.17
Millets	21.57	2	0.43
Total	620.43		134.92

* estimation based on the % residue burning data (Jain *et al.,* 2014)

India produces about 133.57 and 86.74 m t of actual dung through cattle and buffaloes respectively (estimated using formula given by Jain *et al.,* 2014). The states where the crop residue burning practices was observed intensively due to their disposal problem are the only states where production of dung is also higher. So if we utilize this crop residue and dung efficiently for compost making we can reduce GHGs problem up to certain extent and able to recycle plant nutrient to improve soil health with less investment.

The poultry industry has a potential to contribute in agro waste generation. The by-product generation categorized into two stages i.e. from production and dressing plant. From production stage the poultry litter and manure helps in surface dressing of agricultural land whereas the egg shell also have good source of calcium which is of special importance to earth worms health in vermicomposting. However, from dressing plant stage feather contributes about 7-8%. Apart from its use as decorative purpose feathers act as a bedding material as well as source of manure. Blood meal also forms 3.2-3.5% of poultry live weight. Blood meal also used for composting in western countries but its use in India is very less. It may be due to most of Indian population are vegetarian.

The slaughter house industry is an unorganized industry in India. At present there are no official norms for classification of slaughter houses. However, depending upon the type of animals slaughtered, the slaughter houses are classified**.** The local bodies must, therefore, take up modernization of slaughter houses and achieve the pollution control norms. Slaughtering of animals generates wastes consisting of non edible offal (like lungs, large intestines, various glands, animal tissues, organs, various body parts, etc.) stomach/intestinal contents, dung, sludge from waste water treatment, bones, etc. All these types of wastes are required to be disposed by adopting methods like rendering/controlled incineration/burial/composting/anaerobic digestion etc. The slaughter houses are normally controlled by local bodies, which should follow the standards prescribed, but due to non-existence of modernized slaughter houses, environmental pollution arising out of the slaughtering activities cannot be controlled.

In case of the different organic waste material, farm crop waste contains higher amount of NPK. Among the different animal waste cattle excreta contains more NPK which was followed by buffaloes (Table 3).

Table 3. Potentials of NPK from different organic wastes in India

Source	**Plant nutrients (Mt)**			
	N	**P_2O_5**	**K_2O**	**Total**
Cattle	2.977	0.793	1.332	5.102
Buffalo	0.745	0.276	0.487	1.508
Goat and sheep	0.214	0.063	0.020	0.297
Pig	0.044	0.027	0.029	0.100
Poultry	0.027	0.020	0.010	0.057
Other livestock	0.079	0.018	0.069	0.166
Farm crop waste	5.600	2.300	10.700	18.600

Fruit and vegetable waste

At presently, India producing about 221 Mt of fruits, vegetables and perishables but India has capacity to store 23.6 Mt in 5,386 cold storages of which 80 % are used for potatoes. Hence, according to industry estimates, 25 to 30% of fruit and vegetable and 5-7% of food grains in India get wasted every year. Similarly, annually 10% of food grain loss due to rodents. Only 7% of food in India is processed. Therefore, fruit and vegetable producer subjected to loss of 25% worth of produce.

The 40% post-harvest and processing loss (FAO Report, May 2011). If we utilize this waste for compost making we can recycle the nutrient that otherwise will go waste as fruit and vegetable waste contains higher amount of nutrients compared to other agro-waste. The total waste generated in the food grain market against total food grain arrival shown that waste generated from the different APMCs varies from 0.07% to 0.14%. These waste generated is quite low as food grain is not a perishable commodity as like fruit and vegetable but it has great potential of nutrients and can be recycle for returning the nutrients to soil.

The total waste generated in fruit and vegetables and its percentage compared to total arrival of fruit and vegetables in different APMCs. The % waste generated from these APMCs varies from 1 to 11.6% which is quite large amount. It was found that a huge quantum of fresh fruits and vegetables arrive and transacted daily in these Markets. As per traders survey, waste generated in fruits range from 2.6% to as high as 11.4 %. Wastage in Vegetables ranged from 3.15% to 12.6%. Markets like Azadpur generate approximately 4% wastages of both fruits and vegetables. Percent wastage reported by the Market Committee is comparatively quite low as against traders survey. This clearly indicates that a huge amount of food commodity wasted goes unreported. This also account for the lack of statistics and data on the quantum of food waste actually generated.

Why composting?

India has already enjoyed four decades of post green revolution and that to due to use of high yielding varieties and increased use of fertilizer. Although, extensive use of chemical fertilizer created several problems which deteriorated the soil and environment health, causes health hazard and insecurity of quality food, energy crisis, higher fertilizer cost. Such issues related to sustainability in agri-production system and ecological stability are renewed the interest of farmers and research workers in non-chemical sources of plant nutrients like biofertilizers, farmyard manure, green manure, composts etc. With the increased agricultural production due to green revolution, a huge amount of agro waste is also produced in the country. Disposal of such organic wastes from various sources like domestic, agriculture and industries has caused serious environmental hazards and economic problems. Generally, waste from the fruit and vegetable market is collected and dumped into the municipal landfills, causing a nuisance because of high biodegradability (Bouallagui *et al.,* 2004). This result in loss of potentially valuable nutrients (Baffi *et al.,* 2005). In India most common practices of waste processing are uncontrolled dumping which causes mainly water and soil pollution (Bouallagui *et al.,* 2004), whereas air pollution is caused due to burning of crop residue in the field. It leads to emission of GHGs and loss of valuable plant nutrient in the atmosphere (Jain *et al.,* 2014), that can be processed into fertilizer. In this context, recycling of agro waste through composting and vermicomposting represents the key technology for the production of organic manures and their use as nutrient supplements in soil to partially replace the chemical fertilizers or integrated use of both organic and inorganic sources of nutrients.

Benefits of Compost

Environment benefits

1. Water and soil conservation (erosion)
2. Protects groundwater quality
3. Minimizes odors from agricultural areas
4. Avoids methane production and leachate formation in landfills by diverting
5. Organics from landfills into compost
6. Drastically reduces the need for pesticides and fertilizers
7. Off-farm materials can be brought in and added to manure to make compost
8. Composted manure weights about one-fourth as much as raw manure per ton

Agricultural benefits

1. Long-term stable organic matter source
2. Soil pH in favourable range
3. Regenerate poor soils
4. Suppresses certain plant diseases and parasites and kills weed seeds
5. Increases yield
6. Increases length and concentration of roots in some crops
7. Increases SNC and WHC of sandy soils and water infiltration of clay soils
8. Reduces fertilizer requirements
9. Restores soil structure; compost is a soil inoculants
10. Increases earthworm populations in soil
11. Provides slow, gradual release of nutrients
12. Provides opportunity for extra income

Benefits to the Food Industry?

1. Reduces solid waste disposal fees
2. Educates consumers on the benefits of food waste composting
3. Markets your establishment as environmentally conscious
4. Markets your establishment as one that assists local farmers and the community
5. Reduces the need for more landfill space

Despite of numerous benefits, the agricultural use of composts remains low due to several reasons like: Transportation problem as it is bulky in nature; low nutrient value compared to chemical fertilizers; the nutrient composition variable compared to chemical fertilizers; concerns regarding potential levels of heavy metals and heavy application of composts to agricultural soils has been found to result in salt, nutrient, or heavy metal accumulation and may adversely affect plant growth, soil organisms, water quality, and animal and human health

Methods of composting

A.Traditional methods

Anaerobic Decomposition

The Indian Bangalore method (FAO, 1980)

This method of composting was developed at Bangalore in India by Acharya in1939. The method is basically recommended when night soil and refuse are used for preparing the compost. The method overcomes many of the disadvantages of the Indore method such as problem of heap protection from adverse weather, nutrient losses due to high winds / strong sun rays, frequent turning requirements, fly nuisance etc. but the time involved in production of a finished compost is much longer. The method is suitable for areas with scanty rainfall.

Aerobic decomposition

The Indian Indore method (FAO, 1980)

An important advance in the practice of composting was made at Indore in India by Howard during the period 1924 to 1926. The traditional procedure was systematized into a method of composting now known as the 'Indore method'. The raw materials used are mixed plant residues, animal dung and urine, earth, wood ash and water. All organic material wastes available on a farm such as weeds, stalks, stems, fallen leaves, prunings, chaff, fodder leftovers and so on, are collected and stacked in a pile. It may be prepared by pit method or heap method

Large Scale Aeration

Windrow Composting (NRAES, 1992)

Turned Windrows

Windrow composting consists of placing the mixture of raw materials in long narrow piles or windrows which are agitated or turned on a regular basis. The turning operation mixes the composting materials and enhances passive aeration. Typically the windrows are initially from 3 feet high for dense materials like manures to 12 feet high for fluffy materials like leaves.

Passively aerated windrows

The method, passively aerated windrow system, eliminates the need for turning by supplying air to the composting materials through perforated pipes embedded in each windrow. The pipe ends are open. Air flows into the pipes and through the windrow because of the chimney effect created as the hot gases rise upward out of the windrow.

B. Rapid composting methods

While traditional composting procedures take as long as 4-8 months to produce finished compost, rapid composting methods offer possibilities for reducing the processing period up to three weeks.

1. The Berkley Rapid Composting Method (Raabe, 2001) : Shredding and Frequent Turnings
2. North Dakota State University Hot Composting (Smith, 1995) : Use of mineral nitrogen activator
3. EM based Quick Compost Production Process (Hiraoka, 2002): Use of Effective Micro-organisms (EM)
4. Rapid Composting Technology (Virginia, 1997) : Use of Cellulolytic Cultures

Aerobic composting

In IARI the aerobic composting process adopted. A majority of the composting processes involve aerobic composting, wherein arrangements are made for exposing the composting material to oxygen. In this process aerobic microorganisms break down organic matter and produce carbon dioxide, ammonia, water, heat and humus. The intermediate compounds that may be produced are further oxidized and there is no risk of phytotoxicity. The heat generated destroys many human or plant pathogens and kills weed seeds. There is loss of more nutrients specially N as ammonia. Aerobic composting processes are preferred over anaerobic processes. Initially (first 2-3 days) the temperature in the compost windrow is around 20-45^{o}C and mesophilic organisms multiply rapidly, mostly on easily decomposable organic compounds such as sugars and amino acids. They generate heat by their own metabolism and raise the temperature to 50-70^{o}C, where their own activities become suppressed. Thermophilic fungi and bacteria then dominate and continue the process of composting and raise the temperature of compost to 65^{o}C or higher. This heat kills pathogen and weed seeds. Active composting stage is followed by a curing stage and the pit's temperature declines gradually. At this stage another group of thermophilic fungi start to grow. These fungi decompose cellulose and hemicellulose. Curing of the compost provides a safety net against the risks of using immature compost such as N hunger, oxygen deficiency and toxic effects of organic acids on plants.


Wind rows (crop residue and cowdung)   Microbial consortium application

IARI Wind-row composting

Wind-row composting involves placing the mixture of raw materials and cowdung (in the ratio of 5:1) in long narrow piles called wind rows, that are agitated or turned on a regular basis. The height of the wind-rows depends upon the raw materials. It is 0.9 m for dense materials and 3.6 m for light voluminous materials such as dry leaves. The width varies from 3 to 6 m. The size, shape and spacing of wind-rows depend upon the turning mechanism. Bucket loaders with a long-reach can permit high wind-rows, while turning machines permit low, wide wind-rows. There are a number of specialized machines for turning wind-rows that reduce time and labour involved considerably. Some of these machines attach to farm tractors or front-end loaders, while others are self-propelled. The microbial consortium mainly consisting cultures of *Aspergillus awamori*, *A. nidulans, Phanerochaete chrysosporium* and *Trichoderma viride***,** is used before turning and mixing of the raw material. Optimum level of moisture in the heap of compost is maintained by frequent sprinkling of water.


Addition of water for moisture   **Turning and Mixing of compost**

The active composting stage generally lasts 3-9 weeks depending upon the nature of materials and frequency of turning. Where 3 weeks is the goal, the wind-rows require turning once or twice a day during the first week and every 3-5 days thereafter. In general all type of crop residue takes about 60-75 days. Such material needs 3-4 turning, first at the beginning and subsequent turning at 15 days interval. By using the above method the Biomass Utilization Unit is preparing about 5000 tonnes of good quality compost annually.

Loder machine **Sieving machine**

Fine quality leaf compost **Costumer purchasing Vermicompost**

Twigs & wood Shredder machine **Shredded material**

Compost Turner cum Mixer

Crop Residue mixed Farm yard Manure (CRFYM)

As the names indicate this manure mostly uses crop residues and cattle dung and urine as the raw material. At Biomass Utilization Unit, Indian Agricultural Research Institute, New Delhi, CRFYM is prepared using approximately 80% crop residues and 20% fresh cattle dung and urine on weight basis. This manure is prepared by wind-row composting involves placing the mixture of raw materials in long narrow piles called wind rows, that are agitated or turned on a regular basis. The height of the wind-rows depends upon the raw materials. It is about 1.2-1.5m for dense materials and 3.0- 3.6 m for light voluminous materials such as dry leaves and stover of crop residues. The width varies from 2.5 to 3.0 m. Bucket loaders with a long-reach used to make wind-rows of desired size and shape. A specialized machine is used known as 'Turning-cum-Mixing Machine' for turning wind-rows and mixing microbial consortium that reduce time and labour involved considerably. The liquid microbial consortium (diluted 1:100 or 1:50 dilution with water) is sprayed on wind-row at the time of first turning.

This composting process involves aerobic process, exposing the composting material to oxygen. In this process aerobic microorganisms break down organic matter and produce carbon dioxide, ammonia, water, heat and humus. The intermediate compounds that may be produced are further oxidized and there is no risk of phytotoxicity. The heat generated destroys many plant pathogens and kills weed seeds. Initially (first 2-3 days) the temperature wind-rows is around 20-45^{o}C and mesophilic organisms multiply rapidly, mostly on easily decomposable organic compounds such as sugars and amino acids. They generate heat by their own metabolism and raise the temperature to 50-70^{o}C, where their own activities become suppressed. Thermophilic fungi and bacteria then dominate and continue the process of composting and raise the temperature of compost to 65^{o}C or higher. This heat kills pathogen and weed seeds. Active composting stage is followed by a curing stage and the wind-row's temperature declines gradually. At this stage another group of thermophilic fungi start to grow. These fungi decompose cellulose and hemicellulose. Curing of the compost provides a safety net against the risks of using immature compost such as N hunger, oxygen deficiency and toxic effects of organic acids on plants. The active composting stage generally lasts 3-6 weeks depending upon the nature of materials and frequency of turning. Where 9 weeks is the goal, the wind-rows require turning once or twice during the first week and every 15 days thereafter. The process of composting takes about 60-65 days. The C:N ratio of CRFYM produced by the wind-rows method varies from 15.4 to 20.5 depending upon the type of raw material used. It contains 4.8 to 7.0 % humus, 0.4 to 1.0 percent N, 0.2 to 0.4 per cent P and about 1.0 percent K depending upon the type of crop residue. It also contains secondary nutrients like Ca 0.6 to 0.95% and Mg 0.7 to 0.9%, and micro-nutrients like Fe 135-158 ppm, Mn 65-75 ppm, Zn 15-22 ppm and Cu 3-5 ppm.

CRFYM is an excellent soil amendment, which adds to balance of nutrients, while contributing valuable organic material to the soil. The latter is needed for the growth of soil microorganisms, to improve water-holding capacity, soil structure, for pH buffering and the organic complexing of nutrients – making them more available for uptake by plants. The main role of the CRFYM is to add organic matter and to increase humus content of soil.

Advantages of* CRFYM *include

1. Coarse CRFYM on the surface reduces the impact of the falling rain drops and thus reduces surface run-off and erosion.
2. Easily decomposable CRFYM leads to synthesis of complex organic substances that bind soil particles into structural units, called aggregates, which help to maintain a favourable condition of aeration and permeability.
3. Organic matter from CRFYM increases water-holding capacity of soil.
4. Organic matter adds and serves as a reservoir of essential plant nutrients which are released in harmony with the needs of the plants.
5. CRFYM produces organic acids that help in dissolving phosphorus and micronutrients in soils and increases their availability.
6. CRFYM increases exchange capacity as well as buffering capacity of the soils.
7. CRFYM serves as a source of food and energy for the growth of soil microorganisms as well as soil meso and macro fauna (ants, termites, earthworms etc.).
8. CRFYM used as mulch reduces water evaporation losses.
9. CRFYM used as mulch also helps in maintaining soil temperature.
10. The nutrients from manure are released to the plants slowly and steadily. The benefits will last for more than one season.

Biomass Utilization Unit IARI

Table 4. Production and Distribution (Tonnes) during 2015-16

	Produced	Distributed	Sold	Balance
Crop residue compost	4073	2073	4.73	2000
Leaf compost	875	375	-	500
Vermicompost	23	3.0	20.0	1.0

Table 5. Revenue Generated 2015-16(INR)-Estimated values

Material	Sale	Distributed	Total	Value of ready comp
Crop residue compost	-	62,19,000	62,19,000	60,00,000
Leaf compost	-	18,75,000	18,75,000	25,00,000
Vermicompost	2,01,760	30,000	30,000	10,000
Grass	2,32,134	-	2,32,134	
Fodder		-		
Total	**4,33,894**	**81,24,000**	**86,17,894**	**85,10,000**
Market Rate(Rs/t): RMFYM 3000/-, LC 5000/- and VC 10000/-				

The data from indicate that in the year 2015-16 IARI- Biomass Utilization Unit produced about 4073 t, 875 t, and 23 t and distributed about 2073 t, 375 t and 3.0 t of crop residue compost, leaf compost and vermicompost, respectively. The table 5 represents revenue generated from different type composts produced in the Biomass Utilization Unit. In the year 2015-16 Biomass Utilization Unit generated Rs. 4,33,000 revenue from selling of different composts. However, the unit saved Rs. 81, 24,000 by distributing this compost to IARI field. In total IARI compost unit generated revenue worth Rs. 86,17,894 based on the existing market rates.

Conclusion

Food and agricultural commodity are wasted through the food supply chain at various stages starting from Agricultural production till consumption but that can be processed into organic manure through composting. Enrichment of compost with vermivash, additives and microbial inoculants increase its efficiency. Off-farm materials can be brought in and added to manure to make compost which improves soil health. To recycle agro waste generated from various sectors agriculture, efforts needed at household as well as community level. IARI model of composting is an unique model to convert the agricultural waste into different types of valuale composts.

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Utilization of coconut plantation wastes-leaf vermicomposting, vermiwash production and coir composting

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Introduction

Coconut palm is an important plantation crop grown in 2.14 million ha in India supporting livelihood of growers with productivity of over 10000 nuts /year/ha. Besides, the main products such as copra and oil, coconut palm provides health drink, from tender coconuts and numerous kernel based products, sugar from inflorescence sap and many industrial products including products for pharmaceutical applications. The coconut palm produces about 12 leaves a year and over100 the husk & shell from One of the important cottage industries related to coconut palm is the coir industry. It is estimated that the coir-processing factories in India produce roughly 0.5 million tonnes of coir pith waste every year that accumulates in the vicinity and creates an environmental hazard. Rough estimates indicated the availability of about 10 million tonnes in southern India. Among the non-food products of coconut, coir or coconut fibre, coconut pith and shell assume commercial importance. Other parts of the palm especially coconut wood and leaves are recently gaining attention. Among these, coconut leaves and coir dust (a by-product from coir fibre industry) provide opportunities for production of organic inputs for agriculture applications. Coir fibre has many other applications in other industries including use of coir fibre as geotextiles which is also gaining importance in conserving soil and moisture in fragile ecosystems. This chapter covers the utilization of coconut leaves for vermicompost production, vermiwash production and coir products for compost production.

Husk utilization

The husk usually forms 35 to 45 per cent of the weight of the whole coconut fruit when ripe. About 30 per cent of the husk is fiber and 70 per cent is coir dust. At present only 35 per cent of the total husk available is utilised by the industry while there is scope for utilising at least 50 per cent of the husk produced in the country. When the coconut matures, the quantity of the fibre in the husk does not decrease, but it is the moisture in the fibrous mass of the husk which disappears. The thickness of the husk of an ordinary coconut varies from 2.5 to 3.0 cm in the case of thin husked coconut and 4.0 to 5.0 cm for thick husked ones. The product of importance derived from coconut husk are coir fibre and coir pith.

There are two distinct varieties of coir namely 'white fibre and brown fibre. The 'white fibre is extracted from retted coconut husk and is used for making traditional coir products like mats, mattings, rugs and carpets. Brown fibre is extracted from unretted husk. It is mainly used for the manufacture of curled coir. Curled coir is used in the rubberised coir mattresses, sofa cushion, bolsters, pillows, carpet underlay etc. In India, white fibre production has dominance, whereas in other countries, the production is confined to brown fibre. The world production of coir fibre is estimated at 0.310 million tonnes per annum of which the contribution of India and Sri Lanka is about 65 per cent and 32 per cent respectively.

Coir fabrics for ground water recharge

Compared to other natural fibres, coir fibres degrade very slowly and hence coir woven fabrics with loop construction retain moisture in the soil. This property can be used in water harvesting. Besides this, when the degradation of lignin starts, the acidic phenolic leachates may decompose even hard laterites and make the soil porous and helps in down ward seepage of water enriching the ground water table. It has been the experience of the agriculturists to condition the hard soil by stacking the coconut husk in pits surrounding the plants. This can be used in improving ground water level in hard lateritic terrain. Infiltration trenches at suitable locations with bore holes at the bottom to a significant depth (i.e. rocky bed or water table) can be made. These bore holes can be lined with reinforced and treated coir felt and metal chips can be loosely filled inside the trenches and bore holes. The top of the trenches can be covered with coir net with loop structure and fixed to a bamboo frame. This arrangement will ensure the collection of surface rain water and encourage percolation enriching the collector wells, besides raising the ground water level.

Coir pith

Coir pith constitutes as much as 70 per cent of the husk and is a waste product of the coir industry. Extraction of one kilogram of coir fiber generates two kilograms of coir pith. Approximately 180 gram of coir pith is obtained from the husk of one coconut. Accumulation of this waste in industrial yards causes environmental pollution and fire hazard. Pith generally mixed with short fibres contains lignin, cellulose and hemicellulose as major constituents. Coir pith is open cell foam. The cells are of almost uniform size and cylindrical in shape. The walls are very thin and empty cavities (lumen) are comparatively large. Average lumen size of the pith is 50 mm. The maximum water holding capacity is 624.0 per cent. This spongy cork like material left as such is normally resistant to biodegradation and is a source of environmental pollution. Though coir pith has a number of beneficial properties like improving soil physical properties and moisture holding capacity to a great extent, its direct utilization as manure is not advisable as it contains large amounts of lignin (75 per cent) and phytotoxic polyphenols and less of nitrogen. Hence, it is to be applied to soil only after composting.

2.2.1.Coir pith as a manure

Application of coir dust @ 5 tonnes/ha appreciably increases the phosphorous content of the alkali soil. The yield of rice, grapes and sorghum was improved by the application of coir pith @ 10 t/ha. The economic reclamation of saline alkali soils will be affected following the application of coir dust. Coir pith after inoculation with *Pleurotus sajor-caju* and treatment with urea show a definite reduction in the cellulose and lignin contents on incubation for 26 days at room temperature. The total nitrogen and other nutrients increased while the C:N ratio was narrowed from 112:1 to 24:1. Thus, it is feasible to use the inoculated pith as manure in agricultural farms. The ligno cellulosic components of coir pith can be acted upon by ligno celluloytic fungi of which the most effective is *Phanerocheate chyrosporium.* The complex is broken down at the rate of 25 per cent in four weeks thus directly converting coir pith into a biomass product. This can be used as an animal feed or fertilizer. The continuous application of coir dust influences reduction in bulk density, improves the water holding capacity and organic carbon status of soil. Also when coir dust is used for a long period, the water holding capacity of the soil is considerably improved and becomes more porous allowing better root penetration. The ligno cellulosic coir pith is free from heavy metals or manmade polymers. Direct application of coir pith reduces soil microbial population and soil bio-polysaccharides, soil dehydrogenases and soil respiration in all soils except those which are high in organic matter. The undecomposed coir pith with 8-12 per cent of soluble tannin related phenols apparently inhibits plant and microbial growth and also immobilizes nutrient nitrogen in the soil during polymerisation.

Composting of coir pith

Coir pith has many beneficial characteristics, making it a potentially productive resource for use in agriculture if used after proper composting. Composted and stabilized coir pith resembles peat and has characteristics similar to that of sphagnum peat, the most commonly used rooting medium in horticulture and hence it is commercially known as coco peat. It has high moisture retention capacity3 of 500–600% and high cation exchange capacity (CEC) varying from 38.9 to 60 m eq/100 g), which enables it to retain large amounts of nitrogen and the absorption complex has high content of exchangeable K, Na, Ca and Mg. It has also been valued for its high potassium content and low bulk density and particle density.

Even though all these properties make it an ideal material for use as soil amendment and rooting medium for soilless plant culture, direct use of raw coir pith is not recommended due to its high C : N ratio, lignin and polyphenol contents. Nitrogen content is 0.25%, C : N ratio, lignin and polyphenol content being 100 : 1, 37% and 100 mg per 100 g respectively. Agricultural use of this untreated coir pith could lead to microbial immobilization of soil nitrogen and subsequent nitrogen deficiency in plants. But these shortcomings of fresh coir pith can be managed if it is used after composting process.

Composting of organic materials requires a C:N ratio of 30:1 or less, the development of composting technologies for coir pith with high C : N ratio and lignin content involved fertilizer nitrogen supplements and lignin degrading microbial cultures. These technologies have enabled the utilization of composted coir pith as a valuable plant growth medium, plant nutrient source and soil conditioner. The availability of a low-cost, simple and rapid composting technology based on local resources, which is capable of producing good quality compost, is the key factor influencing the acceptance and widespread use by resource-poor farmers. For composting organic materials with high nitrogen content and low C : N ratio such as animal manure, addition of high C : N ratio bulking agents is required6 to facilitate proper microbial activity and is popularly known as co-composting. This method can conserve nutrients in the compost produced. Co-composting of coir pith having low nitrogen content and wide C : N ratio with poultry manure having high nitrogen content and narrow C : N ratio has been hypothesized to solve the current problems in coir pith composting. Poultry manure has been successfully used in the stabilization of organic wastes particularly high in lignin and cellulose, including wood wastes. There are indications from a study on the use of coir pith as a bedding material in poultry farms, that poultry droppings can enhance coir pith composting. The feasibility of co-composting coir pith with solid poultry manure, lime and rock phosphate amendment has been assessed and it was reported that the quality of compost produced by this method is better for its use in agriculture. The recalcitrant coir pith wastes produced from coir processing industries can be composted to useful manure with addition of poultry manure. The composting process can be enhanced upon inclusion of lime and rock phosphate along with poultry manure. ~~The composted coir pith has near-neutral pH, a C : N ratio in the range nearly 20–27, %N and %K ranging above 1 and stable CO2 evolution after 60–65 days of composting. Addition of composted coir pith was found to significantly increase the growth parameters and nodule numbers in the cowpea plants, indicating its use as an organic input.~~

The long term usage of coir pith to soil improves the water holding capacity of soil and become more porous allowing better root penetration. The direct application of un-decomposed coir pith resulted a reduction in soil microbial population soil dehydrogenases and soil respiration in all soils. Composting of coir pith has the advantages of detoxifying phenolic compounds, which are deleterious to microbial growth, reducing the bulk of the material and converting plant nutrients to a form more readily available to plants. A technology has been developed at TNAU using Basidiomycetous fungus, *Pleurotus sajor- caju*, which is capable of detoxifying phenolics of coir pith and producing bio-polymerizing enzymes. To compost one tonne of coir pith five spawn bottles (one spawn bottle contains 350 g of Pleurotus fungus culture raised on sorghum or pearl millet grain) and five kg of urea are required. After 30 days of decomposition, coir pith turns into a black mass of compost with reduced lignin, cellulose, organic carbon and C:N ratio. The volume of the material is also reduced by 50 per cent.

Technologies for large scale composting of coir pith has been standardized at Central Plantation Crops Research Institute, Kasaragod with amendments like poultry manure, lime and rock phosphate @ 10 kg, 0.5 kg and 0.5 kg, respectively for every 100 kg of coir pith as well as inoculation of biopolymer degrading micro organisms at 0.2 per cent level. The raw coir pith with a C: N ratio of 100-112: 1 can be converted to an excellent organic manure with the C: N ratio of 17-24: 1 within a short period of 40-45 days. *Pleurotus* spp. have the capacity to degrade part of the cellulose and lignin present in coir pith by production of enzymes *viz.*, cellulases and lactases. The lignin content also reduces considerably.

In moisture conservation

Coir pith absorbs water over eight times its weight of water and parts with release it slowly. It has been found that by incorporation o 2 per cent by weight of coir dust with sandy soil, the water holding capacity of the ratter is increased by 40 percent. The dust can be buried in pits in layers 8 cm thick alternating with 5 cm thick soil layers, to avoid the breeding of Rhinoceros beetle in coconut g It is also excellent organic mulch in all kinds of soil.

Coconut leaf utilization

The coconut palm bears a crown of leaves at the apex, comprising of the opened leaves and those surrounding the bud in various stages of development. The number of leaves in the crown varies with the variety and ecological and cultural conditions. Generally, an adult palm carries about 25-35 opened leaves on the crown. These leaves belong to four distinct sets. The first set comprises of the oldest 10-12 leaves from the axils of which bunches have been harvested. The next set comprises of the next older 10-14 leaves, supporting the fruits in various stages of development. The third set includes 10-12 opened leaves with spadices in various stages of development in their axils. The last set comprises leaves in the cabbage with the outermost ones in different stages of unfurling and the rest, which have not yet protruded. As the production of nuts progresses, the older leaves wither and fall. These leaves can be effectively for production of vermicompost with proven methods.

Vermicomposting of Coconut Palm Wastes

Conversion of agricultural, urban and industrial refuse into vermicompost by employing specific earthworms is becoming a favoured method of recycling wastes in many countries. Wastes from plantation crops like coconut, arecanut and cocoa, coffees and acacia, which contain high percentage of lignin and phenols, have also been successfully converted to vermicompost using different species of epigeic earthworms. Application of vermicompost rejuvenates the depleted soil fertility, enriches the available pool of nutrients, maintains soil quality and conserves more water and biological resources. The technology involves the use of earthworms as versatile bioreactor for effective recycling of non-toxic organic wastes to produce manure of high quality for sustainable agriculture. The byproducts from coconut plantations are converted to vermicompost with a nutrient content of 1.8 per cent nitrogen, 0.2 per cent phosphorus and 0.2 per cent potassium using a locally isolated earth worm species. Vermicomposting involves using native species of earthworm (*Eudrilus eugeniae*) for conversion of biomass into useful compost. Vermicomposting can be easily done *in situ* in coconut plantations using coconut leaves and other biomass including wastes from intercrops especially from banana. *In situ* recycling of coconut wastes by vermicomposting in trenches dug in interspaces of four coconut palms yield on an average recovery of 70 per cent in a composting period of 90 days. The average nutrient composition of the vermicompost recovered will be around 1.2-1.8 per cent N, 0.1-0.2 per cent P and 0.2-0.4 per cent K, 17.84 per cent organic carbon, and C/N of 9.95:1.00. Total microbial counts and beneficial microbial population will also be more in the coconut leaf compost as compared to the base material. This enables disposal of coconut wastes in a less expensive and eco-friendly manner, with the benefit of producing high quality organic manure in the coconut plantation itself. Various methods such as cement tanks, trenches as well as composting in the coconut basin itself can be adopted for vermicomposting wherein composting in the basins itself reduces cost incurred in transportation of leaves and application of vermicompost. The leaf dry matter production by tall coconut palms is around 32 kg/palm/year and hence the availability of leaf from one ha of coconut plantation can be estimated as 5.6 t/year. In this manner all the leaves produced from one coconut palm can be converted into very good organic manure. The properties of coconut leaf vermicompost are given in Table 1.

This technology can be adopted in plantations with very limited irrigation facilities as only less number of pits or trenches are to be irrigated. The coconut waste used for oyster mushroom production is also found suitable for vermicomposting. The composted spent substrate contains higher levels of micronutrients such as Fe, Zn, Cu and Mn when compared to that of the untreated substrate. As vermicomposting can be carried out during most part of the year, it provides employment opportunities to farm families and self help groups as well as supports income generation.

Apart from coconut leaves, other agro-wastes from coconut based cropping systems such as pineapple waste, banana pseudostem and leaves and glyricidia green manure can also be effectively used along with coconut leaves for vermicomposting. Hence, the agro wastes generated from coconut based cropping system can also be recycled efficiently in the production system. For large scale composting, permanent cement or brick tanks can be constructed to provide an opportunity to maintain appropriate quantity of food substrate, optimum moisture, temperature and other factors which are very essential for production of efficient and quality vermicompost. This will also give proper protection for the worms from predators like rodents, ants, birds and wild boars.

Vermiwash production

Another important product of vermicomposting technology is the vermiwash, which is rich in nutrients in readily available form, plant growth promoting hormones, beneficial microorganisms and can be used for improving the productivity of coconut. Vermiwash has been found to be effective as foliar spray for growth promotion and bio suppression of pathogens in crop plants. All the physiologically active water soluble components of vermicompost such as humic acids, plant growth regulators, amino acids, vitamins, micro nutrients and microbial cells are extracted in water and is known as vermiwash. The water soluble components from vermicompost may be collected by passing water slowly through the worm beds or by simple suspension of vermicompost in water. This is used for foliar applications as such or after sufficiently diluting, based on the need. Vegetables and ornamental plants have been reported to respond very well to this treatment. This bio-liquid is rich in nutrients and plant growth hormones and its application has been reported to stimulate anthurium, increase soil nutrient status and yield of paddy and productivity of marigold.

Vermicompost leachate has also been reported to be suitable as formulation for liquid fertilizer 3 and other agricultural uses. It has been reported that foliar applications of vermicompost leachate improved certain quality parameters of tomatoes besides suppressing Phytophthora disease. Most of these studies mentioned here report the beneficial effects of vermiwash or vermicompost leachate produced from animal manure + earthworms or from the earthworms alone.

The water-soluble components from vermicomposting tanks may be collected as leachate by passing water slowly through the composting beds or by simple suspension of vermicompost in water. This vermiwash is honey brown in color with a pH of 8.5 and contains both major and minor nutrients in appreciable quantity. Growth promoting hormones like IAA and GA are also present in vermiwash. Vermiwash produced from actively vermicomposting substrates of coconut leaf + cow dung by *Eudrilus* sp. had an alkaline pH, contained major and minor nutrients, growth hormones, humic acid and plant beneficial bacteria. Application of appropriately diluted coconut leaf vermiwash (CLV) increased germination and seedling vigour index of cow pea and paddy seeds in laboratory bioassays. The vermiwash characteristics are given in Table 2. Field trials with cowpea, maize and bhendi in India showed its capacity to enhance the biomass and yield of the crops accompanied by higher soil microbial activities.

Table 1. Properties of coconut leaf vermicompost

Parameter	Values
C:N ratio	9.95to 17.0
Total C (%)	35to37
Organic C (%)	17to 20
Humic acid (%)	10to13
IAA (ppm)	0.52to1.15
GA (ppm)	0.23to1.61
Phenols (ppm)	10 to14
WHC %	116to150
Total N (%)	1.8to 2.1
Ca (ppm)	19,500to20,413
K (ppm)	1600to4013
Mg (ppm)	4290to4679
P (ppm)	2100to3043
Na (ppm)	1411to1525
S (ppm)	2915to3041
pH	6.2to7.9

Source: ICAR-CPCRI, Kasaragod

Table 2. Characteristics of coconut leaf vermiwash

Parameters	Conc. (ppm)
N	2.8
P	10.2
K	205
Ca	37.9
Mg	6.5
Fe	Traces
Cu	Traces
Zn	0.07

Mn	0.17
Biochemical Constituents (µg/ml)	
Total Sugars	61.6to111.2
Reducing Sugars	41.9to88.4
Free Amino acids Proteins IAA Gibberellic acid	20.8to32.3 615to890 0.52to1.15 0.23to1.61
Total Phenols	10.2to14.8
pH	7.6to 8.9
Population of Micro organisms (cfu/ml)	
Bacteria	2×10^3
Fungi	85
Actinomycetes	9×10^3
Phosphate solubilizers	25×10^2
N2 fixers	15
Fluorescent Pseudomonads	8×10^2

Source: ICAR-CPCRI, Kasaragod

Animal waste management in organic farming

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Animal waste of varied types available in large quantities in our country having low in nutrient content include solid waste viz. dung, feed waste, soiled bedding ,fodder and liquid like urine and wash water. The waste production in cattle farming is to the tune of 40 kg/day per adult animal. India is having 191.2 million and 102.4 million cattle and buffalo population respectively besides goat, sheep and other domesticated animals and poultry. Considering the large cattle population, the waste production will come to enormous amounts every day and if it goes on accumulation, can cause environmental pollution in terms of surface and ground water pollution. This pollution reduction is therefore, an important need of today. The good locally suitable waste management practices will minimize the impact of animal waste and or manure on the environment. The market and demand for organically agriculture produce are on the increase world over which opened a new export opportunities for the developed countries. Simultaneously domestic consumers are now increasingly looking for better quality of certified food products now. Hence organic farming is receiving attention day by day. Govt of India also recognized it as an priority areas for attention. ICAR has also recognized it as a system of agricultural production worth promotion in certain regions having potential for organic farming and animals are central of it for its sustainability. But very little work has so far been done in the area of organic animal husbandry. This fact makes it imperative that organic animal husbandry is paid due attention by the policy makers, research institute, SAUs and other development agencies. The economic value of dung in billion rupees used as a total of 188 through traditional ways as fuel (109.5) and manure (78.5), 241 as farm yard manure with manure only, 460 as biogas and slurry (fuel=219 and manure=241), 3,078 as biogas and vermicomposting (fuel=219 and manure =2859) and 3,536 as biogas and biofertilizers (219 for fuel and 3317 for manure). The average daily production(kg) of dung and faces from other animals are 13.50 (range 9-18), for horse, 24.00 (18-30) for cattle ,32.50 (25-40) for buffaloes,1.25 (1-25) for sheep and goat,4.00 (3-5) for pig and 3.00 (2.5-3.5) for 100 birds.

Traditionally livestock wastes are directly applied to crops for improving soil fertility. But it causes problems of termite and white grub in the crop. Besides a huge quantity of cow and buffalo dung is dried as patties or dungs cakes for fuel in rural and urban areas. The modern methods of livestock waste utilization include composting, vermi-composting and biogas production which can be used for lighting, heating, cooking, running farm engine, generator sets etc. the slurry after biogas production is also used as good manure for crops. Agro-chemicals like chemical fertilizers, pesticides, weedicides and antibiotics have played a vital role in improving crop and livestock productivity worldwide. But indiscriminate use of chemicals in agriculture and livestock production pose a threat to human and other mammalian species as the residues enter into the food chain directly or indirectly and heldresponsible for many health hazards. Moreover, the food scares like food borne diseases are alerting peopleof harmful consequences of consuming food laced with chemicals and harmful residuesof pesticides and antibiotics. Many chronic diseases, which are on the rise, are beingattributed partly to these agrochemicals, making the sustainability of chemical basedfarming and intensive livestock production questionable. As an alternative, therefore, organic agriculture is rapidly growing around the world including in India.Now a days consumers are becoming more and more health conscious and prefer food produced organically.

Organic wastes are typically by-products of farming, industrial or municipal activities and include animal manures, crop residues, food processing wastes and municipal biosolids. Agriculture has traditionally used animal manures for fertilizer and improving soil physical and chemical properties. Now lot of emphasis has been given to utilize the organic wastes as resource.Possible uses of organic wastes include use as fertilizer and soil amendment, energy recovery (heat, liquid fuels, electricity), and production of chemicals (volatile organic acids, ammonium products, alcohols).Utilization of various organic wastes in agriculture depends on several factors, including the characteristics of the waste such as nutrient and heavy metal content, energy value, odor generated by the waste, availability and transportation costs, benefits to agriculture, and regulatory considerations. The importance of these factors can vary by type of organic wastes, but many of the considerations for utilizing organic wastes are similar for most organic wastes. The emphasis of this paper will be on management of animalwastes to reduce environmental pollution besides using for crop production. Therefore, the disposal of excreta and other waste from animal habitation is one of the most important managemental activities in commercial farms.

Eco-friendly and modern methods of agriculture and livestock waste recycling for enhancing farm profitability

The livestock waste produces greenhouse gases especially methane and $co_2$the total greenhouse gases emission from India in 2007 was 1727.71 million tonnes of CO_2 equivalent (eq) of which maximum was co_2 (1221.76) followed by methane (20.56 MT) and nitrous oxide (0.24 MT). it was estimated that the methane production in India was 296 million tonnes during 2007. Out of that, 59% was produced by livestock, 20.56% by rice field and 5% by manure. This warrants immediate and proper handling of livestock and their wastes Livestock waste is major source of green house gas, pollution, pathogens and odor. 40 % of global methane is produced by agriculture and livestock by-products followed by 18 % from waste disposal globally. It is a rich source of energy and fertilizer elements, which can be recovered for betterment of agriculture. Traditionally the dung cakes are utilized for cooking the food in rural areas particularly in developing countries.

Vermicomposting

It has been estimated that organic resources available in the country alone can produce not less than 20 million tonnes of plant nutrients (NPK). Nutrient composition of manures is given in Table 1. Vermicompost technology has promising potential to meet the organic manure requirement in both irrigated and rain fed areas. It has tremendous prospects in converting agro-wastes and city garbage into valuable agricultural input. From vermiculture, we get well decomposed worm casts, which can be used as manure for crops, vegetables, flowers, gardens, etc. In this process, earthworms also get multiplied and the excess worms can be converted into vermiprotein which can be utilized as feed for poultry, fish, etc. Vermi-wash can also be used as spray on crops. Vermicomposting is the process of turning organic debris into worm castings. It is the use of earthworms for composting organic residues. Earthworms can consume practically all kinds of organic matter and they can eat their own body weight per day, e.g. 1 kg of worms can consume 1 kg of residues every day. The excreta of the worms are rich in nitrate, available forms of P, K, Ca and Mg. The passage of soil through earthworms promotes the growth of bacteria and actinomycetes. Actinomycetes thrive in the presence of worms and their content in worm casts is more than six times that in the original soil.

Table 1. Per cent nutrient contents of manure in animal refuse

Animal refuse	Nutrient Content (%)		
	Nitrogen	Phosphate	Potash
Cattle dung and urine mixed	0.60	0.15	0.45
Horse dung	0.70	0.25	0.55
Sheep dung	0.95	0.35	1.00
Night soil	1.20	0.90	0.45
Poultry manure(fresh)	1.4	1.60	0.85
Raw sewage (fresh)	2.50	-	0.45
Sewage sludge (dry)	2.25	1.10	0.45
Sewage sludge (activated dry)	5.62	3.25	0.60
Cattle urine	1.05	Traces	0.75
Horse urine	1.35	Traces	1.40
Human urine	1.15	0.15	0.25
Sheep urine	1..60	Traces	1.90

Source: Fertilizer Statistics 2007-08 and Hand Book on Fertilizer Usage 1994, Fertilizer Association of India, New Delhi.

Materials needed for preparation of Vermicomposting

Any types of biodegradable wastes like Animal wastes, Crop residues, Weed biomass, Vegetable waste, Leaf litter, Hotel refuse, Waste from agro-industries and Biodegradable portion of urban and rural wastes can be made into vermicompost. The vermicomposting process involves the following phases. Phase 1: Processing involving collection of wastes, shredding, mechanical separation of the metal, glass and ceramics and storage of organic wastes. Phase 2: Pre digestion of organic waste for twenty days by heaping the material along with cattle dung slurry. This process partially digests the material and fit for earthworm consumption. Cattle dung and biogas slurry may be used after drying. Wet dung should not be used for vermicompost production. Phase 3: Preparation of earthworm bed. A concrete base is required to put the waste for vermicompost preparation. Loose soil will allow the worms to go into soil and also while watering; all the dissolvable nutrients go into the soil along with water. Phase 4: Collection of earthworm after vermicompost collection. Sieving the composted material to separate fully composted material. The partially composted material will be again put into vermicompost bed. Phase 5: Storing the vermicompost in proper place to maintain moisture and allow the beneficial microorganisms to grow.

Vermicompost has the following benefits. In soil, it improves soil aeration, Enriches with micro-organisms (Microbial activity in worm castings is 10 to 20 times higher than in the soil and organic matter that the worm ingests), Attracts deep-burrowing earthworms already present in the soil, Improves water holding capacity, the castings are rich in humic acids, which condition the soil and help balance pH, improves nutrient recycling.

It also impacts plant growth through enhancing germination, plant growth, and crop yield; improved root growth and structure, enriching soil with micro-organisms, finished vermicompost can be mixed directly into the soil as a soil amendment, as plant medium or used to make compost tea. It improves nutrition by supply of essential nutrients and aids in the suppression of plant diseases and worm castings contain five times more nitrogen, seven times more phosphorus, and 11 times more potassium than ordinary soil, the main minerals needed for plant growth.

Use of cow urine

Cow is considered a sacred or holy in India, particularly, among the Hindus. In Ayurveda, cow urine (also called Gomutra) is claimed to be quite beneficial and is a natural source of many minerals required by the body. This may be due to the fact that when cows graze in the field, they eat many medicinal leaves which may reflect in their urine. The use of cow urine for therapeutic purpose has a long history in Indian culture. Urine of a pregnant cow is considered special and it is claimed that it contains special hormones and minerals. The reported health benefits of cow urine include: It is used in the treatment of fever by mixing it with black pepper, yoghurt, and ghee. Anaemia can also be treated by a mixture of cow urine, Triphala (a herbal concoction), and cow milk. Cow urine is also said to be helpful in treatment of peptic ulcer, asthma and certain liver ailments. A mixture of gomutra and dharuharidra is used for treating epilepsy. Cow urine also purifies the human body from inside out by flushing out all toxins, thereby reducing large number of health risks, including diabetes, obesity, high blood pressure, etc. and Cow urine is also used as sprays for pest control both in houses as well as for agriculture.

Panchagavya or panchakavyam

Panchagavya or panchakavyam is a mixture prepared by mixing five products of cow i.e. cow dung, urine, milk, curd and ghee. These are mixed in proper ratio and then allowed to ferment. It is believed to be apotent organic pesticide and growth promoter. The Sanskrit word Panchagavya means "mixture of five cow products". It is in Ayurvedic medicine and of religious significance for Hindus. Panchgavya is also used as fertilizers and pesticides in agricultural operations. Panchagavya has the following uses.

- A common usage is as a fertilizer and pesticide. Seeds can be treated with panchagavya. This was found useful in rhizome of turmeric, ginger and sugarcane and they yielded more. It also helps in plant growth and immunity.
- The medicinal usage of panchagavya, particularly cow urine, is practiced in Ayurveda. Proponents claim that cow urine therapy is capable of curing several diseases, including certain types of cancer, although these claims have no scientific backing.
- It can be used as antibiotic growth promoter in the broiler diet
- It is sometimes used as a base in cosmetic products.

Biogas production technology

Gas production from anaerobic biomass digestion is a famous technology. Biogas is a clean, efficient, and renewable source of energy, which can be used as a substitute for other nonrenewable fuels in order to save energy in rural areas particularly in developing countries of Asia and Africa. India and China are the two leading Asian countries using biogas technology. The biogas produced is mainly used for household application in majority of developing countries of Asia and Africa. Biogas can be purified up to 98 % methane content and can be stored into CNG cylinders. Further, the stored biogas was used to run petrol-based auto rickshaws and diesel engines.

Limitations of use of organic wastes

Traditionally, the most common utilization for agriculture and livestock organic by-products has been the application to land for improving the soil physical and chemical properties, and using the nutrients for growing crops. Although utilization of organic waste in agriculture has many benefits, there remain factors that significantly limit that strategy. Some of the challenges and limitations of using organic by-products are as follows.

- Imbalance of nutrients in organic residues compared to crop needs
- The relatively low nutrient concentration compared to chemical fertilizers,
- Possible transfer of weed seed
- Possible environmental concerns, such as emission of ammonia and other gases, odor, and pathogens

Conclusion

Agriculture and livestock waste can be recycled by many modern ways in order to combat rising energy prices, sustainable agricultural and reduce the environmental threats from traditional livestock waste management practices. Management strategies for utilization of organic wastes start with the source, such as animal housing and corresponding manure handling and treatment, because this determines the nature of the organic residues and by-products to be utilized. Selection of manure management and treatment options increasingly depends on environmental regulations for preventing pollution of land, water and air. To better utilize organic wastes other than animal manure, better organization and cooperation is needed between waste producers and waste users to schedule the appropriate application times and rates. More analysis needs to be conducted on a regional basis to develop regional management schemes to handle nutrients and protect the environment.

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Seaweeds- Potential source of Food and Fertilizer

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Algae are classified as unicellular microalgae and macroalgae, which are macroscopic plants. Macroalgae, also known as seaweeds are distinguished according to the nature of their pigments as brown seaweed (phaeophyta), red seaweed (rhodophyta) and green seaweed (chlorophyta). They flourish wherever rocky, dead coral or suitable substrata are available for their attachment. Seaweed biomass is harvested throughout the world as food source as well as for the production of phycocolloid such as agar, agarose, alginate and carrageenan.

With increasing population and declining terrestrial food resources due to rapid urbanization and industrialization and water shortage for irrigation, there is an urgent need to develop and implement innovative food production strategies particularly from utilizing vast marine resources. Among the marine organisms, seaweeds are the best renewable resource as nutritional food and fertilizer. Seaweeds as food and seaweed-derived food flavors, colors nutrients and fertilizers are attracting considerable commercial attention.

Seaweed as potential source of food

Seaweeds have long been part of the traditional diet for the people in China, Japan and Korea for over 2000 years. They are rich in protein (20 to 70% of their dry weight), extraordinary wealth of mineral elements and higher content of iodine, calcium, magnesium, potassium, iron, vitamins C and A, protein, Vitamins B and so much more. Besides serving as best food source, seaweeds are also having high medicinal properties. They are the potent source of antioxidants and anti inflammation. In addition, seaweeds are important source of dietary fiber, mainly soluble fiber which is considered important in preventing colon cancer, cardiovascular disease and obesity.

Green algae belonging to the genera *Ulva*, formerly *Enteromorpha* (Hayden et al., 2003), are common seaweeds distributed worldwide. These algae are harvested to prepare "aonori", which is included in a great variety of dishes, including raw salads, soups, cookies, meals, and condiments. The interest in Ulva as a novelty food is now expanding in western countries.

Ulva contain high percentage of protein (16–22%) carbohydrate (43 -60%) and ash content (12–18%) as dry matter, rich amount of minerals, such as calcium, magnesium iron etc. and all vitamins **(Percival 1979; Msuya and Neori 2008)**. The nutritional benefits of foods made out of this seaweed supplements in many cases surpass those diets based on terrestrial plant foods, improving amino acid balance and quality and quantity of protein, adding a naturally rich combination of minerals, vitamins, fiber, polyunsaturated fatty acids and antioxidants (Mc Dermid and Stuercke 2003; Matanjun et al. 2009).

CSIR-CSMCRI has recently collected 108 Ulva strains from various places covering entire coast line of India and quantified their nutritional and biochemical contents.

Carbohydrate contents

Carbohydrate content estimated from total 108 samples is shown in figure 1. The experiment was conducted in duplicate. Carbohydrate content varied in range of 16.6% to 65.9% of dry biomass. The average value of carbohydrate estimated was 38.75%.

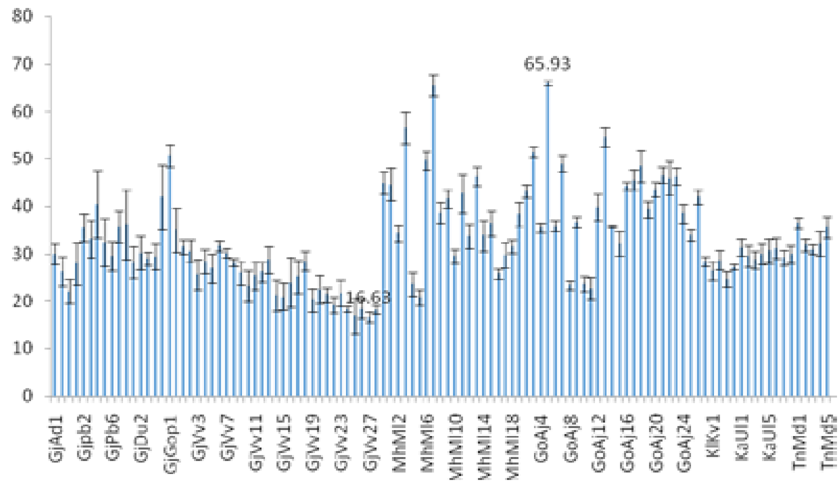

Figure 1. Carbohydrat content of Ulva strains collected from Indian coast

Protein contents

Protein content estimated from all 108 samples is given in figure 2. The experiment was conducted in duplicate. Protein content varied in range of 4.14% to 26% of dry biomass. The average value of carbohydrate estimated was 14.70%.

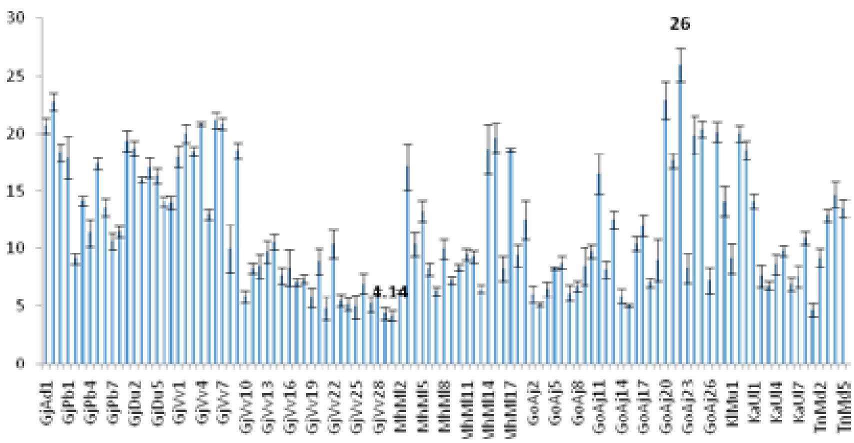

Figure 2. Protein content of Ulva strains collected from Indian coast.

Lipid contents

Lipid content estimated from all 108 samples is shown in figure 3. The experiment was conducted in duplicate. Lipid content varied in range of 0.8% to 3.1% of dry biomass. The average value of lipid estimated was 1.99%. The comparative lipid content from different samples is given in fig. 3.

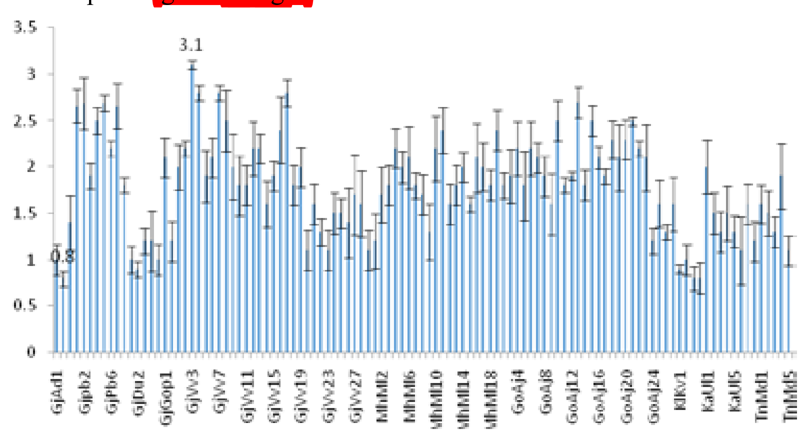

Figure 3. Lipid, content of Ulva strains collected from Indian coast

Seaweeds as potential source of Fertilizer

Seaweeds are in great demand for food, phyco-colloids and crop biostimulant purpose. Globally, at present, 255 species of seaweeds are being commercially exploited, including 145 and 110 species for food and phycocolloids, respectively. The cultivation technology of the seaweeds, namely, Eucheuma (kapppahycus) and Gracilaria—figuring in top 5 cultivated seaweed species in the world— has been standardized by CSIR-CSMCRI, Bhavnagar for growing in Indian coastal waters. The Institute has further developed the technology to extract their phyco-colloids (carageenan, agar/agarose) and biostimulant from these seaweeds. The biostimulant developed has been tested in 20 states of India at 43 centres in collaboration with State Agricultural Universities, ICAR Institutes and farmers with very encouraging results.

The results of this multi-crop multi-locational trials demonstrated an improvement of 10-37% increase in yields of the crop by use of biostimulants of these two seaweed species, depending upon the crops (Figure 4).

The biostimulants prepared from these two species contain several active ingredients in the form of hormones, quaternary ammonium compounds, macro- and micro- nutrients (Table 1)

Table 1 Composition of *K. alvarezii* and *G. edulis* sap [Source: Layek et al. (2015)]

Constituents	**Amount in mgL^{-1}**	
	***Kappaphycus alvarezii* sap**	***Gracilaria edulis* sap**
Indole 3-acetic acid (IAA)	27	8.7
Zeatin	20	3.1
Gibberellin (GA_3)	24	ND
Choline	57	36
Glycine betaine	79	63
Betain aldehyde	present	present
Na^+	198	1952
K^+	33654	682
Ca^{2+}	321	352
Mg^{2+}	1112	311
Zn^{2+}	4.7	0.63
Mn^{2+}	2.1	33
Fe^{2+}	86	13
Cr^{3+}	32	0.20
Cu^{2+}	0.65	0.04
Ni^{3+}	3.5	0.21
P^{3+}	17	ND

ND: Not detected

However, as mentioned earlier, there are many seaweeds found in India which have not yet been explored for their crop biostimulant potential and should be evaluated.

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Seaweed farming: A source of livelihood and bio stimulant for agriculture production

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Marine environment hosts several flora and fauna which are of great importance to mankind for consumption and industrial uses. Several groups of aquatic fauna such as fin fishes, shell fishes, oysters, molluscs, etc are having enormous potential in aquaculture sector and various technical advancements were made in the mariculture sector. Mariculture encompasses the cultivation of many varieties of plants and animals in a wide range of habitats. One of the very important group in marine environment is seaweeds which were often confused as weeds or unwanted plants due to their common name. Marine macro algae, popularly known as seaweeds belong to non-flowering plants and are commonly found in intertidal as well as in the subtidal regions of the sea (Domettila et al., 2013). Based on morphology, cellwall and pigment composition, they are classified into green (Chlorophyceae), red (Rhodophyceae) and brown (Phaeophyceae) algae (Darcy-Vrillon, 1993). Seaweeds or marine macroalgae constitute one of the commercially important renewable marine living resources (Rajasree and Gayathri, 2014). Seaweeds are rich in minerals, trace elements, protein, iodine, bromine, vitamins and many bioactive substances. Seaweeds are the only source of marine polysaccharides known as phycocolloids such as agar, carrageenan and align (Anuraj et al., 2016).Owing to their numerous applications in commercial trade, their mariculture has gained importance and several methods were standardized for culture of seaweeds. Seaweed aquaculture, the fastest growing component of global food production offers a slate of opportunities to mitigate and adapt to climate change (Duarte et al., 2017). The seaweed industry is undergoing a rapid global expansion and currently accounts for 49% of total mariculture production as majority of seaweeds are for human consumption and rest as animal feed additives and fertilizers (Cottier- Cook et al., 2016).A[illegible] stands as the world leader in seaweed cultivation and more than 80% is contributed by China, Korea and Japan. Cultivation of seaweed mainly reduces the stress on harvest of natural stocks and hence various culture methods were developed for the mariculture of seaweeds. The availability of natural seaweed stocks will also be inadequate to meet the growing demand and hence mariculture is recommended.India possesses enormous potential for seaweed mariculture as it's bestowed with a coastline of more than 8129 km with seaweed diversity hotspots like Gulf of Kachchh and Gulf of Mannar. According to Chennubhotla et al. (2013) the annual production of marine algae in India has been estimated to 3, 01,646 tonnes. The rocky beaches, mudflats, estuaries and lagoons on the Indian coasts offer ideal habitats for seaweed farming. The first large scale commercial cultivation of seaweeds in India has been embarked upon by Pepsi foods along a stretch of 10 km of the palk bay side towards Mandapam in Tamil Nadu with technical sport from CSMCRI, Mandapam (Mohammed, 2016).The geography of the Andaman and Nicobar and Lakshadweep islands make it appropriate for freshwater, brackishwater and mariculture activities. The islands are endowed with rich marine resources and also possess immense potential for the development of mariculture. There are about 7450 globally known seaweeds wherein, Indian coastline is gifted with 896 species of marine algae comprising 228 species of Chlorophyta, 210 species of Phaeophyta, 455 species of Rhodophyta and 3 species of Xanthophyta (UmamaheswaraRao, 2011). Rich diversity is reported from Islands as well viz. more than 300 in Andaman Islands (Raghunathan et al., 2013) and around 114 species in Lakshadweep (Kaliaperumal et al., 1989). ~~Seaweeds are marine macroalgae which possess numerous applications in the various industrial and commercial uses.~~ Seaweeds collection as well as culture is one of the major sources of livelihood in developing countries. Hence developing mariculture activities especially seaweed culture by utilizing the available potential resources will surely enhance the livelihood of the island communities.

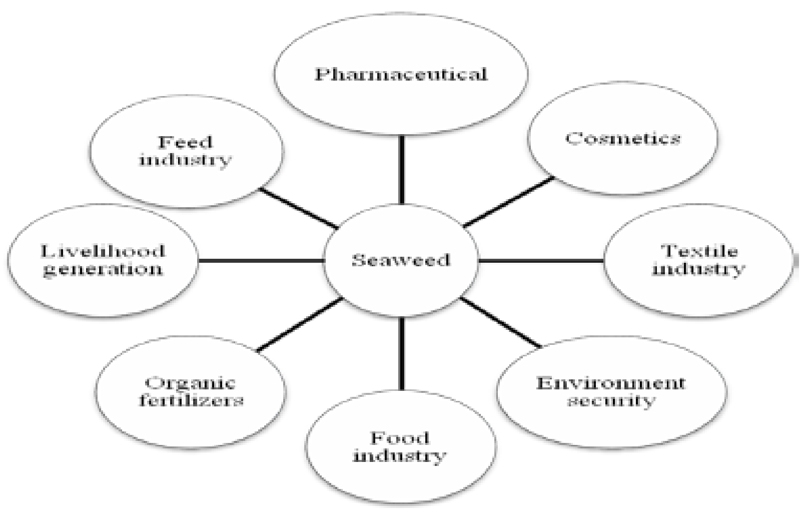

Fig. 1. Uses of seaweed (Arasu et al., 2008; Anuraj et al., 2016)

Table 1. Background of seaweed mariculture in India

Year	Outcome
1964	Experimental cultivation of agar yielding seaweeds *Gelidiella* and *Gracilaria* began in by Central Salt and Marine Chemicals Research Institute (CSMCRI) and CMFRI (Central Marine Fisheries Research Institute).
1983	Viable technology for commercial-scale farming of *Gracilariaedulis*using coir rope nets in Gulf of Mannar
1990	*Gracilaria edulis* culture in lagoons of Krusudai Islands (Mandapam) and Kavaratti Island to Minicoy Islands (Lakshadweep)
2000	PepsiCo Holdings India Ltd. (PepsiCo) made first organized attempt to culture seaweed at an industrial scale
2002	CSMCRI developed the commercial cultivation method of *Kappaphycus alvarezii & Hypnea musciformis*
2003	Bamboo raft technique emerged as a most suitable method for commercial culture of seaweed

(Source: Krishnan and Narayanakumar, 2010)

Opportunities and methods for seaweed cultivation in Islands

Mariculture of seaweeds is a potential avenue for livelihood and commercial activity in India particularly in regions of Tamil Nadu, Gujarat and the actual magnitude of potential of seaweeds was not assessed in Andaman and Nicobar Islands despite possessing sea weed diversity of more than 300 sp with numerous protected bays for the mariculture. Seaweeds from which alginic acid and agar agar can be produced occur in patches and the distribution of the former is more as the distribution of *Turbinaria*, *Sargassum* and *Padina* is dominant in the Bay Islands. (ANDFISH, 2005). ANDFISH, 2005 also recommends use of rafts, longlines and pens for the farming of seaweeds. Culture of nutrient utilizes like seaweeds and molluscs improve water quality (Arasu et al., 2009). The present production of seaweeds in India is about 4502 tonnes which are exclusively from the farming of *Kappaphycus alvarezii* mainly by bamboo rafts using seeded ropes or nets (Anuraj et al., 2016). In Lakshadweep Islands, preliminary studies indicate excellent prospects of augmenting production of valuable carrageen yielding seaweed through mariculture for job opportunities (Planning commission, 2004). Such promising venture is already proven effective in places like Mandapam and Gujarat where sea weed farming is major livelihood activity for women and men. Considering the potential resources available in the islands any of the following culture methods (FAO, 1990) can be selected based on the suitability as Single rope floating raft method, Fixed bottom long line method, Integrated multi trophic aquaculture method.

Some of the commercially important seaweeds of India are as follows:

1. **Agarophytes**

Gracilaria edulis, *G. fergusonii*, *G.arcuaa*, *G.indica*, *G.obtusa*, *G.crassa*, *G.corticatavarcorticata*, *G.corticatavarcyllindrica*, *Gelidiella acerosa*, *Gelidium*, *Pterocladia*

2. **Alginophytes**

Sargassum wightii, *S.longifolium*, *S.ilicifolium*, *S.myriocystum*, *Turbinaria conoides*, *T.ornata*, *T. decurrens*, *Acanthophora spicifera*

3. **Carrageenophytes**

Hypnea musciformis, *Hypnea valentiae*, *Kappaphycus alvarezii*(non native)

Seaweed as biostimulants in organic farming

Agricultural growing practices have been evolving towards organic, sustainable or environmental friendly systems (Bulgari et al., 2015) and hence organic farming is considered as future of farming for agricultural development in many countries. Stress on organic way of culturing agri and allied products is gaining importance recently as awareness on health impacts of using inorganic fertilizers is been understood. The search for organic alternatives to replace the inorganic chemical fertilizers has been experimented globally and many alternative practices to pursue organic culture are currently being developed. One among them is the micro and macro algae, particularly seaweeds found in marine tropical waters. Interactions of algae with the soil community undoubtedly are complex and benefits are dependent on the crop and the local environment conditions (Cragie, 2010). Seaweed aquaculture itself is a rewarding activity and its further prospects in field of agriculture, horticulture and animal husbandry makes them outstanding with regard to their potential in marketing and product development for commercial purposes. Andaman and Nicobar Islands are very rich in diversity and distribution of marine macroalgae or seaweed flora (Karthick et al., 2013). Seaweeds are considered to be nutritionally rich compounds and its applications in various industries are proven to be effective. Traditionally coastal communities worldwide have been using drift seaweeds as soil amendment and fertilizer (Rebours, 2014).The positive effects of the use of sea weeds in organic farming are recognized and their utilization is authorized for organic production under some restrictions (Mattilsynet, 2009). Seaweeds likewise have been used for millennia as fodder supplement to improve animal nutrition and productivity (Cragie, 2010). The potential of seaweed extracts for utilization in agriculture and animal husbandry can be advantageous for organic farming as soil amendments and fertilizers using chemicals can be replaced by seaweed extracts.Scientific experiments have shown that seaweed product can improve and enhance various aspects of plant growth and development (Crouch and Staden, 2008). Agriculture crop performance can be improved with use of seaweed extracts (Carvalho et al., 2013). Growth of plants, yield of grains as well as quality of product was greatly influenced by applications of Liquid seaweed fertilizers (Zodape et al., 2008). The efficacy of the extracts is probably based upon plant hormones (mainly cytokinins) and trace nutrients present in the extracts (Verkleij, 2012), yet their utilization is not maximised though their benefits has been realized and proven.. Seaweed extract is also proven to have positive effect on the production of wheat through soil irrigation (Carvalho et al., 2013). Yield and nutrition quality of okra fruit has been significantly increased using liquid seaweed fertilizer applications (Zodape et al., 2008). Seaweeds such as *Kappaphycus alvarezii* and *Gracilaria edulis* sap also used as foliar spray for sustainable productivity of maize (Singh et al., 2015). The sap of seaweeds *Kappaphycus alvarezii* and *Gracilaria edulis* also proven to be potent low cost plant bio stimulant when applied as foliar spray (Layek et al., 2015) and improve copper uptakes in grapevines(Turan and Kose, 2004)

Advantages/benefits of seaweed farming

1. Low input cost considering natural grown out conditions
2. Low culture period, (40-100 days)
3. Unlike other mariculture practices, no need for feed and management practices
4. Easy to implement technologies
5. Availability of seaweed farming hotspots and species diversity
6. Access to the market and existing demand
7. Suitable livelihood option for small scale fishermen and fisherwomen

Limitations

1. Labour intensive considering the involvement in on sea conditions and needs skilled manpower
2. Raw material scarcity
3. Threats due to predators/poaching
4. Site suitability requirements and knowledge
5. Diseases outbreak ~~such as ice-ice~~
6. Prone to natural disasters like cyclones, floods, storms etc particularly in Island conditions like Andaman and Lakshadweep
7. Grazing fishes,turtles, snails, sea urchin, etc. damages the crops under culture.

Operational constraints in the processing industry such as power and water supply shortages are common. Growth of the industry is limited due to lack of capital for starting and running the industry. Unavailability of row materials results in the economic instability of the industry. Unhygienic beach drying of the seaweeds results in the reduced quality row materials as it results in the occurrences of foreign matters especially sand particles.

Seaweed farming offers array of benefits to the coastal communities and entrepreneurs. Seaweed aquaculture is also seen as sound strategy for coastal developing nations to contribute to climate change mitigation (Duarte et al., 2017). The utility of seaweed extracts and SAP as plant bio stimulants has been proven through several studies and seaweed extracts also has potential to replace the soil amendments through inorganic fertilizer application. The concept of organic agriculture can rely on the application of seaweed extracts to augment production in organic way. Care is to be also taken on the expansion of industry as seaweed aquaculture industry as due to diversification, new diseases are likely to emerge and the risk will intensify in introducing new pests and pathogens to the new regions (Cottier-Cook et al., 2016). The applications of seaweed in commercial industrial uses are undoubtedly in demand and hence suitable culture technologies developed could be adopted in regions conducive for mariculture of seaweeds. In the era of emphasis on organic farming, seaweed could be a best alternative to replace the inorganic fertilizers as the potential and utility of seaweed as plant biostimulant has been experimentally proven. Hence seaweed farming and it's potential as organic fertilizers to be harnessed at maximum extent for the growth and development of agriculture and allied sectors including mariculture for better livelihood and entrepreneurship.

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Fish, Fish Waste and its role in Animal and Crop Nutrition under Organic Farming System

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Fisheries and aquaculture remain important sources of food, nutrition, income and livelihoods for hundreds of millions of people around the world. World per capita fish supply reached a new record high of 20 kg in 2014. Aquatic food production has transitioned from being primarily based on capture of wild fish to culture of increasing numbers of farmed species. A milestone was reached in 2014, when the aquaculture sector's contribution to the supply of fish for human consumption overtook that of wild-caught fish for the first time. Moreover, fish continues to be one of the most traded food commodities worldwide, with more than half of fish exports by value originating in developing countries. Fish is expected to remain predominantly utilized for human consumption, making a valuable and nutritious contribution to diversified and healthy diets. World apparent fish consumption is projected to increase several million tonnes in the next decade to reach 178 million tonnes in 2025. On a per capita basis, apparent fish consumption will be 21.8 kg (live weight equivalent) in 2025. The driving force behind this increase will be a combination of rising incomes and urbanization interlinked with the expansion of fish production and improved distribution channels. The share of world fish production utilized for direct human consumption has increased significantly in recent decades, up from 67% in the 1960s to 87% (more than 146 million tonnes) in 2014. The remaining 21 million tonnes was destined for non-food products, of which 76% was reduced to fishmeal and fish oil in 2014, the rest being largely utilized for a variety of uses like for ornamental purposes, aquaculture purposes (fingerlings, fry, etc.), bait, pharmaceutical purposes and as direct feed for aquaculture, livestock and other animals. Moreover, the fish processing waste has found a new destiny as fish meal and ready to use fertilisers in organic agriculture, from its earlier destined role as a backyard manure.

Industrial Fishery, Fish Meal and Fish Oil

When a fish is caught solely for the fish meal industry rather than for consumption purposes, it is termed an industrial fish and the fishery an industrial fishery. Fish meal may be defined as a solid product obtained by removing most of the water and some or all of the oil from fish or offal. The fish oil mostly is a by-product of the fish meal production line, using a high fatty fish like anchovies and sardines and often offer a collateral, but a lucrative source of revenue from the industry. Most of the world's fish meal is made from whole fish. Most of these fishes are small, bony, with high content of oil, and considered of little edible use. Approximately 4 to 5 tons of whole fish are required to produce 1 ton of dry fishmeal. Peru produces almost one-third of the total world's fish meal supply. Other principal fishmeal producing countries are Chile, China, Thailand, U.S.A., Iceland, Norway, Denmark and Japan. Major groups of industrial fish rendered into fish meal are anchovies, herrings, menhaden, sardines, shads, and smelts. Countries with major industrial fisheries are Peru, Norway and South Africa, while countries like the UK and the USA make fish meal from unsold fish and from offal, which is the heads, skeletons and trimmings left over when the edible portions are cut off. Other countries like Denmark and Iceland use both industrial fish and processing waste. In India, fish meal is manufactured mostly from small, low value fishes from the trawl and purse seine fishery.

Fish meal is generally sold as a powder, and is used mostly in compound foods for poultry, pigs and farmed fish, which is far too valuable to be used as a fertilizer. The use of fish by-products for feeding animals is not a new idea. A primitive form of fish meal is mentioned in the Travels of Marco Polo at the beginning of the fourteenth century. He observed that cattle, cows, sheep, camels and horses were accustom to feed upon dried fish, which being regularly served to them and that they eat without any sign of dislike. The utilization of sardine as an industrial raw material actually started as early as about 800 AD in Norway. A very primitive process of pressing the oil out of sardine by means of wooden boards and stones was employed.

There are several ways of making fish meal from raw fish; the simplest is to let the fish dry in the sun. This method is still used in some parts of the world where processing plants are not available. This product is poor in comparison with the ones made by modern methods. Almost all fish meal is made by cooking, pressing, drying and grinding the fish in machinery designed for the purpose. When fish are cooked and the protein is coagulated, much of the water and oil runs off, or can be removed by pressing, whereas raw fish lose very little liquor even under very high mechanical pressure. This stage of the process removes some of the oil and water. The cooked fish are conveyed through a perforated tube while being subjected to increasing pressure. A mixture of water and oil is squeezed out through the perforations and the solid, known as press cake, emerges from the end of the press. During the pressing process the water content may be reduced from about 70% to about 50%, and the oil content reduced to about 4%.

Fish oil is oil derived from the tissues of oily fish. After screening to remove coarse pieces of solid material, the liquor from the press liquor is continuously centrifuged to remove the oil. The oil is sometimes further refined in a final centrifuge, a process known as polishing, before being pumped to storage tanks. It contains two of the most important omega 3 fatty acids that can be absorbed easily, EPA and DHA. These two fatty acids derived are considered to be the protective elements for the body as they help in solving heart related problems, better brain functions and several other health benefiting factors. It serves as natural remedy for health problems and needless to say it has an important application in the animal feed industry (mainly aquaculture and poultry), where it is known to enhance growth and feed conversion rate (FCR). The refined oil is valuable and is used in the manufacture of edible oils and fats, for example margarine. It can be used in. Other uses include making industrial products such as protective coating, leather chemicals, printing inks, lubricants, aqua feed manufacturing and greases etc. In addition, there are several other specialized uses for small quantities of fish oils. Fish oils usually have to be low in free fatty acids, less than 2%, to obtain the best price; production of high quality fish oils depends on the use of fresh raw material, proper purification and good storage. Fish oil is refined to reduce free fatty acid content, bleached to reduce the color and de-odorized to reduce odour. Fish oil supplement are considered to be an excellent source of Omega-3 acids. It can be also utilized for different industrial applications, including Alkyd resins for paint and polymer, ceramic deflocculates and release agents, rust inhibitors and water repellent.

The water portion of the liquor, known as stickwater, contains dissolved material and fine solids in suspension which may amount to about 9 % by weight. Stickwater is a valuable product containing minerals, vitamins, some residual oil, and as much as 20% soluble and undissolved (suspended) proteins, so that it is normally well worth recovering. The material is recovered by evaporating the stickwater to a thick syrup containing 30-50 % solids, and sometimes marketed separately and known as condensed fish solubles. Mostly, this concentrated product is added back to the press cake and dried along with it to make what is known as whole meal. The final operations are grinding to break down any lumps and particles of bone, and packing the meal into bags or storing it in silos for bulk delivery. Fish oil present in the stored meal can react with oxygen in the atmosphere; the heat generated may damage the meal nutritionally and, on occasion, cause the meal to catch fire; hence, while stacking, the sacks are to be stored with proper ventilation to prevent heat burn. This risk can be prevented by the use of an antioxidant. Ethoxyquin is typically added to commercial fishmeal in a range of 200-1000 mg/Kg feed, to prevent oxidation, but ethoxyquin cannot be used in organic poultry feed. Naturox is an example of a natural antioxidant that can be used as an alternative to ethoxyquin. It contains a blend of tocopherols (vitamin E) and rosemary extract that counters the free radicals that start the oxidation process and cause fishmeal to become rancid. Lecithin is a chelating agent that also helps prevent the formation of free radicals.

Fishmeal for Feed Management in Animal Husbandry

A whole meal made from fatty fish like sardine might contain about 71% protein, 9% fat, 8% water and 12% minerals, whereas a meal made mainly from lean fish or fish offal and dried to the same extent will contain about 66% protein, 5% fat, 8% water and 21% minerals. Fish meal is valuable not only for the quantity but also the quality of its protein as, the amino acids which make up the protein are present in just the right balance for animal or human nutrition. Not only is the balance of amino acids in fish meal suitable for animal feeding, but the availability of the essential amino acids is also greater in fish meal than for example in meat meal. Fish meal is also a valuable source of minerals calcium, phosphorous, magnesium, potassium, of vitamins B_1, B_2, B_6 and B_{12}, and of trace elements, notably zinc, iodine, iron, copper, manganese, cobalt, selenium and fluorine.

Addition of fishmeal to animal diets increases feed efficiency and growth through better food palatability, and enhances nutrient uptake, digestion and absorption. The balanced amino acid composition of fish meal complements and synergistic effects with other animal and vegetable proteins in the diet to promote fast growth and reduce feeding costs. Fishmeal of high quality provides a balanced amount of all essential amino acids, phospholipids and fatty acids (e.g., DHA and EPA) for optimum development, growth, and reproduction, especially of fish larvae and brood stock. The nutrients in fishmeal also aid in disease resistance by boosting and helping to maintain a healthy functional immune system. In many feeding trials, animals fed on diets containing a similar amino acid composition to fish meal have grown less well than those fed on fish meal itself; this has led to the hypothesis that fish meal contains an unidentified growth factor sometimes abbreviated to UGF. Fish meal contains such a wide range of nutritionally valuable materials that whatever is lacking in the diet, fish meal can provide it. Thus the attribute of UGF may be due to nutritional balance rather than to the presence of some unknown growth-promoting substance.The livestock and poultry industries producing large amounts of pork, eggs and chicken, at relatively low prices could not survive without large scale use of high protein animal foods like fish meal.

Table 1. Nutrient content of the various fish meals

Fishmeal type	DM	Energy	CP	EE	CF	Ca	Met	Lys
Anchovy	91	1280	65.0	10.0	1.0	4.0	1.90	4.90
Perch	92	1350	57.0	8.0	1.0	7.7	1.80	6.60
Sardine	92	1300	65.0	5.5	1.0	4.5	2.00	5.90
Tuna	93	1150	53.0	11.0	5.0	8.40	1.50	3.90
Whitefish	91	1180	61.0	4.0	1.0	7.0	1.65	4.30

DM = Dry matter (% of total content); Energy = Energy in kcal/lb; CP = Crude protein (% of total content); EE = Crude fat (ether extract; % of total content); CF = Crude fiber (% of total content); Ca = Calcium (% of total content); Met = Methionine (% of total content); Lys = Lysine (% of total content)

(Source: *Feedstuffs*Ingredient Analysis Table: 2011 Edition, by Amy Batal and Nick Dale, University of Georgia)

Fish meal is an excellent source of protein for poultry and its use is usually restricted to 5% to 10% of the content of poultry diets. Cattle fed on diet containing fish meal recorded an increase in milk production and milk components (fat, protein and lactose). Usually about 10% of the diet of pigs and poultry consists of fish meal; 10% is the upper limit for meal containing 10% fat, because more than about 1% of fish oil in the diet of the animal may taint the taste of its flesh. Fish meals with an extremely low fat content are sometimes made for certain specialized purposes. ~~Other uses of fish meal include the feeding of farmed fish, dogs, cats and cattle.~~ Very small amounts of specially processed meals have been used in prepared foods for humans, and fish meal is also used in the preparation of certain antibiotics for the pharmaceutical industry.

High-quality fish meal normally contains between 60% and 72% crude protein by weight. From a nutritional standpoint, fish meal is the preferred animal protein supplement in the diets of farm animals and often the major source of protein in diets for fish and shrimp. Typical diets for fish may contain from 32% to 45% total protein by weight, and diets for shrimp may contain 25% to 42% total protein. The percentages of inclusion rate of fish meal in diets for carp and tilapia may be from 5-7%, and up to 40% to 55% in trout, salmon, and some marine fishes. Another very important reason why fish meal is sought after as an ingredient in aquaculture diets is because fish meal contains certain compounds that make the feed more palatable. This property allows for the feed to be ingested rapidly, and will reduce nutrient leaching. It is thougt that the non-essential amino acid, glutamic acid is one of the compounds that imparts to fishmeal its palatability.

Unfortunately, fishmeal is unstable and can spontaneously combust if not stored properly. The proteins in improperly stored fishmeal can also begin to break down, resulting in increasing levels of biogenic amines such as histamine. Consumption of high levels of histamine can cause gizzard erosion in chickens. In addition, fishmeal can be a source of food borne pathogens, in particular *Salmonella* spp. The need for good housekeeping practice in the fish meal factory and store has to be emphasized to counter this. Fishmeal belongs to a short list of excellent feedstuffs that provide essential nutrients in a highly digestible concentrated form. The use of fish meal in domestic and farm animal diets will remain a core and efficient practice, particularly for young, rapidly growing, and high-producing animals like maturing fish, berried (egg-laden) shrimp, poultry, and lactating dairy cattle. The beneficial effects of eating wholesome foods will increase the worldwide demand for seafood products resulting in increased use of fishmeal.

Growing plants take nutrition from soil, water and air. Unless there are enough of the right nutrients in the soil, the plant's growth will suffer. Horticultural crops can deplete many of the nutrients in the soil unless we replace them periodically. Fertilization is not that simple as it seem to accomplish. The choice of nutrients used, how much to use and where to put them are very important if we want the most out of the fertilizer. The condition of the soil in which the plants and fertilizers are placed is also important to know. For example, if the soil has too much or too little acidity it will not allow the plants to make good use of the fertilizers added.

The word organic applied to fertilizers usually means that the nutrients contained in the product are derived solely from the remains of a once-living organism. Some organic materials, particularly composted manures, are often registered termed as soil conditioners instead of fertilizers. Soil conditioners do not have a nutrient guarantee, even though various amounts of plant available nutrients are usually present. Soil conditioners are materials having properties that may improve the soil's physical condition. Those soil conditioners with substantial nutrient value have much greatest potential for use in a cost effective manner. In general, organic fertilizers release nutrients over an extended period of time. They act much like the slow-release fertilizers. Some products may also attract animals after application. Cotton-seed meal, blood meal, bone meal, fish emulsion and all animal manures are examples of these materials.

Fish fertilizers and pest repellents

Fish fertilizer is generally available in three forms: meal, emulsion, and hydrolysate. Fertilizers have come a long way since the beginning of agriculture. Much of what we are putting in our soil nowadays is a combination of synthetic compounds and chemicals. Fish fertilizers offer an organic solution for effectively providing nutrients to the soil naturally. They have slower release rates than other types of fertilizers, therefore do not have to be applied nearly as often. When applying fertilizer like fish hydrolysates, we are approaching about as close as we can to burying a whole fish. Microbes love to feed on the organic matter and this makes for very healthy soil and like plants. The thought of fish fertilizer has some of us plugging our noses, while it is true that some fish products are unfriendly to the nose, they have a lot to offer for the crops. Fish fertilizer is made from whole fish and carcass products, including bones, scales and skin. Rather than letting unusable fish products go waste, these items are converted into nutrients for the crops.

Meal

Fish waste can be ground using a hand grinder or stick blender to make manure. Then it can be tilled into the soil, or chunks of fish can be buried at the roots of larger crops. In pre-independent India, burying basket full of oily sardines was an accepted practice for fertilising coconut palms in households as well as in plantations. However, dogs and some wild animals are fond of strong smells, and may dig up, if fish is used as fertilizer. It is always advisable to compost manure before it is used by piling it up so that it heats itself and decomposes. Fish fertilizer is an organic product and hence, it does have the benefits which other organic soil additives have. It feeds plants, microbes and improves soil structure. Keeping aside most of the fish that we humans eat, in many instances some of the other fishes are used in fish fertilizer in some way. This can be from a lack of demand for human consumption, or just the waste being used like head, scales, and fins. Most of what is used in fish fertilizer is low value fish, fish waste, or fish that cannot be consumed by humans. Fish fertilizer has many advantages apart from the available nitrogen and phosphorus that it offer. A hidden advantage is the benefits it is doing for the mini ecosystem in the garden or field. Fish fertilizer is simply one of the best ways to grow quality crops and help renew the nutrients in soil.

In the process of turning fish waste into fertilizers, companies add a number of chemicals, including phosphoric acid, and odour inhibitors. Fish fertilizer can also be 100% organic! Apparently, as long as these ingredients form less than 1% of the finished product, the product can still be called organic.

Emulsion and Hydrolysate

Fish guts and other discarded fish parts are a good source of nitrogen if handled correctly. Fish emulsion and fish hydrolysate start with these left over bits from the fish processing industry or whole fish. These are then treated with enzymes and sometimes chemicals (industrial scale) to break down larger organic molecules into nutrients and other small organic molecules. Further treatment can take one of two paths; it is either heated or cold processed. Fish emulsion is the end product if the heating process is used while fish hydrolysate is the result of using cold processing. After cooking the mixture to kill putrefying bacteria, it's filtered and stabilized with sulphuric and phosphoric acid. It also means that all the juicy extras that make such a difference to soil and plant health are denatured by the heat. So the oils, amino acids, vitamins, hormones, and enzymes are absent in fish emulsion, resulting in a lower quality product compared to hydrolysate. Hydrolysate (odour-free emulsions) is made using "hydrolysed" process, one that involves natural enzymes breaking down the material, rather than heat, which leaves those beneficial nutrients and bio stimulant compounds intact. The oils are especially helpful for supporting fungus, an essential player in the soil community. Fish hydrolysate is generally made from whole fish or by-catch from food fishing. It's often less stinky than emulsion, which reduces the risk of attracting animals. Hydrolysed emulsions claim to retain more amino acids and deliver both macro and micronutrients in a form more usable to plants and soil microbes.

It is true that heat will denature proteins, but they need to be denatured for the plants to use them. Plants can't use most of the large or even small organic molecules from either process. Normally microbes in the soil degrade these to nutrients that can be assimilated by plants. The liquid that remains in a fish meal plant after extracting press cake and fish oil (stickwater) may be converted to fish emulsion. After straining out solids, phosphoric acid or sulphuric acid is added to lower the pH, preventing microbes from growing. All in all, this makes hydrolysate the best option in most situations, since it's a more complete nutrient source with fewer undesirable side effects. It's also a little easier on the human nose. Both emulsion and hydrolysate are usually stabilized with phosphoric acid. This isn't necessarily a problem, since plants and soil will generally benefit from the small additional amount of phosphorus, and it's allowed under organic standards as long as it stays below a certain threshold.

It's this availability and the presence of micronutrients that make fish emulsions or hydrolysate so effective. While chemical concoctions tend to deplete or lockup the soil's natural occurring micronutrients like copper, boron, iron, zinc and others; fish emulsions or hydrolysate restore them in form plants can utilize. The availability of the nutrients in these liquid fertilizers make them as effective as chemical formulas with high N-P-K ratios. They may not be as saturated with nitrogen or phosphorous as chemical fertilizers, but more of those nutrients are made available to the plants. Because of this availability, fish emulsions are effectively used as foliar sprays. Fish emulsion and hydrolysate is useful as a deterrent for pests that attack crops. Made into a liquid fish emulsion, it is mostly used as an insect repellent for mosquitoes and similar. It's also good in the field as it deters mites, caterpillars and even nematodes. When it's sprayed on the crops, the pest infestation tends to reduce. Exactly why it works is not yet clear but there are a couple of possibilities. Firstly, because they are oily and hence smothers nematodes and mites. Secondly butterflies and moths find their host plants by their acute sense of smell. So the acute sense of fish will mask the smell of their host plants. A hydrolysate meant for this purpose can be made by soaking fish waste in water for a few weeks with a bit of jaggery added, strain and use. This concoction needs to put way down in the backyard covered except for some tiny little air holes.

Proponents of fish fertilizers claim that do not apply to other organic fertilizers. Most seem to be centred on the fact that the liquid fertilizer contains proteins and oils. We all know fish oils are very important for our health, but they do little to the health management of horticultural crops except in certain foliar applications. Plants can't make use of large molecules such as oils and proteins. When these molecules are added to soil, microbes digest them and turn them into small molecules like nitrate, and phosphate. It is only then that plants can make use of these molecules. Since the large molecules need to be degraded before plants can use them, there is little difference, to the plant, between proteins and oils from fish, cows (manure), or even plants. Fish fertilizer generally has about 2% nitrogen, which is the same as most organic fertilizers; compost and manure. Some quick release synthetic fertilizers offer immediate nutrients in the garden because they are processed to be readily available for plants to absorb. All-natural fish fertilizers are processed differently in the soil, because they contain nutrients that must first be digested by organisms such as bacteria, earthworms and fungi, before they are available for plant roots to use. All of this microbial activity enhances the strength and vigour of plants by increasing the amount of organic matter in the soil. Fungi and bacteria break down nutrients to make them available to plant roots, and then loosen the dirt as they travel, reproduce, process nutrients and decay, leaving soil aerated with improved levels of organic matter. Plant roots grow faster and stronger in this light, airy soil that is teeming with life. As fish fertilizer improves soil health, it also increases soil fertility by providing the primary nutrients necessary for plants to thrive. Fish fertilizers offer a source of burn-free nitrogen, along with the other primary nutrients of phosphorus and potassium. Unlike synthetic options, they may also provide secondary nutrients, such as calcium. Plants that receive a balance of primary and secondary nutrients experience strong and steady plant growth, leading to vigorous plants that can better withstand disease and pest issues.

Conclusion

Fish is popular worldwide as a near complete protein and is revered by the WHO as an inseparable component in achieving protein food security. A lesser known fact is that, due to its innate nutrient profile, products derived from fish for animal nutrition offers a similar nutrition. The balance of major and trace nutrients makes fish meal an unavoidable part of a healthy compounded animal feed. The performance of products derived from fish for crop nutrition (fertiliser) and pest management (pest repellent) makes it one of the most versatile natural resource. Fish and fish derived products have an important role to play in the organic food production for serving the ever booming human population.

Exploitation of grain (vegetable) legumes, green manuring as nutrition source in organic farms in the islands

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Legumes are flowering plants that produce seed pods and belong to Leguminoceae or Fabaceae family and include important seed, pasture and agro-forestry species. They are harvested as crops for human, animal consumption, pulp for paper production, fuel-woods, timber, oil production, sources of chemicals, medicines, used as living fences and firebreaks among others. Legumes provide many benefits to the soil so they are usually utilized as cover crop, intercropped with cereals and other staple foods. They do produce substantial amounts of organic nitrogen, increase soil organic matter, improve soil porosity and structure, recycle nutrients, decrease soil pH, reduce soil compaction, diversify microorganisms and mitigate disease problems (USDA, 1998). In rotation with cereals, legumes provide a source of slow-release nitrogen that contributes to sustainable cropping systems. The improvement in the production of these crops will therefore contribute substantially to better human nutrition and soil health. Grain legumes also called pulses, which according to FAO are crops harvested exclusively for the dry seeds, play an important role in the nutrition of many people due to their high protein content in seeds. India is the largest producer and consumer of pulses in the world accounting for about 29 per cent of the area and 19 per cent of the production. This year country's pulse production has been estimated as 22 m t from a near-stagnated area of 22– 23 M ha. For meeting the demand of the growing population, the country is importing pulses to the tune of 2.5–3.5 m t every year. In general, pulse crops prefer neutral soils and are very sensitive to acidic, saline and alkaline soil condition Nitrogen is generally the first limiting nutrient for plant growth. Until the invention of synthetic nitrogen fertilizer, early in the 20th century, legumes, with their capacity for biological nitrogen fixation (BNF) in symbiosis with bacteria of the *Rhizobiaceae*, were the main source of agricultural nitrogen. By reducing inputs of nitrogen fertilizers, legumes reduce the cost of production and the potential for N contamination of water resources as well as producing, in the case of pulses, grain of high nutritional value. Grain legume production is increasing world-wide due to their use directly as human food, feed for animals, and industrial demands. Further, grain legumes have the ability to enhance the levels of nitrogen and phosphorus in cropping systems. Considering the increasing needs for human consumption of plant products and the economic constraints of applying fertilizer on cereal crops, grain legumes plays an important role in cropping systems, especially in regions where accessibility and affordability of fertilizer is an issue. However, for several reasons the role of grain legumes in cropping systems has often received less emphasis than cereals.

In Andaman and Nicobar islands, mung bean, urd bean, pigeon pea, cowpea and ground nut are the grain legumes cultivated (Table 1). Cowpea, French beans, faba bean and lab-lab (field bean) are the leguminous vegetables locally grown by the farmers.

Table 1. Grain legumes cultivated in Andaman and Nicobar Islands (2014-15)

Pulse crops	Area (ha)	Production (t)
Mung bean	910	456
Urd Bean	552	325
Pigeon Pea	15	14
Cow Pea	98	49
Ground Nut	4.5	3

(Source: Directorate of Economics and Statistics, 2015)

Importance of pulses in organic agriculture

- Pulses, in symbiosis with certain types of bacteria (e.g. Rhizobium, Bradyrhizobium), are able to convert atmospheric N into N compounds that can be used by growing plants. It has been estimated that legumes, of which pulses are a subgroup, can fix between 72 and 350 kg of n/ha/year.
- Some species of pulses are able to free soil-bound phosphorous, which also plays an important role in the nutrition of plants and food we eat.
- Crop rotations play an important role in organic farming and rotations that include leguminous crops allow the continued future production on the same plot of land.
- Pulses in intercropping systems allow higher underground utilization efficiency due to their root structures and, as intermediate plants, help weed control and protect from diseases and pests.
- Deep rooting pulses such as pigeon peas can supply groundwater to intercropped companion species.
- The versatility of pulses allows them to be used in organic systems in different ways: rotations, intercropping, ley farming and as a cover crop.

Nitrogen Fixation by Legumes

Legume plants grow in cooperation with soil-dwelling *Rhizobacteria*. These bacteria live in nodules on the roots of legumes and convert atmospheric nitrogen (N_2) in the soil and transform it into ammonia (NH_3) that converts to ammonium (NH_4^+) which can be used by the plant. The nitrogen fixation (N_2-fixation) process between the legume plant and *rhizobacteria* is referred to as a symbiotic (mutually beneficial) relationship. *Rhizobia* provide the legume plant with nitrogen in the form of ammonium and the legume plant provides the bacteria with carbohydrates as an energy source. The primary pathways for nitrogen transfer from the legume to the soil are through decomposition of dead legume plant material. The root system and unused leaves and stems of annual legumes die at plant maturity and are decomposed by soil microbes over time. Nitrogen contained in this plant material is released over time and is available to other plants. The addition of nutrients to soil by various crops is given below (Table 2).

Table 2. Nutrient addition (kg/ha) by different grain legumes

Grain legume	Nutrient addition (kg/ha)		
	N	P	K
Urd bean	26.1	2.1	26.8
Pigeon pea	59.7	7.9	75.7
Cow pea	88.5	9.6	104.8
Ground nut	93.1	10.5	63.9
Soybean	58.3	3.3	80.9

(Gangaiah *et al*., 2012)

Seed inoculation

In most cases when growing a legume cover crop the seeds will need to be inoculated with the appropriate strain of *Rhizobia* (nitrogen-fixing bacteria). There are numerous strains of native Rhizobium that occur naturally in different soils. Some of these rhizobia strains are capable of infecting a given legume species (Table 3.) but will vary in their efficiency to fix nitrogen. Ineffective strains will form many small nodules on the legume root, but fix little or no nitrogen. Effective rhizobia strains that fix high rates of nitrogen form fewer but larger nodules that have dark pink centers. When the legume plant matures and dies, nodules on the root system decompose and release the rhizobia into the soil. If the same legume species is planted again the following year or volunteers from seed produced the previous year, sufficient numbers of rhizobia are usually present to provide good nodulation. Thus, there is a restricted number of inoculants that fit with a leguminous plant, and farmers must know which inoculant must be applied according plants and characteristics of soil.

Table 3. Rhizobium spp and their host plants

Rhizobia	Legume Cross-inoculation group
Ensifer meliloti	Alfalfa Group: alfalfa, sweet clover, fenugreek
Rhizobium leguminosarum bv *trifolii*	Clover Group: clovers
Bradyrhizobium japonicum	Soybean Group: soybean (*Glycine max*)
Bradyrhizobium spp.	Cowpea Group: pigeon pea;peanut; cowpea, mungbean,black gram, rice bean; lima bean *Acacia mearnsii; A. mangium;* *Albizia* spp.; *Enterlobium* spp., *Desmodium* spp., *Stylosanthes* spp., *Centrosema* sp., winged bean calopo (*Calopogonium mucunoides*), puero (*Pueraria phaseoloides*)
Rhizobium leguminosarum bv *viciae*	Pea Group: peas (*Pisum* spp.), lentil (*Lens culinaris*), vetches (*Vicia* spp.), faba bean (*Vicia faba*)
Rhizobium leguminosarum bv *phaseoli*	Bean Group: beans (*Phaseolus vulgaris*), scarita runner bean (*Phaseolus coccineus*)
Mesorhizobium loti	Chickpea Group: chickpea
Rhizobium lupine	Group Lupines

Nitrogen Fixing Capacity

The amount of nitrogen available from legumes depends on the species of legume grown, the maturity at termination, the total biomass produced, and the percentage of nitrogen in the plant tissue. The highest nitrogen benefits will be realized by letting the legume grow to full term—through most of its lifecycle—before terminating it. The nitrogen content of legume cover crops is optimized at the flowering stage; no additional nitrogen gain will occur after that point. Nitrogen production is related not only to a later maturity stage but also to higher amounts of biomass production.

Nitrogen Availability

Most of the biologically fixed nitrogen (about 80%) is in the top growth of the plant, and becomes available faster than the nitrogen content in the roots. Legumes break down relatively quickly after being incorporated into the soil, and as they do, the nitrogen is gradually released to the soil as nitrates, an available form for the next crop in the rotation.

Legumes in cropping system

In addition to the increasing demand for grain legumes, these species bring to cropping systems the crucial capacity to decrease or eliminate the need for direct applications of some fertilizers. Grain legumes bring to cropping systems a much decreased demand for fertilizer. Legumes have the capacity to meet much of their own nitrogen requirements through symbiotic nitrogen fixation so that crop growth can be potentially fully sustained without nitrogen fertilizer. Some grain legumes have the unique capacity to recover phosphorus from the soil that is in forms unavailable to other crops. The need to decrease phosphorus application to cropping system could be a very important attribute grain legumes might bring to cropping systems. Progressive increase in available N status after each year was observed with the inclusion of leguminous crop in the rotation. The fixation of atmospheric nitrogen by the leguminous crops might have contributed for the increased soil N status**.** When compared to first year, the soil available N status was improved in groundnut – rice – blackgram (14 kg/ha), rice – rice – greengram (12 kg/ha), rice – rice – blackgram (9 kg/ha) onion – rice – blackgram (8 kg/ha) at the end of the fourth year (Porpavai *et al*., 2011).

Legume residue for cattle feed

In India, 40% of the cattle feed is crop residue and it is predicted that this share will increase to 70% by 2020. Most of those residues come from cereals, and legumes contribute only 10% of the total. To improve rumen digestion and animal growth, it will be necessary to have crop residue that has substantially greater nitrogen concentration than the 0.6-0.8% provided by cereal residue. In crop-livestock cropping systems, where cattle feed on cereal crop residues, nitrogen concentration of cereal residue is often much below the threshold needed in animal diets. Nitrogen concentrations of at least 1.0 to 1.2% are needed for microbial population in the rumen of livestock for an efficient feed digestion, which are virtually never reached by cereal residues but legume residues are at or above this threshold. Therefore, it is possible that legume crop residues will be playing an increasing role as a source of inexpensive fodder or even key N-rich additive in cattle production.

Legume residue	Litter fall (t/ha)
Urd bean	0.35
Pigeon pea	2.00
Cow pea	2.18
Ground nut	0.85
Soybean	1.18

(Gangaiah *et al*., 2012)

Recovery of phosphorus from soil by legumes

Phosphorus, being a key nutrient, plays a significant role in crop productivity. However, its low availability due to poor fertilizer use efficiency, slow diffusion, and high fixation in soil necessitates the need to apply P in quantities in excess of the crop requirements. It is desirable to identify and incorporate suitable crop species in rotations that are efficient in mobilizing P from the soil-P pool. Leguminous crops are bestowed with this potential and their beneficial effect is mostly attributed to improved N status of soil through symbiotic N_2 fixation, enhanced P availability and to break soil borne disease cycles. The different leguminous crops with potential to mobilize P from soil P pool include white lupin, chick pea, soya bean, mung bean, faba bean, ground nut, pigeon pea, cow pea and field pea.

Legume plants can increase synthesis of organic acid in roots under low P Condictions. The major fractions of exuded organic acids include citrate, oxalate and malate that mobiize P by displacing phosphate from soil matrix. Citrate exhibits the greatest ability to desorb P, followed by oxalate, while malate, malonate and tartarate moderately effective. Citrate is particularly effective at mobilizing P from Fe and Al-phosphates in acid acids and Ca-phosphates in calcareous soils.

A common difficulty in recovering phosphorus from the soil is that it is not readily available to plants because phosphorus complexes in the soil with aluminum, iron and calcium. These complexes are essentially insoluble resulting in very little movement of phosphorus in the soil solution, and none of the complexes can be taken up directly by roots. Grain legume species, however, have evolved mechanisms to allow recovery of phosphorus from unavailable forms. One mechanism is the exudation of organic acids from legume roots which decreases the pH in the soil surrounding the roots and releases phosphorus. The organic acids exuded by grain legumes include malate, citrate, oxalate, tartrate and acetate. However, the effectiveness of these organic acids in mobilizing phosphorus is highly dependent on the soil and the soil environment. Release of organic acids may not be functional in acid soils.

There is considerable evidence for the importance of organic acid exudation from roots in the acquisition of soil and fertilizer P by plants. The addition of organic acids, particularly citrate, to soils can solubilize significant quantities of fixed P, or reduce the sorption of newly applied fertilizer. A number of species respond to P deficiency by increased rates of organic acid exudation from their roots, which may be beneficial under P-limiting conditions. The organic acids exuded from the roots of different legume are given below (Table 4)

Table 4. Organic acids exuded from the roots of different legumes

Legume crops	Organic acid	P solubulized
Pigeon pea	Malonic and Piscidic acids	Fe and Al phosphates
Chickpea	*Oxalic and malic acid*	Ca phosphate
Mung bean	*Citrate*	Al phosphate
Black gram	*Citric and Oxalic acid*	Non-labile P in soil
Ground nut	*Oxalic and citric acid*	Fe Phosphate
Faba bean	*Malate and citrate*	Non-labile P in soil
Cow pea	*Citric acid*	Non-labile P in soil
Pea	*Citrate*	Non-labile P in soil

Pulse crops for fertility improvement in coconut plantation under island ecosystem

The inter spaces of coconut forms excellent avenues for intercropping especially pulses, as they enrich soil through N fixation. Field studies were conducted for two years (2014-16) at Sipighat farm, CIARI, Port Blair to study the performance of different pulse crops and its effect on soil fertility. The experimental soil was sandy loam with pH 5.2, organic carbon 0.6 %, E.C 0.3 dSm^{-1}, available N (205 kg ha^{-1}), P (4.5 kg ha^{-1}) and K (95 kg ha^{-1}) at the start of the experiment. The treatments comprise of three pulse crops viz., red gram, green gram and black gram and their varieties. The results indicated that red gram, green gram and black gram recorded a mean seed yield of 503 and 606, 347 and 472 and 312 and 468 kg ha^{-1}, respectively in 2014-15 and 2015-16. All pulse crops besides their seed production, produced stover (excluding 4 t sticks, can be a fuel wood source) of 1.5 t in red gram and 2.7 t/ha in black and green gram that can serve as potential fodder to livestock. The productivity of coconut indicated a slight improvement (2 nuts/tree) under intercropping of pulses as compared no inter crop (55 nuts/tree). The N content of the soil at the end of 2 years study showed depletion under monocropped coconut and buildup when intercropped with pulses. The buildup of available N was highest with red gram (29 kg/ha), followed by green gram (13 kg/ha) and was least after urd bean (8 kg/ha) (Subramani *et al*., 2016).

Underutilized grain legume of the islands

Beach pea (*Vigna marina*)

Vigna marina is a wild and underutilized potential crops under cultivated *Vigna* species. It is a prostrate, creeping vine and a perennial plant. The flowers are yellow in colour and are pea-type in shape. It is salt tolerant and occupies sandy beaches, seashores, and beach ridges in tropical areas of world. In particular, beach pea possesses succulent stems and leaflets, the later being ovate, its legume grain are bold, seeds are oval in shape, brown – reddish brown in colour. It is a legume and has a symbiotic relationship with certain soil bacteria; these bacteria form nodules on the roots and fix atmospheric nitrogen. It also acts as cover crop and dune stabilizer. It could be a potential source of salt tolerant genes which could provide a means to t transfer salt tolerance to other closely related bean species.

Green manuring in organic farming

It is a practice of turning undecomposed green manure crop into soil in the same field where the crop is grown (e.g., Sunhemp, Sesbania). They are a cheap alternative to artificial fertilizers. Green manures are usually ploughed into the soil when the plants are still young, before they produce any crop and often before they flower. They are grown for their green leafy material which is high in nutrients and protects the soil. Traditionally India has been using green manures like dhaincha, sunnhemp, wild indigo, cowpea, cluster bean, greengram, blackgram, berseem, etc either as a catch crop, shade crop, cover crop or forage crop. It was observed that as the 6.7 million hectares area is covered under green manure, which accounts for 4.5 per cent of net sown area (142 million ha) of the country. The practice of green manuring is most common in rice growing states like A.P., U.P., Karnataka, Punjab and Orissa which contribute 41, 16, 11, 6 and 5 per cent to the total area under green manuring in India, respectively. Whereas, the share of Gujarat (3%), M.P. (3%), Himachal Pradesh (2%) and Haryana (1.7%) is not very encouraging and concerted efforts are to be made out at all levels to bring more area under green manuring that too in irrigated area, if nutritional need of organic farming is to be made. India has maximum number of organic growers (400551). *Sesbania aculeata* and *Crotolaria juncea* have higher rate of biomass production and both can produce dry matter to the extent of 16 to 19t/ha within a short period of 45-60 days and on an average about 5.0 t/ha dry matter can easily be produced, which is sufficient for meeting out nutritional demand of a crop either in *kharif* or *rabi* season.

Advantages of green manuring

- It adds organic matter to the soil
- The green manure crop return plant nutrients taken up by the crop from deeper layers, to the upper top soil
- It improves the structure of soil and other physical properties
- It facilitates penetration of rain water, thus decreasing run-off and erosion
- The green manuring crops hold plant nutrient that would otherwise be lost by leaching
- Leguminous plants add nitrogen to the soil
- It increases the availability of certain plant nutrients like phosphorus, calcium, potassium, magnesium and iron

Important green manure crops

1. Dhaincha (*Sesbania aculeate*)

It is fairly resistant to drought and water stagnation of water. The roots have plenty of nodules. It yields about 10-15 tonnes of green manure per ha and requires a seed rate of 30-40 kg/ha. Use of effective *Rhizobium* strain with seeds fixes the nitorgen upto 1 kg/day

2. Sunnhemp (*Crotalaria juncea*)

It is a quick growing green manure crop and gets ready for incorporation in about 45 days after sowing. It does not withstand heavy irrigation leading to flooding. The crop is at times subject to complete damage by leaf eating caterpillars. The crop cn produce about 8-12 tonnes of green biomass per ha. The seed requirement is 30 kg/ha.

3. *Sesbania rostrata*

One of the important features of this green manure is that in addition to the root nodules, it produces nodules in the stem. The stem nodulation is an adaptation for waterlogged situation since flooding limits growth of green manures and may reduce root nodulation. Under normal condition, both root and stem nodules are effective in N fixation. It has higher N content of 3.56% on dry weight basis. Biomass production is higher during summer (April – June) than in winter (Dec – Jan.) season. This green manure can also be produced by raising seedlings (30 days old) and planted in the paddy field along the bunds or as intercrop with rice. Use of *Rhizobium* bacteria increase the nitrogen fixation about 60 – 100 kg/ha/year.

4. Cow pea

Cowpea is one of the important leguminous green leaf manure crops. As this plant is easily decomposable, it is very well suited for green manure purpose. Use of effective *Rhizobium* bacteria increase the fixation of nitrogen upto 40 kg/ha

5. Wild Indigo *(Tephrosia purpurea)*

The green manure is suitable for light textured soils, particularly in single crop wetlands. It establishes itself as a self sown crop. About 3-4 tonnes of green manure is obtained in one ha.

6. Pillipesara (*Phaseolus trilobus*)

This is a dual purpose crop yielding good fodder for the cattle and green manure. Pillipesara comes up well in hot season with sufficient soil moisture. Loamy or clayey soils are best suited. After taking one or two cuttings for fodder or light grazing by animals, the crop can be incorporated into the soil. About 5-8 tonnes of manure can be obtained from one ha.

Nutrient addition by green manures

The green manure contributes about 60-200 kg N in about 45 to 60 days (Palaniappan, 1992). Some promising green manures are *Crotolaria juncea* (sunhemp), which is quick growing, more succulent and easy to produce seed, could accumulate 16.8 t/ha biomass with 159 kg N/ha. *Sesbania aculeata* (dhaincha), which could accumulate high biomass of 26.3 t/ha and is widely adapted could contribute about 185 kg N/ha. Similarly, the stem nodulating, water logging tolerant *Sesbania rostrata* could add biomass of 24.9 t/ha with N accumulation of 219 kg/ha. The drought tolerant self seeding *Tephrosia purpurea* could produce biomass of 16.8 t/ha which contribute 115 kg N/ha. Estimates suggest that a 40- 50 days old green manure crop can supply up to 80-100 kg N/ha. Even if half of this N is crop utilizable, a green manure crop can be a substitute to 50-60 kg. fertilizer N/ha (Sharma *et al*., 2013). Some of the potential green manuring legumes are dhanicha, sunhemp, cowpea, mung, bean, guar and berseem etc. Dhanicha, sunhemp, mung bean and guar grown during *kharif* season as green manure crops have been reported to contribute 8-21 tonnes of green matter and 42-95 kg N/ha. Almost any crop can be used for green manuring, but legumes are preferred because of their ability to fix nitrogen from the air. Green manuring with legumes is called legume green manuring. These crops should be turned into the soil before setting of seeds. Legume green manuring could be profitably used on lands where, it was not possible to add animal manures. In red gram, green manuring of Daincha with 125 % Recommended dose of N +Sub soiling + micronutrient mixture @ 12.5 kg ha^{-1} recorded higher biometric characters, yield attributes (number of pods $plant^{-1}$, number of seeds pod^{-1}, test weight), yield (456 kg ha^{-1}) and B: C ratio (1.63). The soil fertility status was improved (O.C %: 0.24 and available N: 282.5 kg ha^{-1}) over the initial status (O.C %: 0.19 and available N: 278 kg ha^{-1}) of soil due to green manuring (Venkata Lakshmi, 2014). The biomass and nutrient potential of important green manure are given below (Table 5)

Table 5. Nutrient potential of green manures

Green manure	Biomass (tonnes/ha)	N addition (kg/ha)
Sesbana aculeata	22.30	145
S. rostrata	20.06	146
Crotalaria juncea	18.40	113

Under island condition, the practice of green manuring has limited utility due to absence of ensured seed supply. The study conducted at CIARI revealed that biomass production ranged from 18 t (dhaincha) to 30 t (Sunnhemp). Green manure seed production ranged from 1200 kg/ha (Sunn hemp) to 815 kg/ha (dhaincha).

Techniques of green manuring in the field

The maximum benefit from the green manure crop cannot be obtained without knowing the:

1) Right time of growing.
2) Right time of incorporating in the soil.
3) Time required for decomposition

(a) Time of sowing of the green manure crop

Time of sowing of the green manure crop varies according to local conditions and resources available. Normally, green manure crop is sown immediately after monsoon rains. But, if irrigation facility is available, green manure crop can be grown as catch crop after harvesting of rabi crop during April and May. Sunnhemp and dhaincha are suitable for growing in April-May and can be buried in June-July before planting of main *kharif* crop. In rainfed areas intercropping of dhaincha with paddy in row ratio of 4:1 can be done.

Green manures and undersowing

Undersowing involves growing a green manure at the same time as that of main crop. Sometimes they are sown with the crop or slightly later when the crops are already growing. This reduces competition between the green manure and the crop. No extra time is spent preparing the land and sowing the green manure.

(b) Stage of burying of green manure crop

Burial of green manure crop at specific time provides maximum nitrogen and organic matter. This specific stage is when plant is immature and has started flowering, as the basic aim of green manuring is to provide maximum succulent green matter at burying. During early period of crop growth N content, protein, water soluble constituents are maximum, whereas fibre, hemicelluloses, cellulose, lignin and C:N ratio are less. Therefore, tissues of immature plants usually decompose more rapidly as compared to matured plants.

Method and depth of burial of green manure crop

Before a crop is sown the green manure is dug back into the soil. Green manures should not be ploughed in as this buries the plants and the nutrients too deep. They should be turned in just under the soil surface. Here, it decomposes and the nutrients held inside green manure plants are released. Immature crop can decompose at any depth, but mature crop should be buried at less depth. If the weather is dry green manure crop should be buried at more depth compared to moist season. If moisture in soil is less water should be supplied externally. Green manure crop should be buried at higher depth in sandy soil and in heavy soils at less depth for proper decomposition.

(c) Time interval between burial of green manure crop and the sowing of the next crop:

If the green manure crop is succulent, then there is no harm in transplanting the paddy immediately after turning in the green manure crop.

Green Leaf Manuring

This refers to turning of green leaves and tender green twigs collected from shrubs and trees grown on bunds, waste lands and hereby forest areas. Green/green leaf manuring in rainfed land helps to improve physical and chemical properties of the soil, maintenance of organic matter and serves as a source of food and energy for microbial population in the soil. The criteria for selection of green leaf manuring crops in rainfed regions are: multipurpose use, high biomass production, fast initial growth, more leaf than wood, N fixing ability, good affinity with mycorrhiza, efficient water use, tolerant to pests and diseases, easy and abundant seed formation, high seed viability, high N content. The common shrubs and trees useful for this purpose are Glyricidia, Sesbania and pungam.

1. Glyricidia (*Glyricidia maculeata*)

This is a shrubby plant that comes up well in moist situations. Under favourable conditions, it grows well like a tree. It can be easily grown in waste lands, farm road sides, field bunds, etc. The crop can be established by stem cuttings or seedlings planted in the field borders. It is used for fuelwood, living fences, crop support, animal forage, green manure and soil stabilization. In the islands, the loppings rich in nitrogen are used for vermicomposting. In coconut plantations, it has been grown between rows of coconut and found to be excellent crop supporter. It can be pruned for its tender loppings and compound leaves for green leaf manuring at the time of puddling rice. On an average, a well – established plant yields 12 – 15 kg green matter. About 400 plants on the peripheral bunds yields 5-6 tonnes green manure/ha. It is an extremely versatile plant which can fulfill a number of roles in smallholder agricultural production system.

Application of *Gliricidia* leaves on growth and yield of maize in an alley cropping system indicated that within 15 days 52% nitrogen released in incorporated and 50% in surface. Therefore, uptake of nitrogen was also maximum in 2WAS (weeks after sowing) treatment equal to that of urea may be attributed to sloppy land and high rainfall, in this island, which causes heavy runoff loss or urea. The recovery of nitrogen of *Gliricidia* pruning by the current maize crop ranged from 18 to 45%. It was maximum in 2WAS treatment. Further, Nitrate N was greater in the soil treated with *Gliricidia* leaves at zero week sowing (0WAS) and 2WAS treatment compared to that in control in all the sampling dates (Annual report, 2003-04, CIARI). In alley cropping system, *Gliricidia* hedgerows produced pruning biomass of 8.7 t/ha/yr. The nitrogen content (%) was 2.10. In addition, *Gliricidia* hedgerow, raised across the slope, arrested soil erosion. Besides these, *Gliricidia* was found as a suitable standard for black pepper produced 3 kg berries per *Gliricidia* shrub (Annual report, 2002-03, CIARI).

2. Karanj (*Pongamia glabra*)

It is a leguminous tree grown in wastelands. On an average, a tree can yield 100 – 120 kg of green matter. The leaves contain about 3.7% N (on dry weight basis).

3. *Sesbania speciosa*

It is a valuable green manure for wetlands and can be grown in a wide range of soils. Seed production is prolific however; pods are frequently attacked by insects. This green manure can be raised on the field borders. Sesbania seedling (21 days) can be planted in a single line at 5-10 cm apart in the borders of the fields. In about 90 days it produces about 2-4 tonnes of green manure per ha. It does not affect the rice yield by shading or root effect. The manure can be incorporated into the field. About 300 – 400g of seeds is sufficient to raise nursery and plant the seedlings around the boundary of one hectare. To control insects *Verticillium lacanii* (Liquid) fungi is useful.

Other legume crops suitable for tropical islands

Legume vegetable crops

Cow pea

Cow pea is a kharif legume crop and is grown across India for seeds, green pods, animal fodder and organic green manure. They do well in sandy and sandy loam soils. The crop will be ready for harvesting in 3 months. Tender pods should be harvested frequently before they become fibrous. It can be used as green fodder and green manure.

Lab-lab

It is known as Dolichos bean or field bean is bushy, semi-erect plant. It is a multipurpose crop grown for pulse, vegetable and forage. It is also grown in home garden as annual crop or on fences as perennial crop. It is one of the major sources of protein in the diets. It is an excellent N fixer and is sometimes grown as cover crop.

French beans

It is an important vegetable crops cultivated in the islands. They are used in daily vegetable cooking, animal fodder and for soil improvements as well. Green beans are harvested before they become mature. It can be grown in wide range of soils. It is necessary to have well drainage of soil. Soil pH range 5.5 -6.0 with cool climatic condition is suited for beans. The beans will be ready after 3 months. The average yield is 10 – 12 t/ha.

Legume forage crops

Stylosanthus

It is an erect growing perennial forage legume. It is adapted to tropical climate and tolerant to low fertility acidic soil and soil with poor drainage. The crude protein content ranges from 15-18 %. Seed rate is 10 kg/ha. It yields 30-35 t/ha/year. It is a good pasture legume.

Lucerne

It is also termed as 'queen of forages'. It is a deep rooted perennial forage legume adapted to wide range of climatic condition. It is very palatable and nutritious forage containing 15-20 % crude protein. Lucerne adds nitrogen to soil and improves soil fertility.

Legume cover crops

Desmodium

It is a large trailing and scrambling perennial. It has a strong taproot and the long trailing stems can root at the nodes if in contact with moist soil. It has good shade tolerance. It also acts as cover crop under plantations.

Calopogonium

Calopo (*Calopogonium mucunoides*) is a vigorous, hairy annual or short-lived perennial training legume. It can reach several meters in length and form a dense, tangled mass of foliage, 30-50 cm deep. Calopo is mainly used as cover crop, alone or in mixture with other legumes, especially in rubber, oil palm or coconut plantations. It is used for green manure. It provides soil protection, reduces soil temperatures and improves soil fertility and controls weeds. It also withstands flooding conditions.

Conclusion

Soil health degradation is one of the most important problems faced by the farmers in the islands. The uncontrolled use of chemical fertilizers is deteriorating the soil physical, chemical and biological properties. Therefore, to overcome these problems the organic farming is promoted in the islands. The organic farming depends on organic manures like farm yard manure, compost, legume crops, green manuring etc. Grain legumes and green manure crops are fertility building crops and may be broadly defined as crops grown for the benefit of the soil. The green manuring crops improve the humus, organic carbon, nitrogen and soil microbial growth. They help to increase the supply of nutrients available to plants.

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Non chemical weed management in organic farming

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Among the agricultural pest, weeds are the most costly category owing to their large negative impacts on yields but also due to the labour intensive operations needed for their management than insect pests and disease in crop plants. Weed has been defined as unwanted and undesirable plants that interfere with utilization of land, water resources and thus adversely affect crop production and human welfare. Generally **agricultural soils holds millions of weed seeds per hectare which greatly reduce crop yield by competing with the crop for natural resources like nutrients, light, and water. Weeds by way of harbouring pests (nematodes, insects, pathogens) reduce both yields of crops and quality of the produce.** Non-chemical weed management encourages weed suppression rather than eradication which reducing competition for natural resources and alternate host for pest and diseases of crops ultimately enhance the yield performance and aesthetic value of crop produces (Gnanasoundari and Somasundaram, 2014). Andaman & Nicobar Islands receives an average annual rainfall of 3080 mm of during May to December that is more conducive for weed proliferation. However, during post rainy season (December - April), weeds are less menace owing to water shortage. Plantation and spices are mostly grown in the undulating topography that are prone to erosion and nutrient loss, hence to regulate it, natural under story vegetation is retained. Islands mostly covered by green vegetation like grasses and broad leaved weeds that becomes the major sources of soil weed seed bank. Most of the weed flora in these islands is convergence of native as well as exotic one. Non-chemical weed management is only way to control the weeds and safeguard this fragile ecosystem because of indiscriminate use of herbicides can adversely affect not only crops, but also aquatic fishes and finally the biodiversity.

Major weed threat in the Islands

The weed flora of a particular area is determined by many interrelated factors such as climate, edaphic and biotic factors. In a given environment, however, the weed vegetation is most strongly affected by biotic factor and cultural practices such as fertilizer management, irrigation, cultivar grown, tillage, weed management and crop rotation (Kim and Moody, 1980). In Island, 250 prominent weed species belonging to 49 families are reported in agricultural and non agricultural lands. Weed flora in most widely grown food crops of Islands i.e. rice was found similar in both low-lying and upland condition. Sedges of *Cyperus rotundus, C. difformis, C.iria, Fimbristylis aestivalis, Schoenoplectus juncoides*, grasses of *Echinochloa colonum,* broad leaved weeds of *Marselia quadrifolia, Monocharia vaginalis, Phyllanthus urinaria, Sphenoclea zeylanica* are found in rice crop. *Echinochloa colonum, Cynodon dactylon*, *Blumea* spp. and *Cyperus iria* are found major weed flora during post rainy season (Raja *et al.,* 2008). In plantation crops, *Panicum sp, Pennisetunm cenchroides, Mimosa pudica, Hyptis suaveolens, Wdelia chinensis* are dominant weed flora. *Chromolaena odorata, Mimosa pudica, Lantana camara* have emerged as important weeds in pasture lands. *Hygrophila erecta* and *Scirpus littoralis* forming thick mats on the soil in low lying areas of pasture and plantation crops have emerged as severe menace for their production (Gangaiah *et al.,* 2016). Continuous rainfall of islands is more conducive for weed growth and their management is difficult. The difficulty gets compounded in organic farms that don't advocate use of herbicides.

Weed management in the Islands

In Islands, weed management is by primitive means which includes the integrated use of preventive, cultural and curative methods. Quarantine is useful preventive method to minimize entry of new weeds and their spread in the islands and very cost effective as compared to other required inputs. However, this is neglected in the Islands. The various weed management practices followed in the Islands in diverse condition that are suitable for organic agriculture are described below.

Preventive methods

Prevention is an essential component of an integrated weed management strategy. The saying "*An ounce of prevention is better than a pound of cure*" is indeed very applicable to weed management. Its aim is to avoid initial introduction; development of infestation; weeds dispersal and their propagules which may good weed prevention strategies in individual and group responsibilities as well as government also enacted laws to prevent the introduction and dissemination of weed propagules from exotic crops/seeds materials ultimately helps in reducing the weed density in the cropping areas. Crop rotations, cover crops, seedbed preparation, soil solarisation and composting are important methods of preventing weed emergence and spread in crop fields.

Selection of weed free seed and competitive varieties

Use of certified seeds and weed free seeds prevents the entry of new weeds in these islands and quarantine also checks the contamination of weed seeds and allows them only to have the good quality seeds.

Management of irrigation and drainage systems

In islands, ponds, small drains and streams are major sources of irrigation during post rainy season. High intensity of rainfall causes soil erosion, which leads to movement of weeds propagules between uncultivated lands to cultivated land.

Aquatic weeds also creates more difficult to regulate the weed infestation, hence farmers deserves more attention during irrigation and drainage of excess rainfall.

Use of well decomposed organic manures

Island farmers exclude fertilizers use because of fragile ecosystem and governments also insist on organic manure production and use by way of providing more subsidy to the growers. Partially rottened manures saturated with weed seeds are the key source for proliferation of weed seeds in islands. Composting can be used as an alternative weed control method to manual and mechanical methods which also reduces soil compaction (Zinati, 2017). Compost production generates more temperature during degradation which effectively control weed seed viability. Compost extract significantly reduce weed biomass in lettuce by 19 and 34 % as compared to hand hoeing and control.

Crop rotation

Crop rotation involves alternating different crops in a systematic sequence on the same land. Crop rotation is more important preventive methods for weed control which reduces the soil weed seed bank. Continuous crop rotation (annual and perennial crops) affects the abundance and diversity of weed (Bond and Grindy, 2001). But, monoculture leads to build-up of certain weed species, while diverse crops are used in a rotation, weed germination and growth cycles are disrupted by variation in cultural practices associated with each crop. Crop rotations or crop sequences which weed species are severely limited in their potential to grow, reproduce and proliferate needs to identification.

Intercropping

Intercropping suppressing the weed better than sole cropping provides an opportunity to utilize crops as tools of weed management. Intercrops act as smother crops which reduce weed intensity by shading. Pearl millet intercropped with cluster bean and moth bean significantly reduced the density and dry matter (*Tribulus terrestris*, *Cenchrus biflorus, Corchorus tridense* etc.,) of individual and total weeds as compared to sole crop of pearl millet reduced nutrient uptake by different weeds lead to hang up of weed growth and crop weed competition due to smothering effect of intercrops on weeds (Kiroriwal and Yadav, 2013). Banana intercropped with cowpea producing dense canopy and covering the ground area suppressed weed growth completely during initial growth stage of 2.5 month, after that uproot cowpeas used as organic mulch provided effective weed control for another 2 month (Singh and Sairam, 2016).

Cover crops

Quick growth and dense ground covering by the crop will suppress weeds. **Cover crops occupy the** field **before or after periods of main crop production which** improving soil physical characteristics, reducing nutrient leaching and erosion, and adding N, can suppress weed establishment and growth, thereby reducing the number of weed seeds and vegetative propagules infesting succeeding crops under changing environmental conditions (Liebman and Davis, 2000). Cover crops such as rye, red, clover, buckwheat and oilseed, radish or winter wheat or forages can suppress weed growth. Highly competitive crops may be grown as short duration smother crops within the rotation.

Tillage

Weed management is carried out by primary, secondary tillage and intercultural operations were found effective in weed control. **Farmers mostly followed tillage practices for reducing soil weed seed bank by inversion of topsoil because of upper soil layer contains more weed seeds than deeper. Deep ploughing is more effective for eradication of perennial weeds** like *Cynodon dactylon* provided the rhizomes after tilling are collected and destroyed. **In island, farmers follow puddling in rice and cultivator for other crops which reduce soil weed seed bank. Bunding and** levelling of rice fields was found effective in reducing the weed density upto 28 % as compared to unlevelled and unbunded field as the farmer facilitates uniform standing of water (Pramanik *et al*., 2001).

Mulching

Soil surface covering with any materials can reduce weed problems by preventing/ suppressing weed seed germination/ seedlings emergence by blocking light transmission.

Live mulches are usually a plant species that grows densely and near to the ground but not grown for harvest instead to provide ecological benefits including protecting soils from erosion, improving soil fertility, suppressing weeds, and reducing pest populations. Weeds can be suppressed by the introduction of living mulches into cropping systems. Presence of green vegetation covering the soil creates a radiation environment that is unfavourable for weed germination, emergence, and growth.

Mulching with crop residues (paddy straw, *Gliricidia* leaf, banana leaf) influenced significantly higher water productivity and reduced loss of moisture due to weeds leading to higher pod yield of groundnut (Ravishankar *et al.,* 2014). Minimum density of weeds was recorded where straw mulch (10 t/ha) + FYM (20 t/ha)was applied followed by straw mulch 10 t/ha 50% N (pressmud) + 50% N (VC) treatment because straw mulch provided effective control of weeds in turmeric at 60 and 120 DAP at Faizabad. Organic mulches like rice bran (2.5 t/ha), mustard seed meal (2.5 t/ha), rice husk extract, mustard plant extract along with 1 hand weeding recorded significantly lower total weed density and biomass as compared to weedy check and other weed management treatments in basmati rice-potato-french bean cropping system at Jammu. In Coimbatore, significantly lower total weed density, dry weight and higher weed control efficiency (91.2%) were recorded in crop residue mulching 5 t/ha than PE pendimethalin 1.0 kg/ha at 45 DAS in Okra (AICRPWM, 2017).

High amount of fertilizer application in ginger/ turmeric crops which favour weed emergence in initial stage that later on compete with the crop for resources. Coconut leaves mulching at 12.5 t/ha may be done in ginger/turmeric bed thrice which helps to reduce weed intensity in addition to enhanced germination, microbial activity, organic matter, and reduce stem borer incidence besides preventing erosive soil loss due to heavy rains. Annual weeds germination and re-growth of perennial weeds were significantly reduced by 4.5, 3.0, 3.5 and 3.9 times by straw, peat, saw dust, grass mulch, respectively than annual weeds (Pupaliene *et al.,* 2015). Black plastic mulch reduces weed growth and development in banana owing to reduced light penetration under island condition (Wendy *et al.,* 2012).

Soil solarization

Soil solarization refers to disinfestation of soil by the heat generated from trapped solar energy. It is a hydrothermal process that takes place in moist soil which is covered by plastic film and exposed to sunlight during the warm months. Soil solarization for 2-4 weeks almost completely prevented the emergence of many annual weeds up to 4 cm *(Digitaria sanguinalis, Malva, Echinochloa, Chenopodium, Amaranthus retroflexus, Solanum nigrum)*. Weeds seed germination after soil solarization was much decreased in the top layer which increased with sample depths. Bindweed, *(Convolvulus arvensis*) emerged in solarized by black polyethene, *C. rotundus* survived 80°C for 30 minutes, but *Cynodon dactylon* and *Sorghum halepense* rhizomes were sensitive. Soil solarization reduced dodder seed germination laid on soil surface. Soil weed seed bank was tremendously reduced by soil solarisation (Abu Irmaileh, 2009). Annual weeds were effectively controlled by solarised plot than perennial weeds in ginger at 45 days after planting (Pillai *et al.,* 2016).

Cultural methods

Worldwide, it has been one of the most widely used weed control options for centuries. Cultural weed management options includes crop rotation, increasing the competitive ability of a crop, delayed or early seeding, flooding, inclusion of green manure and cover crops, and intercropping. The ability of crops to compete against weeds could be increased by selecting the right crops and cultivars, considering the weeds present as well as the climate, ensuring rapid and uniform crop emergence through proper seedbed preparation, and by using the right seed and seeding depth, increasing planting density and adapting planting patterns wherever possible to crowd out weeds, adequate and localized resource like water, fertilizer application, and optimum management of the crop, including insect pest and disease management.

Selection of crops and cultivars

Selection of crops and cultivars is an important indirect weed control method; as different crops have different competitive ability. Care should be taken during selection of crop, tall cereal varieties are essential to limit weed and enable to quickly shade the soil between the rows and is able to grow more rapidly than the weeds (Parish, 1990).

Cereals have strong competitive ability against weeds followed by oilseed rape, peas and potatoes/vegetables. Perennial pasture crop are usually more competitive against weeds during initial stage. Production of weed biomass is used as a measure of weed suppression ability of wheat cultivars (Bertholdsson, 2005). Traditional land races or tall cultivars are restricted light through crop shading which reduce both weed dry weight and weed density compared with modern cultivar. Some of the traditional varieties have more competitive ability with weeds through production of more root growth, early vigour, more leaf area index and allelochemicals.

Higher seeding rate

Increased the seed rates can provide a competitive edge to a crop by more quickly shading out weeds. Plant density may manipulate the ability of the crop to compete with weeds for resources. Increase in seeding rate which favour rapid canopy development can suppress weeds faster (Grichar *et al.,* 2004). **In warmer season, higher density of sorghum with narrow row spacing helps shade all weeds.**

Crop establishment

Transplanted crops give more advantages in control of weeds over direct sown crops. Use of paddy cum dhaincha seeder is an effective way to reduce weeds at early stages over direct seed rice in absence of herbicides. Early crop establishment suppress weed seed germination and development owing to lesser light transmittance. Row planted crops/seeds were found effective in weed management because of weeds can be easily removed with help of animal drawn (junior hoe) implements.

Brown manuring devoid of herbicides

Weather parameters that prevailed in the islands are more conducive and played a crucial role in *dhaincha* growth which smothers weed growth and contributed substantial amount of green biomass and nutrients to the rice crop. Co culture of *dhaincha* with paddy provides partial shade on initial stage and produce more biomass (8.2 t/ha) which incorporated by using conoweeder reduced weed density and dry weight compared to crops (Ravishankar *et al.,* 2007; Anitha and Mathews, 2010). This method of weed control is ecological, agronomical and economically effective one.

Cover cropping (Live mulch)

Dual cropping of azolla with rice which incorporated with cono weeder or rotary weeder at 20 and 40 days after transplanting recorded significantly lower weed density besides fixing atmospheric nitrogen (Gnanasoundari and Somasundaram, 2014). Legume crops like *dhaincha* or sunnhemp grown under the coconut canopy and incorporated into the soil surface at 30 days after sowing which suppress weed emergence in addition to supply of organic manure. In Islands, multi-tier cropping system was found more effective method to control weed emergence. Cattle grazimg on weeds preventing seed set can effectively reduce weed seed bank. Green manuring (*Sesbania rostrata*) of rice has numerically reduced weed density of monocots and broad leaf weeds than no green manuring at Dapoli (AICRPWM, 2017).

Manure placement/Selective use

The impact of application of organic sources of nutrients selectively crops on weed performance indicators are yet to ascertain.

Irrigation management

Efficient use of water is key to controlling weeds of a crop. Precision irrigation management can help to reduce weed pressure. Surface and subsurface drip irrigation supplied to the root zone of crops without wetting the surrounding soil reduces weed seed germination owing to deficit of moisture to the weeds and maintenance of dry soil between crop rows. Drip tape buried below the surface of the planting bed can provide moisture to the crop root zone and minimize the amount of moisture available to weeds closer to the surface. Large vegetable seeds can germinate, grow, and provide partial shading of the soil surface without supplemental irrigations that would otherwise provide for an early flush of weeds (Newton, 2012).

Curative methods

Curative methods are effective in killing of existing vegetation, reduction of weed emergence by hoeing, ridging, by manual or animal or mechanical harrowing and use of organic herbicides(soap based product, clove oil, cinnamon oil and acetic and citric acid, corn gluten meal) and bio control agents. Island farmers, mostly adopting the intercultural operation than other methods of curative methods weed control.

Cultivation methods

In Andaman &Nicobar Islands, rice is grown in aquatic, semi aquatic and terrestrial conditions. In new emerging rice cultivation technique *viz*., System of Rice Intensification (SRI), facilitating aeration through limited water use and weed management by rotary hoe techniques were found to enhance rice as well as water productivity.

In SRI method, wide rows, younger and single seedlings facilitate more weeds growth at initial stages. Hand operated rotary-weeder can be used for weeding, which simultaneously incorporate the weeds and stir the soil and return the weeds to the soil as green manure. Weeder can be operated between the rows in both the directions in four times at 10, 20, 30 and 40 days after transplanting and the leftover weeds can be removed at 20 and 40 days after transplanting manually. Rotary weeding is necessary in SRI which can effectively enhance yield through aeration that stimulates root growth and biological activity of soil (Ramamoorthy, 2004).

Low tech mechanical devices such as cultivators, finger-weeders, brush weeders, and torsion-weeders tend to be used in low density crops, while spring-tine harrows are mainly applied in narrow-row high-density crops. Hand-weeding may also be used after mechanical inter-row weeding to deal weeds left in the crop row. Pre and post emergence weed harrowing in peas and spring cereals is most effective against the early and late emerging weed species (Lundkvist and Verwijst, 2011). Hoe-ridger and brush weeder are developed for intra-row control of weeds in sugar beet and vegetable crop with minimal soil disturbance used for leafy greens soil can be thrown into the row to bury in – row weeds using spider wheels (Peruzzi *et al.,* 2017).

Sensor-based techniques for weed control

Recently weed detection systems (laser transmitters and receivers) have been used to guide tractor mounted machinery in a straight line across a field (Home *et al.,* 2001) which analysis image based on shape of leaf/colour and use spectral sensing or light reflectance to detect weeds in between crop under non-chemical weed control systems. Infra red sensor are also used to detect crop plants which transmitted signal to a computer that activate an air cylinder to push the hoe blade out of position before it reaches the crop plant (Vale, 2003).

Robotic weed control

Precision agriculture may become a key element of modern site-specific weed control which provides the basis for spatial heterogeneity (Bajwa *et al.,* 2015). Robotic weed control system has four core technologies such as guidance, weed detection and identification, precision in-row weed control, and mapping. Now day's robots are available commercially for weed control as Robovator and robocrop in Denmark and England, respectively. *Removeed* used infrared light sensors to detect and removes weeds both from the inter- and intra-row space by using cutting blades, without any risk for the crop. However, small and medium sized farms are yet to use robotic weeders (Riethmuller, 2007).

Organic herbicides

Organic herbicides are mostly non selective, pre emergence (corn gluten meal and mustard seed meal) and post emergence (ammonium nonanoate, fatty acid, acetic acid, clove oil cinnamon oil, D-limonene) from soap based products. Pre emergence application or pre plant incorporation of corn gluten meal and mustard seed meal effectively inhibited germination, root and shoot length in many weed species such as *Solanum nigrum, Chenopendium album, Portulaca oleracea, Amaranthus retroflexus* (Bingaman and Christians, 1995; Yu and Morishita, 2011). Ammonium Nonanoate is non selective post-emergence contact herbicide that effectively controls small annual broad leaf and grass weeds in organic crop production. Fatty acid like pelargonic acid provided excellent weed control at low application rates and volumes. Acetic acid concentration increases weed control efficiency increases in annual broad leaf weeds than grass and perennial weeds. Clove oil, D-limonene effectively control actively growing and emerged annual, perennial grasses and broadleaf weeds (Webber *et al.,* 2012).

Thermal method

Thermal method of weed control is defined as rapid heating of plant tissues to destruct plant cell integrity. direct heating (flaming, infrared radiation, hot water, hot air, hot foam, etc.) and indirect heating (electrocution, microwave, laser radiation, ultraviolet radiation, etc.) are two important methods which affects physiological functions of the plants that leads to wilt and prevents water moving from the roots to the leaves. Onions have some tolerance to flaming and more successful in both pre and post-crop emergence conditions and after transplanting. Transplanted cabbage has some tolerance to heat, allowing band flaming may be used along the crop row which cause crop damage during early stage, but the crop usually recovers. In a young pear orchard, flaming kept weed growth in check and started cultivation but the efficiency of flaming is greatly reduced during dew or rain present on the plants. Early morning and early evening are the best times to operate the flame (Wei *et al.,* 2010).

Pneumatic weed control

Pneumatic weed control has been used successfully in carrot, maize and sugar beet and more suitable in dry soils. This method injects compressed air into the soil to loosen and uproot small weeds on either side of the crop row with an operating depth of 15 mm and speed of 5-6 km/hr (TNAU, 2015).

Use of lasers and ultraviolet light

Laser light affects the whole weeds plant which due to absorption of energy in the tissue to conversion into heat through that meristem is destroyed (Marx *et al.*, 2012). Laser wavelengths, radiation intensities as well as the weed species and their growth stage should be considered before application of laser light treatment. Laser method of weed management can improve labour work efficiency, ecofriendly and enhance utilization of resources which leads to change farmers traditional working style (Ge *et al.*, 2013). Higher weed density requires more laser power while fast operation of machinery because of it can't be injected adequately into plant tissue. Lasers light have been shown to inhibit the growth of water hyacinth (*Eichornia crassipes*). This method did not normally kill the weeds but reduced the plants size and produced fewer daughter plants and covered less water surface than the untreated (Wei *et al.,* 2010). Recently, CO_2 lasers are used as a device for cutting down weeds. The use of ultraviolet light for weed control has been patented but remains at an experimental stage.

Biological methods

Biological control aims to suppressing growth and development of weeds by using living agents *viz.*, insects, bacteria, or fungi and animals. Animal grazing is more economical way of weed management in many situations. Cattle, chickens, ducks, goats, pigs, have long been used for grazing which reduce seed setting by weeds and also prevent the soil weed seed bank. Cattle grazing were effective methods for control weeds in coconut plantations (Senarathne and Perera, 2011). Rice cum fish farming, herbivorous fishes (Tilapia, Common carp) increased water turbidity which intern inhabited weed photosynthesis and reduced the cost of weeding (Severino and Christoffoleti, 2004). In rice cum duck farming, ducks significantly reduced weed density by eat emerging weed plants, weed seeds and trampling the weeds under control upto 90%, which oxygenating the water and encouraging vigorous growth of the rice roots and enriched the soil's nutrients, probably through their excreta (Hossain *et al.,* 2005). Natural enemies may be used to reduce the abundance of certain weed species. Seed feeders insect can greatly enhance fungal attack by piercing the seed coat up to *98% of Abutilon theophrasti* which infected by *Fusarium* spp. when gaps were created in the weed's seed coat. Synergistic interactions between granivores and pathogens may have their greatest impact on the seeds of small-seeded weed species (Liebman and Davis, 2000). Weed seeds closer to the soil are more likely to be eaten or damaged by insects, animals, other predators and disease causing organisms. Some promising examples in Indian context include; control of *Eupatorium odorata* by leaf eating caterpillar, lantana by *Telenomia scrupulosa, Salvania molesta* (aquatic weed) by *Pablinia achminata* (grass hopper); water hyacinth by *Neochetine cichhornae* and *N. bruchi*; *Parthenium* by *Zygogramma bicolorata*. In 2012, KVK, Port Blair has released *Zygogramma bicolorata* for management of *Parthenium hysterophorus.*

Bio-herbicides

Bio-herbicides are biological control agents applied in similar ways of chemical herbicides to control weeds. The active ingredient in bio-herbicide is a living organism and it is applied in moderate doses. Most commonly, the micro organism used is fungus and its prologues are spores or fragments of mycelia; in this case bio-herbicide is also called a mycoherbicide. Commercial bio-herbicides first appeared in the market in the USA in early 1980s with the release of product, '*Devine*' in 1981 and in the next year, the release of the product '*Collego*'. Inspite of considerable public research efforts and many promising candidate organisms only one bio herbicide '*Bio Mal*' has been recognized in Canada. Reduction in growth and competitiveness of weeds may be sufficient to reduce crop yield losses. For example, defence mechanisms of bracken fern (*Pteridium aquinum*) as response to invasion by the fungus *Ascochyte pteriodis* by reducing lignin production.

Table 1. List of commercially available mycoherbicides against target weeds

Trade name	Pathogen	Target weed
Devine	*Phyophthora palmivora*	*Morreria odorata* (Strangler vine) in citrus
Collego	*Colletotrichum gleosporoides f.sp. aeschynomene*	*Aeschynomene virginica* (northen joint vetch) in rice and soyabean
Biopolaris	*Biopolaris sorghicola*	*Sorghum halepense* (Johnson grass)
Biolophos	*Streptomyces hygroscopius*	General vegetation (non-specific)
LUBAO 11	*Colletotrichum gleosporoides f.sp. Cuscuttae*	*Cuscutta sp.* (Dodder)
LUBAO 01	*Alternaria cassiae*	*Cassia abtusifolia*
ABG 5003	*Cercospora rodmanii*	*Eichhornea crassipes* (water hyancinth)

Allelopathic effect

Allelopathy, where toxic chemicals produced by one crop suppress other plants. Crops and weeds exhibit alleopathy ability which produce allelochemical as end products, by-products and metabolites liberalised from the plants such as phenolic acids, flavanoides, and other aromatic compounds *viz.,* terpenoids, steroids, alkaloids and organic cyanides**.** Now a day's allelochemicals and other natural products or their derivatives could form the basis for weed control. Black mustard extract were produced in large quantities of allyl isothiocyanate which inhibitory to the germination of grass seeds. Sorghum seeds interfere the germination and growth of annual broadleaf weeds which suppressed weed density up to 1 year due to roots exude a sorgoleone that exhibits phytotoxicity. Allelopathic cover crops may enhance the weed suppression through interfere with cell elongation, photosynthesis, respiration, mineral ion uptake and protein and nucleic acid metabolism and also environmentally safe (Weston, 1996). Mulching of eucalyptus leaf litter registered the highest weed control efficiency of 62.0 and 51.8% at 20 & 40 DAS, respectively. The aqueous extracts as well as growing plants inhibit seed germination and seedling growth of *Abutilon theophrasti, Datura stramonium, Ipomoea* spp. weeds. Soil incorporation of sunflower residues reduced of dicot weeds by 66% due to allelopathic effect.

Conclusion

Integrated nonchemical weed management methods should be used to reduce weed pressure in organic farms. Crop diversification and organic amendment should added to weed control by enhancing soil weed seed and seedling mortality and delaying weed seedling emergence relative to crop emergence; decreasing resource uptake by weeds and declining variation in weed growth between years. Organic growers should integrate, multiple approaches to controlling weeds based on wide range of options and **carried out at different spatial and temporal scales.**

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Plant Disease Management in organic farming

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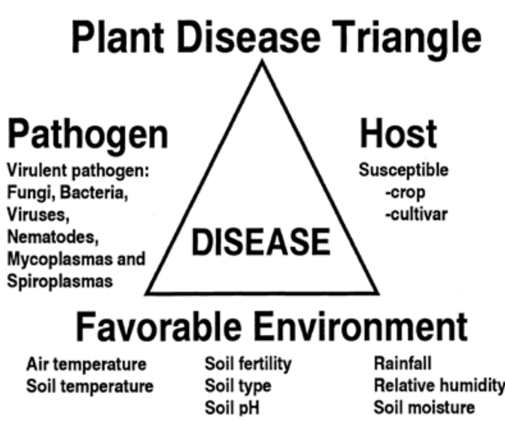
Introduction

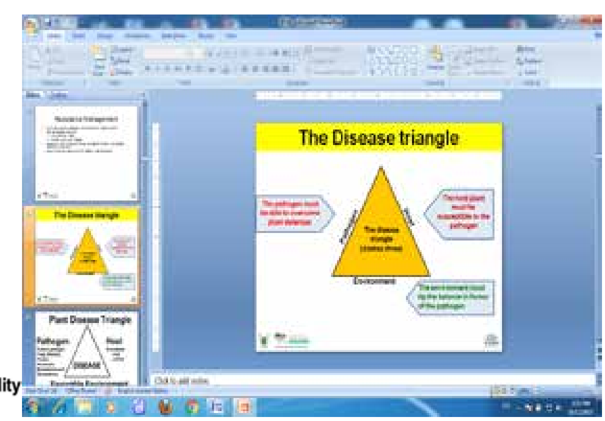
One of the major challenges facing organic producers is disease management. The losses in agriculture production due to disease can be significant and devastating under favorable conditions. The losses may be caused by varieties of factor such as fungi (*Alternaria* spp., *Cercospora* spp., *Colletotrichum* spp., *Curvularia* spp., *Diplodia* spp., *Fusarium* spp., *Helmitosporium* spp., *Phytophthora* spp., *Pythium* spp., *Rhizoctonia* spp., *Pestalotia* spp., powdery and downy mildew genera etc.,) bacteria (*Erwinia* spp., *Pseudomonas* spp., *Ralstonia* spp., *Xanthomonas* spp., *Agrobacterium* spp., *Phytoplasma* etc.,) viruses (Cucumber mosaic virus, Tomato spotted wilt virus, Cauliflower mosaic virus, Banana bunchy top virus, Bean yellow mosaic virus, Chilli mosaic virus, Papaya ring spot virus, etc.,) and nematode (*Meloidogyne* spp., *Radopholis* spp., *Pratylenchus* spp. etc.,).For the control of these challenging pathogenic organism a lot of pesticides are used. Concerns over environmental pollution and food quality degradation caused by excessive use of pesticides and fertilizers have prompted to find alternatives for agrochemicals. Integrated pest management (IPM) was first introduced by A.D. Pickett in Nova Scotia, Canada in the 1940s in order to harmonize chemical and biological control (Whalon and Croft, 1984; Bartlett, 1956; Smith and Allen, 1954; Stern *et a*l., 1959). Similar to IPM, Integrated disease management (IDM) is an approach to disease control that utilizes regular monitoring to determine whether and when management are needed and employs physical, mechanical, cultural, biological and chemical tactics to keep pathogen populations low enough to prevent unacceptable damage (Thies and Tscharntke, 1999). In simple terms, IDM can be a procedure to manage pest populations by harmonizing control methods such as application of antagonistic organism, pesticides and cultural practices, with the intent to minimize economic damage and harmful environmental side-effects by managing the population of pathogens instead of eradicating or removing the pathogens. Organic agriculture seeks to use nature as the model for system design. Since nature consistently integrates the plants and animals into a diverse landscape, a major tenet of sustainable agriculture is to create and maintain diversity. Humans should not kill all living things in nature and allow nature to do some of its jobs with its diversity. It is impossible to leave everything in its natural status in our agriculture fields because man needs the food from the land. However, humans can respect nature and design cropping systems to be as close as possible to nature. The principles of organic agriculture or nature farming do not allow complete eradication of organisms and suggest pests be suppressed to populations below those which cause economic losses to the crop.

Alternative integrated disease management has been developed for organic crop production. Biodiversity enrichment is one system of practices in integrated pest management. Practices that entirely eliminate pest insects, even when not based on chemical pesticides, are not necessarily good for biodiversity, because in long-term disease control, the natural enemies of pest insects must persist by having access to prey, which, particularly in the case of specialist enemies, may be helped by the persistence of small pest populations. So keeping in the above view disease management in organic agriculture are given bellow.

Knowledge about Disease Development

Disease development is dependent upon three conditions: a susceptible host plant, a favorable environment and a viable pathogen. All three of these factors must be present for disease to occur. This concept is known as a 'disease triangle.' Each side of the triangle represents one of these factors: host plant, environment and pathogen. When all three sides of the triangle are complete, disease occurs. If one of the conditions is not present (one side of the triangle is missing), then disease does not occur. Altering any of the three components directly affects the disease triangle which can be broken and disease development prevented.





Plant Disease Triangle

Factor influencing disease management in organic agriculture

Host related Factor

Host plant genetic makeup determines its susceptibility to disease. This susceptibility depends upon various physical and biochemical factors within the plant. A plant's stature, growth habit, cuticle thickness (a protective outer layer on plant tissues), and shape of stomata (small openings that allow water, oxygen and carbon dioxide in and out of plant tissues) are a few physical factors that influence disease development. Plants may also produce biochemical compounds that limit or prevent colonization or infection. Growth stage and ability to deter pathogens can also impact plant susceptibility to disease. For example, young leaves are often more susceptible to infection than mature leaves.

Environment related factor

Environment plays an important role in disease development. Pathogens generally require specific environmental conditions for infection and spread. Most plant pathogens require high humidity and moderate temperatures. Other pathogens, such as bacteria and water molds, require surface water for spread. In some disease cycles, environmental conditions influence the development of symptoms. For example, extreme temperatures or drought can cause plant stress; this loss of vigor can increase host susceptibility to both infection and disease development. Other environmental factors affecting disease can include those resulting from planting and maintenance practices. For example, high density plantings can a have higher relative humidity, while overhead watering increases leaf surface moisture needed by pathogens to infect plant leaves. Many disease caused by *Botrytis* spp., *Pythium* spp., or *Phythophthora* spp., can be suppressed by manipulating the environmental component i.e., reducing the moisture level in the soil or atmosphere.

Pathogen related factors

Pathogens removal of from infected plant parts and other remnants of pathogens make them unavailable for infection. Many pathogens, however, have developed specialized structures that ensure survival during adverse conditions. For example, several water molds and fungi are capable of surviving in soil for many years until conditions are favorable for infection. Pathogens may also survive winter temperatures and other harsh conditions in infected plant tissue. If a susceptible host and favorable environment are not available, some pathogens can assume a dormant state for many years.

Nutrition related factor

One of the fundamental strategies for maintaining plant health and suppressing plant disease is managing nutrition. Proper nutrition can often influence the fine line between host susceptibility and resistance; certain nutrient regimes can suppress *Fusarium* spp., *Rhizoctonia* spp, *Thielaviopsis* spp, *Verticillium* spp and powdery mildew by increasing the resistance of the host. In many case the amount of an element needed to suppress disease far exceeds the plant's nutritional requirement for that element indicating that many elements may function in multiple mechanisms in suppressing the disease. Chemical interaction with the soil, pH and or/with specific community of microorganism can in turn influence the development of disease. For example, the form of nitrogen can have striking effects on plant disease through root medicated change in pH, microbial profile in rhizosphere and alterations in the availability and function of micronutrients. In addition, Ca only composes approximately 0.5% of the dry weight of most plants. Yet Ca is routinely applied in great quantities to the field to affect soil pH and to suppress certain plant disease.

Both essential and beneficial elements can directly and indirectly affect defense mechanism in plants. Direct effects include metabolic pathways that lead to the production of lignin, phenol, phytoalexin and other defense related compounds. Many of these pathways utilize enzyme that require Mn, Cu, Zn, Mo and B as cofactors or as activators. Other elements like K and Cl influence the osmotic relations, water cycling and root exudation which in turn influence beneficial microbes. Indirect mechanisms include effect on nitrification, soil pH and chemical transformation of micronutrients like Mn.

Disease caused by plant pathogenic fungi and their management

Fungi are small generally microscopic, eukaryotic, usually filamentous, branched, spore-bearing organisms that lack chlorophyll. Fungi cause many economic diseases such as powdery mildew, downy mildew, leaf spot, anthracnose, rust, damping off, wilt and root rot etc., some of the important disease, their cause and management are as follows.

Powdery Mildew

Powdery mildews are probably the most common, conspicuous, widespread, and easily recognizable plant diseases. They affect all kinds of plants except gymnosperms. Powdery mildews appear as spots or patches of a white to grayish, powdery mildew growth on young plant tissues or as entire leaves and other organs being completely covered by the white powdery mildew. In early stage powdery mildew appear as tiny, pinhead-sized and spherical at first white, later yellow-brown and finally black cleistothecia may be present singly or in groups on the white to grayish mildew in the older areas of infection. Powdery mildew is most common on the upper side of leaves but it also affects the underside of leaves, young shoots and stems, buds, flowers, and young fruit.

Causal Organism

The powdery mildew diseases of the various crop or other plants are caused by many species of fungi of the family Erysiphaceae grouped onto several main genera. These genera are distinguished from one another by the number (one versus several) of asci per cleistothecium and by the morphology of hyphal appendages growing out of the wall of the cleistothecium.

Powdery mildew Disease in	Casual agent
Cucurbits	*Erysiphe cichoracearum*
Okra	*E. cichoracearum*
Legumes	*E. polygoni*
Tomato/Chilli	*Leveillula taurica/oidiopsis taurica*
Shade and Forest trees	*Phyllactinia* spp
Grape	*Uncinula necator*
Mango	*Oidium mangiferae*
Papaya	*O. caricae*
Brinjal	*Sphaerotheca fuliginea*

Management

Powdery mildew can be managed with resistant varieties and regular foliar applications of bio fungicide. It is not possible to escape infection because the pathogen produces many wind-dispersed spores, especially in case of cucurbit crops which are grown widely, and conditions often are favorable for this disease. The powdery mildew fungus tolerates a wide range of temperatures below about 37^{0}C and it does not need a period of free moisture on leaves to infect, in contrast with other foliar fungal pathogens. Rain is actually unfavorable for disease development. Removing affected tissue is not likely to be helpful because powdery mildew typically does not start in foci and the action of removing leaves could dislodge spores, further spreading the pathogen. Stressed plants are more susceptible.

Management of powdery mildew in organic Agriculture

- Good air circulation ensures lower humidity levels, inhibiting the growth of powdery mildew. Crowded plants will also provide too much shade for the lower leaves, encouraging fungi growth.
- Never use the infected plant leaves or fruit as mulch. Trim off infected leaves and stems and dispose of properly.
- While the water will not encourage mildew growth, splashing the leaves with water will spread the spores. Run a hose to the base of your plants instead of using a sprinkler system.
- Numerous studies have shown milk and/or whey to be an effective anti-fungicide. The milk and whey are believed to produce free radicals which are toxic to the fungus. *Mix 60 parts water with 40 parts milk or whey and spray onto the affected plants bi-weekly* or *mix one 28g powdered milk to 2 liters of water.*
- Baking soda changes the pH of the fungus and kills it. *Mix 1 tbs of baking soda and 1/2 tsp liquid hand soap with one gallon of water.* Spray solution on affected leaves, and dispose of any remaining solution. Do not apply during daylight hours. It may be best to test one or two leaves to see if the solution will cause the plant to suffer sunburn.
- Potassium bicarbonate is a safe, effective fungicide. It is used as a leavening agent, and is used in wines and bottled waters. *Mix 3 tbs potassium bicarbonate, 3 tbs vegetable oil and half teaspoon soap into a gallon of water (*Williams and Williams, 1993 & 1985; Ziv and Hagiladi, 1993).
- Sulfur is a natural product that is very effective at preventing and controlling powdery mildew. Sulfur can be bought as a dust, or as a liquid which can be added to sulfur vaporizers. Follow the dosing instructions closely and wear gloves, eye protection and a face mask. Avoid inhaling or coming into contact with the sulfur.
- Neem oil is made from the seeds and fruit of the evergreen neem tree. Neem oil works by disrupting the plants metabolism and stopping spore production. *Mix 3 tbs of neem oil to one gallon of water.* Take precautions to avoid sunburn of leaves and avoid spraying the plant's buds and flowers.
- Copper is a very effective fungicide, but it is very important to follow label directions closely. Too much copper will be detrimental to the plant and the soil.
- Vinegar is very acidic. When sprayed on powdery mildew it changes the fungus pH which effectively killing it. *Mix 4 tbs of vinegar with 1 gallon of water. Reapply every three days.*
- Garlic has high sulfur content and is an effective anti-fungicide. Garlic oil can be bought commercially if you do not wish to make the solution at home. Garlic works best when added to organic oil mixtures. *Crush six cloves and add to 28 ml of organic oil such as neem oil and 28 ml of rubbing alcohol. Let set for two days, then strain and retain the liquid and crushed garlic. Again soak the garlic, this time in one cup of water for a day. Strain out and dispose of the crushed garlic. Add the oil and alcohol mixture and garlic water to one gallon of water. Spray your plants, coating only the leaves.*

Downy Mildew

Initial symptoms of downy mildew observed as small yellow spots and small irregular black spots with yellow-green border. First symptoms also can be a water-soaked spot. Infection does not expand beyond veins thus spots develop an angular appearance as the spots expand. Sometimes several spots occur together forming a yellow patch that can have an orange tint, especially in pumpkin.

Downy mildew genera

Some of the most common or most serious downy mildew disease with causal agent is listed below.

Downy mildew disease of	Causal agent
Lettuce	*Bremia lactucae*
Crucifers	*Hyaloperonospora parasitica*
Corn	*Peronosclerospora maydis* and *P. philippinensis*
Sugarcane	*P. sacchari*
Grape	*Plasmopara viticola*
Sunflower	*Plasmopara halstedii*
Cucurbits	*Pseudoperonospora cubensis*
Grasses and millets	*Sclerospora graminicola*

Management

- Cultural practices include selecting growing sites with good air drainage, full sunlight and low humidity. Using drip irrigation, or scheduling overhead irrigation to avoid excessive leaf wetness, will also reduce disease incidence. When detected early, disease spread might be slowed somewhat by removing and destroying infected plants and by taking care not to transport the disease by hand or on infected tools and equipment.
- Application of a wettable powder formulation of *Bacillus subtilis* @ 2g /lit is found effective on management of Downy mildew (Fravel, 1999).
- On the appearance of disease spray the crop with copper fungicide @ 2g/lit at 15 days interval.
- Application of Hydrogen peroxide @ 0.4% is an effective preventive and curative method for powdery and downy mildew management (Hofstetter, 1993).
- Potassium bicarbonate is a safe and effective fungicide. *Mix 3 tbs potassium bicarbonate, 3 tbs vegetable oil and half teaspoon soap into a gallon of water for foliar application (*Williams and Williams, 1993 &1985; Ziv and Hagiladi, 1993).
- Baking soda changes the pH of the fungus and kills it. *Mix 1 tbs of baking soda and 1/2 tsp liquid hand soap with four liter of water.* Spray solution on affected leaves, and dispose of any remaining solution. Do not apply during daylight hours. It may be best to test one or two leaves to see if the solution will cause the plant to suffer sunburn.

Anthracnose disease

Several species of *Colletotrichum* cause serious anthracnose diseases of numerous important annual crop and ornamental plants. Some of them produce their teleomorph, *Glomerella cingulata*, with some frequency and are sometimes referred to as Glomerella diseases. Such species also causes cankers and dieback of woody plants. Anthracnose disease is widespread and common in areas where moisture conditions is more which help in promote disease development.

Anthracnose Disease of	Causal organism
Chilli and ripe fruit rot	*Colletotrichum cpsici*
Tomato	*C. coccodes*
Crucifers	*C. higginsiannum*
Cauliflower	*Gloeosporium concentricum*
Cucurbits	*C. laginarium*
Beans	*Colletotrichum lindemuthianum*
Beans	*Colletotrichum truncatum*
Spinach	*Colletotrichum spinacicola*
Yam	*Colletotrichum gloeosporioides*
Banana	*Gloeosporium musarum*
Citrus	*Colletotrichum gloeosporioides*
Custard apple	*Glomerella cingulata*
Guava	*Colletotrichum psidii*
Mango	*Colletotrichum gloeosporioides*
Ginger	*Colletotrichum zingiberis*
Pepper	*Colletotrichum necator*
Turmeric	*Colletotrichum cpsici*

Cercospora Diseases

Cercospora diseases are almost always leaf spots. The spots either stay relatively small and separate or may enlarge and coalesce, resulting in leaf blights. The diseases are generally widespread among most cereals and grasses, many field crops, vegetables, ornamentals and trees. Losses from Cercospora diseases are usually small, but in some hosts and occasionally in others, they can be significant. Some of the important diseases caused by *Cercospora* spp. are as follow.

Name of disease	Causal organism
Leaf spot in Brinjal	*Cercospora melongenae*
Cercospora leaf spot of Carrot	*C. carotae*
Frog eye leaf spot of Chilli	*C. capsici*
Ring spot of Cabbage and Cauliflower	*Mycosphaerella brassicicola*
leaf spot of Colocassia	*C. colocasiae*
Cercospora leaf spot of Cucurbitaceous crop	*C. cucurbiticola, C.memordicae, C.citrullina*
Leaf spot of Elephant Foot Yam	*C. amorphophali*
Cercospora leaf spot of French Bean	*C. cruenta*
Cercospora leaf spot of Dolichus Bean	*C. dolichii*
Cercospora leaf spot of Ladies Finger	*C. abelmoschi*
Cercospora leaf spot of Raddish	*C. cruciferarum*
Cercospora leaf spot of Spinach	*C. beticola*
Sigatoka leaf spot of Banana	*C. musae/Mycosphaerella musicola*
Leaf spot of Custard Apple	*C. annonae*
Cercospora leaf spot of Guava	*C. sawadae*

Management of Anthracnose and Cercospora disease in organic agriculture:

- Use clean seed.
- Use hot water treated seed. For cabbage and Brussels sprouts, soak seed for 25 minutes in 50^0C water; soak for 20 minutes for Chinese cabbage, broccoli, and cauliflower. Precise time and temperature control is essential to minimize damage to the seed.
- Use clean transplants.
- In case of cruciferous crops long rotations (three years) with non crucifer crops or cruciferous weeds, such as wild mustard, are helpful.
- Destroy cull crop and crop debris after harvest.
- Plant later plantings upwind of earlier plantings.
- Allow for good air movement (e.g., wide spacing, rows parallel to prevailing winds, not close to hedgerows).
- Use practices that maximize air movement and minimize hours of leaf wetness (e.g., good weed control, wide spacing, etc.).
- After harvest, destroy remaining crop, and bury infected debris deeply. A three-year crop rotation is recommended for soil borne pathogens.
- Foliar Spray of Copper oxychloride/Copper hydroxide/Copper fungicide @ 3g/ liter at 12-15 days interval.
- For management of root rot or foot rot in perennial crops especially fruit crops drench the tree trunk around the 30cm radius with Copper oxychloride @ 7g/liter water and always keep graft point 22-25 cm above ground level.
- Spray the plants with wettable sulphur @ 2-3g/liter
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Alternaria leaf spot disease

The disease is characterized by the appearance of typical brown mostly circular lesions with concentric rings and reddish borders on affected areas. The lesions may coalesce to form larger lesions and result in extensive defoliation. The fungus survives as mycelium in infected crop residue.

Management of Altenaria leaf spot disease

- Early blight can be seed-borne, so buy from a reliable supplier.
- Hot water seed treatment at 50^0C for 25 minutes is recommended to control early blight on tomato seed. See chlorine treatment procedures under bacterial diseases.

- Provide optimum growing conditions and fertility. Stressed plants (including drought) are more susceptible to early blight.
- In case of early blight disease in solanaceous crop use crop rotations of at least three years to non-hosts (i.e., away from tomato and eggplant).
- Drip irrigation is preferred. If using overhead irrigation, start before dawn, so plants are dry early in the day. The key is to keep the period of leaf wetness to a minimum.
- Stake or cage plants to keep fruit and foliage away from soil.
- Each season, disinfect stakes or cages with an approved product before use. Sodium hypochlorite at 0.5% is effective and must be followed by rinsing and proper disposal of solution. Hydrogen peroxide is also permitted.
- Foliar Spray of Copper oxychloride/Copper hydroxide/Copper fungicide @ 3g/ liter at 12-15 days interval.

Club root disease of Cruciferous

Club root of cruciferous is caused by *Plasmodiophora brassicae*. This disease is characterized by large, irregular galls on the roots and those on the lateral roots take the shape of spindle. The attack occurs both in seed beds and in main fields. The disease is more serious in the soil with pH below 7. The infected roots enlarge rapidly to form clubs.

Management of Club root disease of Cruciferous

- For management of club root (*P. brassicae*) of cruciferous maintain soil pH above 7.2 and high calcium and magnesium levels.
- Rotate infested fields out of brassicas for a minimum of seven years.
- Avoid excessive irrigation.
- Avoid overcrowding and weeds that prevent air circulation in the field.

Fusarium disease

Commonly found throughout the Island, Fusarium wilt is a soil-borne pathogen that attacks Okara, cucurbits tomato, eggplant, fruit crops, pepper plants etc.,. Disease fungi (*Fusarium spp.*) enter through the roots and interfere with the water conducting vessels of the plant. As the infection spreads up into the stems and leaves it restricts water flow causing the foliage to wilt and turn yellow. Disease symptoms often appear later in the growing season and are first noticed on the lower (older) leaves. As the disease progresses, the younger leaves will also be affected and the plant eventually dies. In many cases, only one branch or side of the plant shows symptoms.

Fusarium wilt can survive for years in the soil and is spread by water, insects and garden equipment. The fungal disease develops during hot weather and is most destructive when soil temperatures approach 80˚F. Dry weather and low soil moisture encourage this plant disease.

Management of Fusarium wilt

- Avoid using old seed with low vigor.
- Purchase clean seed grown in areas where no wilt occurs.
- If wilt is found, rotate to non-susceptible crops for three years.
- Destroy the crop after harvest.
- Maintaining pH at an upper range (6.8-7.0) may decrease disease severity.
- Deep plowing to bury root debris has been shown to reduce the disease in some studies. Avoid wet soils.
- Crop rotation to grass green manures, cereal crops, pasture, or grass hay crops may reduce soil infestation, increase soil organic matter, and improve soil structure to reduce disease. However, to avoid problems with seed corn maggot, do not incorporate organic matter immediately before planting. Plant seeds shallowly in warm, moist (but not wet) soils to speed germination.
- The addition of organic matter such as cover crop green manure (single and mixed species), seed meals, dried plant material, good quality compost, organic waste, and peats can be very effective in controlling diseases caused by pathogens such as *Fusarium* spp. (Klein *et al*., 2011), *Pythium* spp. (McKellar and Nelson, 2003; Veeken *et al.,* 2005), *Rhizoctonia solani* (Diab *et al*., 2003) and *Sclerotinia* spp. (Lumsden *et al*., 1983). Organic matter improves soil structure and its ability to hold water and nutrients; it also supports microorganisms that contribute to biological control.
- Solarization during the hot summer months can increase soil temperature to levels that kill many important soilborne fungal and bacterial plant pathogens, including *Verticillium dahlia*, certain *Fusarium* spp., *Sclerotinia* spp., *Agrobacterium tumefaciens*, *Streptomyces scabies*, nematodes, and weeds. (Stapelton, 2012).

- Anaerobic soil disinfestation works by creating anaerobic soil conditions by incorporating easily decomposable organic materials (wheat bran, molasses, rice straw, and rice bran, etc.,) into soil that is irrigated and subsequently covered with plastic film effective against a wide range of soil borne pathogens, including *Fusarium oxysporum* f. sp. *lycopersici*, *Verticillium dahliae* and *Ralstonia solanacearum* as well as the nematodes *Meloidogyne* spp. and *Pratylenchus* spp. (Shinmura, 2004)

Damping off and seed rot disease

A soil-borne fungal disease that affects seeds and new seedlings, damping off usually refer to the rotting of stems and root tissues at and below the soil surface. In most cases, infected plants will germinate and come up fine, but within a few days they become water-soaked and mushy, fall over at the base and die.

Several fungi can cause decay of seeds and seedlings including species of *Rhizoctonia*, *Fusarium* and *Phytophthora*. However, species of the soil fungus *Pythium* are most often the culprit. Damping off typically occurs when old seed is planted in cold, wet soil and is further increased by poor soil drainage. High humidity levels, rich potting soils and planting too deeply will also encourage its growth. Fungal spores live in the soil and are primarily a problem in seed beds. They can be transported on garden tools and in garden soils taken into the house or greenhouse.

Management of Damping off and seed rot

- Application of Hydrogen peroxide as a pre-plant dip treatment for control of damping-off, root rot, and stem rot diseases at a 1:100 dilution
- Foliar application of Hydrogen peroxide is applied as a 1:100 to 1:300 dilutions for control of fungal and bacterial pathogens. Test a few plants for sensitivity before spraying an entire field.
- Other measure same as fusarial disease management practices.

Disease caused by Plant Pathogenic Bacteria

Bacteria are microscopic, single-celled prokaryotic organisms, without a defined nucleus, that reproduce asexually by binary fission (one cell splitting into two). They occur singly or in colonies of cells. Plant pathogenic bacteria cause many different kinds of symptoms that include galls and overgrowths, wilts, leaf spots, specks and blights, soft rots, as well as scabs and cankers. The taxonomy of plant pathogenic bacteria is currently in flux based on recent advances on how bacteria are classified. Most plant pathogenic bacteria belong to the following genera: *Erwinia* spp.*, Pectobacterium* spp., *Pantoea* spp., *Agrobacterium* spp*., Pseudomonas* spp*., Ralstonia* spp., *Burkholderia* spp., *Acidovorax* spp., *Xanthomonas* spp., *Clavibacter* spp., *Streptomyces* spp., *Xylella* spp., *Spiroplasma* spp., and *Phytoplasma.* Bacteria that cause plant diseases are spread in many ways—they can be splashed about by rain or carried by the wind, birds or insects. People can unwittingly spread bacterial diseases by, for instance, pruning infected orchard trees during the rainy season. Water facilitates the entrance of bacteria carried on pruning tools into the pruning cuts. Propagation with bacteria-infected plant material is a major way pathogenic bacteria are moved over great distances. No matter how the bacterial pathogens are disseminated, they require a wound or natural opening, such as stomata, to get inside a plant host. Once inside they then kill host cells, by the means described above, so that they can grow. Between hosts they may grow harmlessly on plant surfaces and then can overwinter or survive unfavorable environmental periods or the absence of a susceptible host by either going dormant in infected tissue, infested soil or water, or in an insect vector.

Bacterial Disease management

- Resistant varieties, cultivars or hybrids are the most important control procedure.
- Bacteria-free seed or propagation materials.
- Buying seeds produced in dry climates is recommended
- Sanitation, particularly disinfestations of pruning tools.
- Avoid excessive overhead irrigation, especially late in the season.
- Avoid working in the crop when it is wet.
- Pruning of the infected twigs is followed to reduce the inoculums in orchards for citrus canker.
- The destruction of volunteer plants and weed hosts brings down the inoculum level.
- The crop residue may be burnt or ploughed deep into the soil with watering to ensure decomposition which is helpful for the pathogens which cannot live saprophytic ally in the soil.
- The control of insects is helpful in reducing the soft rot of vegetables (*Erwinia* spp.) and the citrus canker (*Xanthomonas campestris* pv. *citri*).
- The avoidance of cultural mismanagement favorable to disease is important such as water logging in the nurseries (against the bacterial leaf blight of rice), flooding or over irrigation in the field. (against the soft rot disease)
- Prolonged exposure to dry air, heat, and sunlight will sometimes kill bacteria in plant material.

- In case of trellising or caging in tomatoes, stakes and cages should be either new or cleaned and disinfected. Sodium hypochlorite at 0.5% is effective and must be followed by rinsing and proper disposal of solution. Hydrogen peroxide is also permitted.
- In case of bacterial wilt in solanaceous crop use a three-year crop rotation away from tomato, brinjal and pepper.
- There is some prospect of biological control with the application of organic matter in the form of compost and green manure and even inoculation of antibiotic micro paganism, encouraging antagonism by the application of superphosphate, application of phages in seed plant and soil, as well as by inoculating with bacteriocin- producing strains.
- Crop rotation to reduce over-wintering.
- The use of antagonistic or biological control products may also be effective for managing bacterial diseases of plants.
- Foliar sprays with Bordeaux mixture and copper oxychloride against leaf spots and blights.
- Spray copper oxychloride @ 3g/liter of water for checking further spread of the disease.

Viral disease and their management

The plant virus particles consist of infectious nucleic acid referred to as genome, which is encapsidated within a protective coat. The genome which carries the genetic information is made up of either DNA or RNA. The DNA and RNA may be single stranded or double stranded. Plant viruses are minute, non-cellular pathogens that multiply within the cells of their hosts. This is usually to the detriment of the host and results in the development of disease symptoms.

Plant viruses require a wound for their initial entrance into a plant cell. Wounds in plants can occur naturally, such as in the branching of lateral roots. They may also be the result of agronomic or horticultural practices, or other mechanical means; fungal, nematode, or parasitic plant infections; or by insects. In some cases, the organism creating the wound can also carry and transmit the virus. Organisms that transmit pathogens are called *vectors*. Mechanical and insect vector transmissions are the two most important means by which plant viruses spread. The activity of humans in propagating plants by budding and grafting or by cuttings is one of the chief ways viral diseases spread. In fact, plant virologists use grafting and budding procedures to transmit and detect viruses in their studies. The seedling offspring of a virus-infected plant is usually but not always free of the virus, depending on the plant species and the kind of virus. Insect transmission is perhaps the most important means of virus transmission in the field. Insects in the order Homoptera, such as aphids, planthoppers, leafhoppers, whiteflies and mealy bugs—that have piercing sucking mouthparts—are the most common and economically important vectors of plant viruses. Some plant viruses can also be transmitted in pollen grains or by seed.

Management of Viral Disease in crop plants

No single method is likely to provide perfect control. Nevertheless, by using a combination of the following management options disease control can be successfully implemented.

Exclusion/avoidance

- Plant virus-free seed and seedling transplants
- Grow crops in regions where the disease seldom occurs or during periods when the virus or its vector are at a low level
- Quarantine (international, state and regional).

Reduction in virus inoculum levels

- Control weeds and other virus hosts and insect vectors
- Destroy old crops promptly
- Separate new crops from maturing crops and avoid overlapping crops, especially continuous year-round cropping.

Protection of the host

- Plant virus-resistant or virus-tolerant varieties
- Use highly reflective mulches and oil sprays to deter insects
- Use barrier crops and bare land to reduce vector activity
- There are no chemical sprays or biological control approaches to eradicate viruses, although biocontrol products can be used to control insect vectors.

Some of the common fungicide used in organic agriculture for management of diseases

Group of fungicide	Application method	Disease control
1.Sulphur Fungicide	Sulphur is mostly used against plant diseases like powdery mildew, downy mildew and other diseases. The key to its efficacy is that it prevents spore germination. For this reason, it must be applied prior to disease development for effective results. Sulphur can be applied as a dust or in liquid form. It is not compatible with other pesticides.	Powdery mildew of fruit, vegetable, flower and other crops. It is also effective against rust and other foliar diseases.
a.Sulphur Dust	Sulphur dust is available in the market in the form of dust and applied with the help of rotator duster. Dust particle are deposited on plant surface and provide protection against many foliar diseases.	
b.Wettable sulphur	Wettable sulphur is a fixed formulation of sulphur which is a least phytotoxic and available in the market as a wettable form and applied @ 0.25%.	
c.Lime-sulphur	Lime-sulphur is formed when lime is added to sulphur to help it penetrate plant tissue. It is more effective than elemental sulphur at lower concentrations. However, the odour of rotten eggs usually discourages its use over extensive fields. It can be prepared by boiling of 0.4kg of rock lime and 0.3kg of sulphur in 10 liters of water in an open pan for one hour and allow to settle for several hours. The clear supernatant is filtered and is called as lime sulphur or calcium polysulphide and applied in the field @ 0.25%.	
2.**Copper fungicide**	Copper fungicide has been successfully used for over 150 years, on fruits, vegetables and ornamental plants. Copper fungicide has both fungicidal and bactericidal properties.	Mainly used for seed treatment, foliar application against blight, downy mildew and rust. It is also effective against bacteria and many foliar plant pathogenic fungi(*Altenaria, Cercospora*, *Colletotrichum*, *Curvularia*, *Helminthusporium*, *Pestalotia* & *Phytophthora*)
a.Cuprous oxide formulation	Cuprous oxide is a fixed formulation of copper which is a least phytotoxic and protective fungicide. In the market it is available as Funfimar, Perenox, Copper Sandoz, Copper 4% dust or Cuproxd.	
b.Copper oxychloride formulation	Copper oxychloride is protective fungicide. It is commercially available as Blitox, Cupramar 50% WPFytolan, Bilmix 4%, Blue copper 50, Cobox, Cuprax etc.	
c.Copper sulphate	**Bordeaux mixture:** It can be prepared by mixing of 90 g of copper sulphate in 4.5 L of water in plastic bucket. In another bucket mix 125 grams of hydrated lime with 4.5 litres of water. Stir both the mixture separately with wooden stick. Then copper sulphate solution is slowly added to lime solution with constant stirring or alternatively both the solutions may be poured simultaneously to a third container and mixed well (Fibl, 2011; IFOAM, 2003 & IFOAM, 2003)	It is effective against *Phytophthora*, downy mildew, damping off, leaf spot and rust diseases.
	Bordeaux paste: It is prepared by mixing of 1 Kg of copper sulphate and 1 kg of hydrated lime in 10 litres of water.	It works as a wound dressing fungicide. It applied as a pent after pruning in tree crops.
3.Potassium bicarbonate	Potassium bicarbonate is a safe, effective fungicide. *Mix 3 tbs potassium bicarbonate, 3 tbs vegetable oil and half teaspoon soap into a gallon of water for foliar application.*	Powdery mildew, downy mildew and other leaf spot diseases.
4.**Baking soda**	Baking soda changes the pH of the fungus and kills it. *Mix 1 tbs of baking soda and 1/2 tsp liquid hand soap with four liter of water.* Spray solution on affected leaves, and dispose of any remaining solution. Spray only once and leave as long gaps as possible (several months). Do not use during hot weather and test the mixture on a few leaves because of possible phytotoxic effects.	Powdery mildew, downy mildew and other leaf spot diseases
5. **Crude oil**	Crude oil mixture is prepared by mixing of 62 ml crude oil and 6.2 g soap in 1 liter of water.	Foliar Fungi

6.**Hydrogen peroxide**	Hydrogen peroxide is a good protective and eradicative fungicide. It is used as seedling deep @5ml/liter and foliar application @4ml/liter for management of fungal and bacterial disease.	It can be used as seed treatment and also effective against *Phytophthora*, *Pythium* and fungal and bacterial leaf spot diseases
7.**Acidic clays**	Acidic clays have a fungicidal effect due to aluminium oxide or aluminium sulphate as active agents. They are used as an alternative to copper products but, are often less efficient.	Active against foliar fungi
8. **Sea Water**	Sea Water is one source of good fungicide and insect repellant as well as providing the plant with added trace mineral elements. However it may need dilution with fresh water to reduce its toxicity to plants especially those with thin leaves and sensitive tissues.	Active against foliar fungi

Application of botanicals and other preparation for management of Plant Diseases in organic agriculture

Organic/Botanical product	Application method	Disease control
1. **Milk**	Milk solution is prepared by mixing of 1 L of milk to 10 to 15 L of water and spray every ten days interval for effective control measure	Blights, mildew, mosaic viruses and other fungal and viral diseases.
2. **Cow urine** –	Cow urine diluted with water in ratio of 1: 20 and used as foliar spray is not only effective in the management of pathogens & insects, but also acts as effective growth promoter for the crop.	Active against foliar fungi and plant pathogenic bacteria.
3.Vinegar	Vinegar is very acidic. When sprayed on powdery mildew it changes the fungi's pH, effectively killing it. *Mix 4 tbs of vinegar with four liter of water. Reapply every three days.*	Powdery mildew and other fungal diseases.
4.Garlic (*Allium sativum*) Cloves	Chop garlic clove finely, soak in two teaspoon of oil for one day. Mix with half litter of soapy water and filter. Mix one part solution with 20 parts water, then spray.	*Alternaria*, *Cercospora*, *Colletotrichum*, *Curvularia*, *Diplodia*, *Fusarium*, *Helmitosporium*, and *Pestalotia* (fruit rot, early blight, purple blotch, leaf spot, leaf mold, frog eye, anthracnose, fruit rot, smudge, leaf blight, and fruit and stem rot, damping off, stem and root rot, wilt, and curly top.)
5.Cassia Leaves	Chop and grind the cassia leave with the help of little water and filter the extract by pressing in muslin cloth. Extracted juice used as 1-cup juice per liter of water for foliar application.	*Altenaria, Cercospora, Colletetrichum, Diplodia, Fusarium, Helminthusporium and Pestalotia.*
6.Amaranths (*Amaranthus gracilis*)	Extract juice from one-kilogram of amaranths leaves and mix in three litters of water for foliar spray (Rivera, 2004).	*Altenaria, Cercospora, Colletotrichum, Curvularia, Helminthusporium, and Pestalotia*
7.Papaya (*Carica papaya*)	Take one Kg of fresh papaya leave and extract the juice and applied as two to five table spoon full juice per liter of water for foliar application.	*Cercospora and Diplodia.*
8.Sensitive Plant (*Mimosa pudica*) Whole plant	Take 450g of sensitive Plant and soak in water and use infusion as spray against foliar fungi.	*Diplodia* and *Pestalotia* (fruit and leaf spot.)
9.Warmwood (*Artemisia absinthium*) leaves	Extract juice and use as spray at the rate of two to five table spoon of juice per liter of water for foliar application.	*Altenaria*, fruit rot, early blight, purple blotch and leaf spot.
10.Ginger (*Zingiber officianale*) rhizome	Extract juice and use as 10% concentration for foliar spray.	*Cercospora* leaf mold, leaf spot, early blight and frogeye disease.

11.Gliricida (*Gliricida sepium*) Leaves	Extract juice of one kilo leaves and then mix juice with three litters of water and use as a foliar spray.	*Cercospora* leaf mold, leaf spot, early leaf blight and frogeye disease.
12.Rred Onion (*Allium sepa*) Bulb	Chop finely and soak in two teaspoon of oil for one day. Mix with half litter of soapy water and filter. Mix one part of the solution to 20 parts of water for foliar application.	*Cercospo*ra (leaf mold, leaf spot, early blight, frogeye disease); *Colletotrichum* (leaf spot, anthracnose, fruit rot); *Curvularia*, *Fusarium* (leaf spot, leaf blight); *Helminthusporium* (leaf spot, leaf blight); *Pestalotia* (wilt, curly top, leaf blight and leaf spot).
13.Drumstick (*Moringa oleifera*) Leaves	Extract juice from one kilo leaves and mix with three litters of water and use as foliar spray.	*Altenaria* spp., *Colletotrichum* spp., Diplodia spp. and *Pestalotia* spp.
14.Jatropha (*Jatropha multipida*) Leaves	Extract juice from one kilogram leaves and mix in three litters of water and use as spray against	*Diplodia* spp. (fruit and stem rot) and *Fusarium* spp. (damping off, stem and root rot, early blight, wilt and curly top).

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Microbial resources for pest and disease management and plant growth promotion in organic farming approaches

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The current global population of 7.0 billion is expected to reach 7.5 billion by 2020 and 9.2 billion by 2050. This ever-expanding human population has virtually compelled us to keep pace with the increasing global demand for food. The UN/FAO forecasted that global food production has to be increased by over 40 per cent by 2030 and 70 per cent by 2050. In order to meet the contemplated goal, it is paramount to produce more food from lesser land, using less water, energy and other inputs and keeping in harmony with the fragile environment. Despite the achievement of great improvement in food production by using chemicals, the use of alternatives has become an inevitable option in managing the pest and diseases and for better plant growth promotion to avoids the ill effects of chemical residues. Isolation, characterization and utilization of useful microbes derived from diverse natural environments is a promising method for organic management of pest and diseases and better plant growth and development. The utilization of microbes in organic agriculture is broadly classified into following three categories

I. Microbes as biocontrol agents for plant disease management	II. Microbes as biofertilizers for plant growth promotion	III. Microbes as biocontrol agents for pest management
• *Trichoderma* spp • *Bacillus* spp • *Pseudomonas* spp • *Chetomium* spp	• *Rhizobium spp* • *Azotobacter spp* • *Azospirillum spp* • *Bacillus spp* • *AM Fungi*	• *B. thuringiensis* • *Polyhedro viruses* • White halo fungus • White muscardine fungus • Green muscardine fungus

Microbes for biological control of plant diseases

In terms of plant disease management, biological control is the reduction of inoculum density or disease producing activity of pathogen or parasite in its active or dormant stage, by one or more microorganism accomplished naturally or through manipulation of the environment, host or antagonist or mass introduction of one or more antagonists.

The term applies to the use of microbial antagonists to suppress diseases as well as the use of host specific pathogens to control weed populations. In both fields, the organism that suppresses the pest or pathogen is referred to as the biological control agent (BCA). Several organisms such as fungi, bacteria, viruses, predatory nematodes, insects, mites and some invertebrates have been used as bio-control agents against a wide range of pathogenic organisms.

Advantages of biological agents

- Bio friendly organisms and bio products help to maintain ecological balance
- Identification of indigenous / native isolates of bioagents would be less expensive compared to chemicals
- Problems of resurgence of pathogens/insects can be minimized
- Help to achieve pollution free environment
- Reduces residues and health hazards
- Once established, they remain effective over long periods especially for perennial crops

Limitations in the use of bioagents

- Non-identification of native isolates
- Non adaptability and establishment of the introduced bioagents in the given locality
- Specificity of bioagents to certain species of insects/pathogens
- Variation in the performance due to interaction with other micro flora, fauna, pathogens and insects
- Non compatibility with chemical management practices.

Mechanisms of biological control

Biological control can result from many different types of interactions between organisms. Researchers have focused on characterizing the mechanisms operating in different experimental situations. In all cases, pathogens are antagonized by the presence and activities of other organisms that they encounter. Different mechanisms of antagonism occur across a spectrum are given below.

- *Plant Growth Promotion*: Production of growth promoting substances *viz*., auxin,cytokinins, by the bio-control agents will improves the plant growth

- *Competition:* Bio-control agents will make the non-availability of nutrients for the growth of pathogenic microorganisms by exudates/leachates consumption and physical niche occupation. In general, for all soilborne pathogens
- ~~such as species of competition from other soil- and plant-associated microbes.~~
- *Fusarium* and *Pythium*, which infect through mycelial contact, are more susceptible to
- *Siderophore production:* Siderophore is an iron chelating agent which makes iron unavailable for the growth of pathogen leading to starvation of pathogen.
- *Antibiosis:* Production of antibacterial and antifungal antibiotics by the bio-controlagents limits the growth and multiplication of fungal as well as bacterial plant pathogenic microorganisms. Examples of antibiotics are 2,4-diacetylphloroglucinol, Phenazines and Cyclic lipopeptides. Examples- *Trichodermin, Dermadin, Surfactin, Zwittermycin, DAPG, Phenazine*
- *Lytic Enzymes:* Enzymes like chitinase, gluconase are produced by bio-control agents which are involved in the degradation of the cell wall of the pathogen that leads to the death of the pathogen. Example, chitinases, glucanases
and proteases are effective in degrading the cell wall of the various pathogens.
- *Induced systemic resistance:* Bio-control agents enhance the defense capacity ofthe plant against the broad spectrum of pest and diseases. Colonization of plant roots by *Trichoderma* sp. has been shown to induce plant defence responses, mobilizing compounds that make plants more resistant to pathogens.

Methods of application of biological agents

The different means of application of bio-control agents are:

- *Soil application:* The application of antagonists directly to the soil will reduce the multiplication of pathogens thereby reduces the soil borne diseases. Apply the commercial product @ 2.5 kg / ha.
- Procedure for soil application of *Trichoderma* commercial formulation in field:
- Mix 2.5 kg of formulation along with 50 kg of moist FYM (Farm yard manure)/ha under shade.
- Cover FYM with any plastic for 3 days to allow the growth and multiplication of *Trichoderma* in FYM.On 7th day, mix well and apply the FYM enriched with bio-control agent in field.
- *2. Seed treatment* - Mix 10g of*Trichoderma*or any commercial formulation perlitre of cow dung slurry for treatment of 1kg of seed before sowing (cereals, pulses and oilseeds). The treated seeds should be shade dried before sowing.
- *3. Nursery treatment:* Drench nursery beds with @ 5g formulation per litre ofwater before sowing.
- *4. Cutting and seedling root dipping:* Mix 10g of formulation per litre of water (2.5 kg/ha seedlings) and dip the cuttings and seedlings. The seedlings, after pulling out from the nursery can be treated with water containing the formulation. A minimum period of 30 minutes is necessary for soaking the roots and prolonged soaking will enhance the efficacy.
- *5.Foliar application* - Spray the product at 0.2% (2g in 1 L of water) concentrationcommencing from 45 days after transplanting at 10 days interval for 3 times depending on disease intensity. The recommended product for single spray is 1 kg per ha. If there is no disease incidence, a single spray is sufficient. Spray solution can be applied by sprayer or other watering systems (drip system) after filtering with filters

Types of bio-control agents employed commonly in Agriculture

A variety of biological controls are available for use, but further development and effective adoption will require a greater understanding of the complex interactions among plants and the environment.

A. Trichoderma viride

Trichoderma is a very effective biological control agent for plant disease management especially the soil borne diseases. It is a

free-living fungus which is common in soil and root eco-systems. It is highly interactive in root, soil and foliar environments.

It reduces the growth, survival or infections caused by pathogens by different mechanisms like competition, antibiosis, mycoparasitism, hyphal interactions, and enzyme secretion.

Recommendation

- Soil application-@ 2.5 kg/ha along with 50 kg of FYM (farm yard manure)
- Seed treatment-@ 10 g/kg of seeds
- Nursery treatment-@ 10 - 25 g/100 m^2
- Cutting and seedling root dip: dipping in 10g in 1 lit for 10 min.
- Plant Treatment: Drench the soil near stem region with 10g in 1lit of water
- The seed treatment delivers the inoculums to the growing seedlings where it colonizes the spermosphere and also the developing root system, protecting crop plants from damping-off diseases.

B. Pseudomonas fluorescens

Pseudomonas fluorescens suppress plant diseases by production of number ofsecondary metabolites including antibiotics, siderophores and hydrogen cyanide. This microbe has the unique ability to enter the plant vascular system, reach the various parts of the plant system and act as a systemic bio-control agent against various fungal and bacterial diseases. It also acts as plant growth promoter.

Recommendation

- Soil application- @ 2.5 kg /ha along with 50 kg of FYM
- Seed treatment-@ 10 g/kg of seeds
- Seedling dip- @ 2.5 kg /ha seedlings
- Foliar application- @ 0.2% to control foliar diseases
- Sucker treatment: 10g /sucker

C. Bacillus subtilis

Bacillus subtilis spore forming bacteria which, when applied to the seeds or plants, it colonize the developing root system of the plants. The bacteria compete with and thereby suppress plant disease fungal organisms such as *Rhizoctonia*, *Fusarium*, *Aspergillus*, and others. *Bacillus subtilis* continue to live on the root system and provide protection throughout the growing season. Therefore, even if treated seeds are stored for prolonged periods, the bacteria stay alive, and then grow and multiply after the seeds are planted.

Recommendation

- Soil application: 5 kg /ha along with any organic fertilizer
- Seed treatment: 10 g/kg of seeds
- Seedling treatment: 100 g/L prior to planting

Microbes as biofertilizers for plant growth promotion

Biofertilizers are one of the important components of the organic farming in vegetable crops. They are cheap, eco-friendly and sustainable and improve growth and quality of crops. They are the carrier based containing efficient living organisms which, when applied to seed, plant surfaces, or soil, colonize the rhizosphere and promote growth by increasing the supply or availability of primary nutrients to the plant. This includes nitrogen fixers, phosphorus solubilizers and mobilizers stimulating plant growth through the synthesis of growth-promoting substances. Biofertilizers are having the high potential in the nutrient management in maintaining the nutrient status of the soil. Among the vegetable crops, solanaceous crops are having the highest demand and it includes potato, tomato, brinjal, capsicum and chilli. They are rich in vitamins and minerals. For solanaceous crops, the biofertilizers like *Azotobacter*, *Azospirillum* and Phosphate solubilizers are commonly required.

Types of bio fertilizers used in organic agriculture

Following are free living and associative nitrogen fixers and phosphorous solubilizers mainly used for vegetable crops.

Azotobacter

It is the important and well known free living nitrogen fixing aerobic bacterium fixes about 20 to 25 kg atmospheric nitrogen/ha. It is primarily found in neutral to alkaline soils and in aquatic environments. It is used as a biofertilizer for all non-leguminous plants especially wheat, paddy, bajra, jowar, maize, mustard, cotton, cumin, banana, sugarcane, tobacco, castor, vegetables *etc*., as well as horticultural crops. It also produces certain growth substances good for the growth of plants and antibodies that suppress many root pathogens. The bacterium produces abundant slime which helps in soil aggregation. Azotobacter has been found to produce some antifungal substances which inhibit the growth of some soil borne and foliar pathogens like *Aspergillus, Curvularia, Alternaria, Helminthosporium, Fusarium etc*.

Certain growth promoting substances released by these cultures are useful for increasing the seed germination, plant growth and ultimately the yield. In certain conditions they also exhibit anti-fungal activities and thereby fungal diseases may be controlled indirectly. About 10 to 15% increase of crop yield can be achieved with the use of these cultures.

Azospirillum

This is also a nitrogen fixing microorganism beneficial for non-leguminous plants. It is useful for the cereals and cash crops *viz.* wheat, paddy, bajra, jowar, maize, mustard, cotton, banana, sugarcane, tobacco, vegetables, and horticultural crops *etc.* They perform the associative symbiotic relation with the graminaceous plants. It belongs to bacteria and is known to fix the considerable quantity of nitrogen in the range of 20-40 kg N/ha in the rhizosphere in non-leguminous plants such as cereals, millets, oilseeds, cotton etc. *Azospirillum* cultures synthesize considerable amount of biologically active substances like vitamins, nicotinic acid, indole acetic acids, and gibberellins which will increase the crop growth. Besides nitrogen fixation, they will increase the disease resistance and drought tolerance. Growth promoting substances released by these cultures are useful for increasing the seed germination, plant growth and ultimately the yield. In certain condition, antifungal activities exhibited by this culture indirectly controls fungal diseases. Crop yield upto 10 to 15% is increased with the use of this culture.

Phosphorus solubilizing bacteria – Bacillus spp

Phosphorus, both native in soil and applied in inorganic fertilizers becomes mostly unavailable to crops because of its low levels of mobility and solubility and its tendency to become fixed in soil. Phosphorous solubilizing microorganisms have inherent capacity to dissolve part of the fixed phosphorus and make it available to the crop by secreting certain organic acids. The PSB are life forms that can help in improving phosphate uptake of plants in different ways. They can solubilize the insoluble phosphate when applied to crops and can increase the yield by 10-30%. It produce enzymes which mineralise organic phosphorous to a soluble form and anti-fungal activities and thereby fungal diseases may be controlled indirectly. Phosphobacteria can be mixed with *Azospirillum* and *Rhizobium* in equal quantities. PSB cultureare useful for all the crops *i.e*. cereals, cash crops, leguminous crops, horticultural crops, vegetables, etc.

AM Fungi

The transfer of nutrients mainly phosphorus and also zinc and sulphur from the soil ~~*milleu*~~ to the cells of the root cortex is mediated by intracellular obligate fungal endosymbionts of the genera *Glomus, Gigaspora, Acaulospora, Sclerocysts* and *Endogone* which possess vesicles for storage of nutrients and arbuscles for funneling these nutrients into the root system. By far, the commonest genus appears to be *Glomus*, which has several species distributed in soil.

Availability for pure cultures of AM (Arbuscular Mycorrhiza) fungi is an impediment in large scale production despite the fact that beneficial effects of AM fungal inoculation to plants have been repeatedly shown under experimental conditions in the laboratory especially in conjunction with other nitrogen fixers.

Rhizobium

This belongs to bacterial group and the classical example is symbiotic nitrogen fixation. The bacteria infect the legume root and form root nodules within which they reduce molecular nitrogen to ammonia which is reality utilized by the plant to produce valuable proteins, vitamins and other nitrogen containing compounds. The site of symbiosis is within the root nodules. It has been estimated that 40-250 kg N / ha / year is fixed by different legume crops by the microbial activities of Rhizobium. The percentage of nodules occupied, nodules dry weight, plant dry weight and the grain yield per plant the multistrain inoculant was highly promising for the higher N fixation rates.

Methods of application of Biofertilizers

Seed treatment

One packet of the inoculant is mixed with 200 ml of rice kanji to make a slurry. The seeds required for an acre are mixed in the slurry so as to have a uniform coating of the inoculant over the seeds and then shade dried for 30 minutes. The shade dried seeds should be sown within 24 hours. One packet of the inoculant (200 g) is sufficient to treat 10 kg of seeds.

Seedling root dip

This method is used for transplanted crops. Two packets of the inoculant is mixed in 40 litres of water. The root portion of the seedlings required for an acre is dipped in the mixture for 5 to 10 minutes and then transplanted.

Main field application

Four packets of the inoculant is mixed with 20 kgs of dried and powdered farm yard manure and then broadcasted in one acre of main field just before transplanting.

Benefits of Bio-fertilizers in organic farming

- Bio-fertilizers are supplement to chemical fertilizers.
- Bio-fertilizers are cheap and can reduce the cost of cultivation.
- Fix biological nitrogen in the soil, which is readily available to the plant.
- Increase crop yield by 10% on an average.
- Improve soil properties, sustain soil fertility and health.
- Provides plant nutrient at low cost and useful for the consecutive crops.

Microbes as biopesticides for pest management.

Bio pesticides or Biological Pesticides are certain types of pesticides derived from animals, plants, bacteria and certain minerals. In other words, bio pesticides include several types of pest management intervention through predatory, parasitic or chemical relationships.

Microbial pesticides consist of microorganism (e.g., a bacterium, fungus, virus or protozoan) and sometimes include the metabolites that bacteria or fungi produce as the active ingredient. Microbial pesticides can control many kinds of pests, although each separate active ingredient is relatively specific for its target pest.

Many microbes including bacteria, viruses and fungi could be effectively utilized for successful management of economically important pests. Mainly the soil borne bacterial species *Bacillus thuringiensis* is well utilized in the management of lepidopteran pests. the few important microbial resources for organic pest management are enlisted below.

S. No.	Microbial agent	Target insect
Bacteria		
	B. thuringiensis subsp. *kurstaki*	Lepidopteran pests
	B. thuringiensis subsp. *israelensis*	Lepidopteran pests
	B. subtilis	Soil-borne pathogens
Virus		
	Ha Nuclear polyhedral virus	Gram pod borer, *Helicoverpa* armigera
	Sl Nuclear polyhedral virus	Tobacco caterpillar, *Spodoptera litura*
	Granulosis virus	Coconut rhinoceros beetle, *Oryctes rhinoceros*
	Amsacta Nuclear polyhedral virus	Red hairy caterpillar, *Amsacta albistriga*
Entomopathogenic Fungi		
	Green muscardine fungus, *Metarhizium anisopliae*	Coconut rhinoceros beetle, *O. rhinoceros*
	White muscardine fungus, *Beaveria bassiana*	Lepidopteran larvae, Coffee berry borer, thrips, grasshoppers, whiteflies and aphids
	White halo fungus, *Verticillium lecanii*	Coffee green scale, *Coccus viridis*
	Paecilomyces fumosoroseus and *P. lilacinus*	Whitefly
Entomopathogenic nematodes		
	Heterorhabditis sp.	Lepidopteran larvae
	Verticillium chlamydosporium	Plant parasitic nematodes

Water Management in Organic Agriculture : Key Issues

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Natural resource management without causing ecological imbalance is an important parameter for ensuring sustainable agriculture. On the other hand, owing to huge demand for food grains to feed the ever growing population, we have adopted the capital and resource intensive agricultural technologies putting tremendous pressure on natural resources like land and water which led to environmental and soil pollution. Hence, there is a need to strike a balance between the jump in food grain production and ecological safety. This holds more relevance as we have to ensure food security of the nation in the backdrop of climate change (Brahmanand *et al.,* 2013). In this context, sustainable agriculture has to be given higher emphasis as it aims at feeding the present generation without compromising the needs of future generation.

Sustainable resource management in agriculture is a gradual and long term practice that efficiently utilizes the natural resources and it involves several components. Organic agriculture or farming is one of its major components which needs to practiced on large scale throughout the world. It emphasizes on an efficient recycling of locally available natural resources for optimizing the crop productivity in long run. It stresses on maintaining soil fertility and sustainable utilization of water resources. In other words, efficient soil and water conservation measures would be given higher importance in organic farming. It discourages the use of chemical fertilizers as they pollute the soil and environment. Most importantly, the excessive use of chemical fertilizers may lead to ground water pollution and its associated human disorders. Once the polluted groundwater is utilized for irrigation, the crops get affected by uptake of heavy metals. The excess nitrogenous fertilizers may result in a phenomenon called eutrophication. This is very dangerous for crop production and agriculture.

Organic farming also prioritizes the use of optimum quality of irrigation water to maintain the quality of economic produce so that the human health is protected. This necessitates us to follow the water quality standards. The organic form of nutrients can be supplied to plants through most efficient irrigation methods such as drip irrigation. Moreover, the nutrient and water interactions play critical role in deciding the level of productivity and quality of final economic crop produce which is also affected by organic farming quite differently compared to inorganic fertilizer application.

Under this background, we need to focus on all the components of sustainable practices of water management to ensure food security of India without degrading the soil and environmental base. Let us discuss the best or standard water management practices that go in hand with the organic farming (Fig.1).

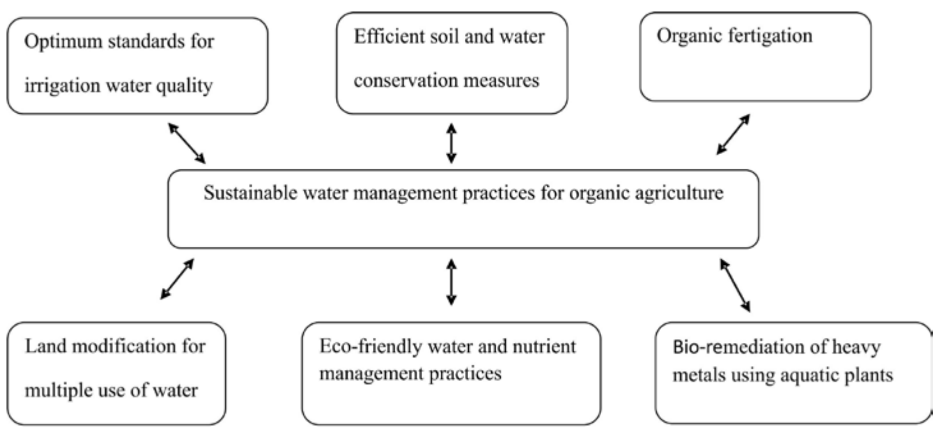

Fig.1 : Components of sustainable water management practices for organic agriculture

Optimum standards for irrigation water quality

Irrigation water generally carries some quantity of salts along with it as it is not considered to be pure in nature. Irrigation water is usually drawn from surface or ground water sources, which typically contain salts in the range of 200 to 2000 ppm. Hence, each irrigation event adds salts to the soil. Use of such saline water may affect the crop growth and may lead to soil degradation. Similarly, other quality parameters of irrigation water also have to be taken into consideration while practicing organic agriculture.

Total soluble salts

The salinity of water is the concentration of total soluble salts in it. It is very important single criterion of irrigation water quality. The concentration of soluble salts in water is indirectly measured by its electrical conductivity (ECw). The quality of saline waters has been categorized into five classes as per USDA classification given in Table 1.

Table 1. Salinity classes of irrigation water

Salinity class	Micro mhos/cm	Milli mhos/cm
C1-Low	< 250	< 0.25
C2-Medium	– 750	0.25 – 0.75
C3-Medium to high	– 2250	0.75 – 2.25
C4-High	2250 – 5000	2.25 – 5.00
C5-Very high	> 5000	> 5.00

Sodium Adsorption Ratio (SAR)

SAR of irrigation water indicates the relative proportion of sodium to other cations. It is estimated as follows:

$$SAR = \frac{Na^+}{\sqrt{\dfrac{Ca^{++} + Mg^{++}}{2}}}$$

The increase in SAR of water increases the exchangeable sodium percentage (ESP) of soil.

$$ESP = \frac{100\ (0.23+0.0042\ SAR}{1 + (0.23+0.0042\ SAR)}$$

As per USSSL, the sodicity classes of water are shown in Table 2.

Table 2. Sodicity classes of water

Sodium class	SAR value
S1-Low	< 10
S2-Moderate	10 – 18
S3-High	18 – 26
S4-Very high	> 26

Residual sodium carbonate

Bicarbonate is significant in its relation to Ca and Mg. Calcium generally reacts with bicarbonates and precipitate as calcium carbonate. As Ca and Mg are lost from water, the proportion of sodium is increased leading to sodium hazard. RSC is estimated as follows:

RSC (meq/lit) = $(CO_3^{--} + HCO_3^{--})-(Ca^{+} + Mg^{+})$

RSC is expressed in meq per litre. Water with RSC more than 2.5 meq/L is not suitable for irrigation. Water with 1.25 to 2.5 meq/L is marginally suitable and water with less than 1.25 meq/L is safe for use.

Boron content

The excess dose of Boron affects the crop growth and for normal crop growth the safe limits of boron content are given in Table 3.

Table 3. Permissible limits of boron content in irrigation for crops

Boron (ppm)	Quality rating
< 3	Normal
3 – 4	Low
4 – 5	Medium
5 – 10	High
More than 10	Very high

Ameliorating ways to reduce the effect of poor quality irrigation water

The efforts must be paid to ensure that the crops are not subjected to salinity during their critical growth stages like germination. Optimum method of irrigation is important to reduce the negative effect of saline irrigation water. Poor quality irrigation water is not suitable for use in sprinkler method of irrigation. Crops sprinkled with waters having excess quantities of specific ions such as Na and Cl cause leaf burn. High frequency irrigation in small amounts as in drip irrigation is desirable as it improves water availability and uptake t in the wetted zone. Similarly, provision of adequate internal drainage is necessary to avoid build of salt in the soil solution to levels that will limit crop yields. Some of the practices like cultivation of over aged seedlings of rice with 45 days duration or 60 days duration proved to be beneficial in providing better resilience to the crops in resisting the saline environment.

Efficient soil and water conservation measures

Organic agriculture stresses on conservation and utilization of soil and water on sustainable basis and hence it encourages the agronomic practices that aid in obstructing rain drops thereby reducing the splash effect. It also helps in improving infiltration rate and in reducing the runoff losses by the use of contour cultivation, mulches, dense-growing crops, strip-cropping and mixed cropping (Saini, 1996). Let us briefly discuss on the following practices.

Contour cultivation

Contour cultivation refers to a method of cultivation of crops on the level across or perpendicular to the slope. This will facilitate tillage and planting operations on the contour. The cultural practices such as ploughing, sowing and intercultivation are done across the slope resulting in reduced soil and water loss (Reddy and Reddy, 2010). Contour farming is effective on gentle slopes and it should be integrated with engineering measures in regions with higher slopes. Organic ginger cultivation in Kandhamal and Koraput districts of Odisha is an example under this practice.

Strip cropping

It refers to a combination of contouring and crop rotation in which alternate strips of clean crops /erosion permitting crops and soil conserving crops / erosion resisting crops are grown either at right angles to the direction of the prevailing wind, or following the natural contours of the terrain to prevent soil erosion. The width of the erosion permitting and erosion resisting crops vary as per the slope of the field. The normal ratio between the erosion resisting crops and erosion permitting crops is 1: 3.

Conservation tillage

The moisture conservation practices like mulching and zero tillage would be instrumental in saving considerable amount of moisture in organic agriculture. Conservation tillage, if adopted as an agricultural best management practice (BMP) would play significant role in reducing soil erosion and positively influence surface hydrologic properties, which in turn result in reduced runoff and increased infiltration (Jalota *et al.,* 2006 and Singh *et al.,* 2009). This is highly suitable to organic agriculture. The positive effect of no tillage on soil moisture conservation compare to conventional tillage was also revealed by a study conducted by Van Wie *et al.* (2013) in USA.

Compartmental bunds

The total field is divided into small compartments with pre defined size under this practice with an objective of retaining the rain water where it falls and thereby arresting soil erosion. They can be used in deep black soils receiving low to medium rainfall. The bund former is used to form compartmental bunds. The size of compartments generally varies from 6mx6m to 10mx10m. These compartments increase infiltration rate and increase water and nutrient availability and hence suits well in organic farming.

Dead furrow and shallow trenching

The dead furrow and shallow trenching are the field management practices for conservation of both soil and water in watersheds and suits well in organic agriculture. Dead furrow is an open trench which is left in between two adjacent strips of land after finishing the plough (Kumar *et al.,* 2011). The size of dead furrows may be about 20 cm wide and 15 cm deep and they may be placed across the slope at 3-5 m intervals. Shallow trenching is another effective practice for soil and water conservation which are designed along the contour. Shallow trenches are used for sloping lands as well as on degraded lands for soil and water conservation.

ICAR-flexi rubber dam

To give more flexibility in release and control of water flow across the streams and for efficient soil and water conservation, research efforts were made at ICAR-Indian institute of Water Management, Bhubaneswar in collaboration with Indian Rubber manufacturing Research Association (IRMRA), Thaneand ICAR-CIRCOT, Mumbai to fabricate rubber sheets instead of cement material. As a result, five rubber dams were initially installed at different locations of Khurda district, Odisha with innovative manufacturing, fabrication and installation technology. This is the first indigenous rubber dam in our country. Now this is being upscaled to 25 more locations in different agro-climatic zones of India. The rubber dam height can be raised up to 1.5 m by filling water through inlet pipe (inflation mechanism) and it can be lowered to base level by releasing the water through outlet pipe (deflation mechanism).The main advantages of this rubber dam are in the form of better erosion control and flood control during excess water flow and suits well in organic farming. It also provides cushion as a reservoir for storing water during scanty rainfall period so that supplemental irrigation can be provided to the crops. This technology has a potential to benefit farmers in rain fed agro-ecologies which constitute about 52% of the net sown area. The average productivity of rice in *kharif* season at Baghamari enhanced from 2.87 t/ha to 4.67 t/ha. The average productivity of green gram in *rabi* season at Baghamari enhanced from 0.63 t/ha to 0.92 t/ha and the productivity of sunflower and cucumber in *rabi* season is 0.84 t/ha and 4.3 t/ha, respectively. The increase in cropping intensity at Baghamari is 31% due to cultivation of green gram, sunflower and cucumber. The productivity of summer vegetables like pumpkin, ridge gourd, brinjal and cowpea at Chandeswar enhanced by 35%, 47%, 40% and 27% due to assured water supply from installed rubber dams.

Plate1: Rubber dam with adjacent paddy fields at Chandeswar, Odisha

Land modification of multiple use of water

The land has to be modified in such a manner that the natural resources can be most efficiently utilized for enhancing water productivity. Let us discuss about three successful examples of land modification which have practical application in organic agriculture.

Raised and sunken bed technology

In medium and lowlands under high rainfall region, land modification such as raised and sunken bed technique would be highly effective in utilization of the available water, higher crop productivity, cropping intensity and economic net returns. The raised sunken bed technique was developed by ICAR-Indian Institute of Water Management, Bhubaneswar for lowlands of Khurdha district where farmers could grow vegetable crops on raised bed and rice or other aquatic crops like colocasia in sunken portion. The land is converted into alternate sunken and raised beds (1:1) each of 30 m length and 5 m width. Fish spawn can also be raised up to fingerling stage in the sunken beds together with rice. The adoption of the technology increased kharif paddy and pointed guard yield from 4.2 t/ha to 5.2 t/ha and 4.24 t/ha to 4.74 t/ha respectively in addition to fish yield of 1 t/ha. The water stored in sunken beds can be used for providing supplemental irrigation to rabi crops such as pointed gourd and snake gourd. Raised and sunken bed system facilitated conservation of available water resources and crop diversification resulting in higher economic net returns to the farmers (Rs. 60,000/- per hectare). This is a good practice for organic farming as it conserves the soil and water by reducing the runoff and encouraging the infiltration. The dimensions of the raised and sunken bed may be modified as per the topography, soil type and land ecosystem.

Sub surface water harvesting structure (SSWHS)

Sub surface water harvesting structure (SSWHS) developed by ICAR-Indian Institute of Water Management, Bhubaneswar is highly useful for coastal waterlogged areas where fresh water floats above the saline water below ground could be tapped (Sahoo *et al.,* 2004) (Plate 1). The depth of structure should be restricted with in sandy zone below ground up to 5 meter. SSWHS can be created in 0.1 ha with 4 m depth which will create a structure of 4000m^3 and on an average, it has the potential to enhance the water productivity to Rs. 36/m^3 by involving pisciulture and *rabi* vegetables. The participatory approach of implementing SSWHS facilitates more crop per drop and it improves the financial status of the several poor farmers living below poverty line in coastal waterlogged areas and also gives better employment opportunity. This has been well adopted by the farmers in super cyclone affected areas of Erasama block, Jagatsinghpur district, Odisha.

Plate 2 : Sub surface water harvesting structure at Erasam block, Odisha

Integrated rice-fish farming with in-field refuge system

In rainfed lowland rice areas spread in high rainfall regions, water starts accumulating in the field with onset of monsoon season and water depth rises up to 60 cm or more and continues till maturity of the crop (Jahn *et al.,* 2001 and Biswas *et al.,* 1986). For augmenting water productivity of lowlands under such a situation, rearing fish along with rice can be an option (Brahmanand *et al.,* 2009; Brahmanand and Mohanty, 1999; Frei *et al.,* 2007; Mohanty et al., 2004). There is an ample scope for increasing productivity of low lands by introducing fish in rice ecosystem with both out-field and in-field refuge systems. In tropical Asia, rice fields are usually fertilized with two major sources of fertilizer i.e. inorganic and organic. Inorganic fertilizer is widely used for the nutrition of the rice crop is very much prone to losses of N leading to poor nutrient use efficiency. If used in rice-fish system, inorganic fertilizer may depress fish growth due to increasing level of NH_3 concentration in water. On the other hand, organic manure, a conventional source of fertilizer, is considered to be suitable for stable growth and yield of rice. Apart from supplying nutrients, it may act as a substrate for the growth and development of fish food organisms. Therefore, it is imperative to develop efficient nutrient management practice for rice and fish dual culture system with in-field refuge system by considering both organic and inorganic sources under intermediate deep water situation. A field experiment conducted in Khurdha district of Odihsa revealed that rice-fish farming system recorded significant increase in grain yield over sole rice farming. Organic source of fertilizer treatments recorded higher yield of fish than inorganic fertilizer source or control. maximum fish yield of 528 kg ha^{-1} was harvested in integrated nutrient management treatment i.e. O_{75} I_{25} treatment where 75% N was supplied through organic source and 25% N through inorganic source. Two stage rain water conservation technique where out field refuge of 10% of the main field area is used for fish cultivation also suits well for organic farming under rainfed medium lands.

Eco-friendly water and nutrient management practices

Eco-friendly nutrient measures like application of leaf extract coated fertilizer materials would provide better resilience to crops under excess stress conditions and hence they should be promoted under organic agriculture. Nutrient loss in general and nitrogen loss in particular is very high in waterlogged rice ecosystem leading to poor nutrient use efficiency. This is mainly due to higher leaching and denitrification and hence we need to concentrate on evolving eco-efficient agricultural practices for enhancing nutrient use efficiency under this ecosystem. Keeping this in consideration, a field investigation was carried out during 2012-2013 at Balisahi village of Pipli block of Puri district of Odisha to study the performance of rice under different nutrient treatments in waterlogged ecosystem. Different methods of fertilizer application such as band placement and broadcasting and different types of nitrogen supplying fertilizers were applied as treatments to test the response of rice crop in terms of growth, yield and nitrogen use efficiency. Superior grain yield (3.8 t/ha) of rice was recorded with shallow submergence (10-25 cm) compared to intermediate level of submergence (25-50 cm) (3.51 t/ha) and band placement of N @ 60 kg/ha resulted in significantly superior grain yield (3.82 t/ha) compared to broadcasting of nitrogen fertilizer (3.49 t/ha) at maturity. Nitrogen @ 60 kg/ha applied through nitrification inhibitors like dicyandiamide has resulted in superior grain yield of rice (4.1 t/ha) compared to other nutrient treatments. However, the urea coated with eco-friendly neem leaf extract and pongamia leaf extract has also given encouraging results (3.82 t/ha) compared to sole urea and control treatments. The nitrogen use efficiency of 23.5 kg grain / kg N applied and 22.3 kg grain / kg N applied was also recorded with N @ 60 kg/ha supplied through urea+dicyandiamide and urea+neem leaf extract and pongamia leaf extract.

The organic fertigation is a practice of supplying nutrients through organic sources in drip irrigation as a result of which the quality of crop produce would be maintained. Similarly, in industrial areas, the polluted industrial effluents can be treated with aquatic weeds like water hyacinth for bio-remediation of heavy metals such as chromium, cadmium and lead.

Conclusion

Water and nutrient interactions play vital role in crop production and they show different dynamics in organic farming compared to inorganic farming. As organic manures are slow in nutrient release pattern, low in concentration of nutrients and have to be applied in bulky quantity, adequate quantity of irrigation with optimum frequency should be ensured by water management practices. Overall, to enhance the land and water productivity to ensure food security, the higher emphasis must be given to all the key components of sustainable water management practices for organic farming such as optimum standards for irrigation water quality, efficient soil and water conservation measures, eco-friendly water and nutrient management practices, land modification for multiple use of water.

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Post harvest handling of organic produce

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It is a fact that organically grown produce have high amount of vitamin and certain nutrients in addition to low level of pesticide residues and heavy metals. However, researchers show no significant flavor difference between organically grown and conventionally grown foods. Instead, taste differences appear to come from the food variety, its growing conditions, and its maturity and harvest time. Unlike the past, most of today's organic foods compare very favourably in appearance with conventionally grown foods. Optimal quality organic produce that combines the desired textural properties, sensory shelf-life and nutritional content is resulted from the careful implementation of recommended production inputs and practices, careful handling at harvest and appropriate post harvest handling and storage. The inherent quality of produce cannot be improved after harvest, only maintained for the expected window of time characteristics of the commodity. Part of successful post harvest handling is knowing what this window of opportunity is under the specific conditions of production, season, method of handling and distance to market. Among the benefits of organic production, it is often more common to harvest and market near or at peak ripeness than in many conventional systems.

Handling of organic foods

The two primary concerns in handling organic fruit are maintaining the identity of organic fruit and preventing contamination with post-harvest chemicals. Organic fruit is identical in appearance to non-organic fruit. Bin tags, labels, scale tickets, and lot control documents must clearly identify the fruit as organic. Handlers of organic fruit must demonstrate that they have procedures in place to maintain the identity and segregation of organic fruit at all times. Organic fruit must be packed only after the dump tanks and lines have been cleaned. Sodium hypochlorite not to exceed 0.2% may be used in dump tanks. Biodegradable soaps may also be used in the dump tank and detergents are not allowed. Naturally derived citric and acetic acid may be used to remove calcium deposits. Waxes are generally not used, though natural waxes are allowed on organic fruit. Irradiation, diphenylamine (DPA), thiabendazadole (TBZ), and ethoxyquin are not allowed.

Table 1. Handling of organic vs conventional crops

S no	Parameters	Organic crops	Conventional crops
1	Cleaning agents	Quaternary ammonia products are not allowed because they leave a residual sanitizer	No restriction
2	Detergent	Biodegradable soaps only	No restriction
3	Waxes	Only natural waxes should be used (carnauba wax or wood rosin).	Allowed
4	Ingredients	Minerals (including trace elements), vitamins and similar isolated ingredients are prohibited	Allowed
5	Irradiation	Prohibited	Allowed
6	Storage	SO_2 cannot be used to prevent browning and for CA storage, DPA treated foods are not allowed.	No restriction
7	Wrapping	Non-treated tissue wrap (Bio-Save10™ and Bio-Save 11™ etc	No restriction but should be product specific
8	Packaging	Paper, wax paper, paper coated with PE ,Polystyrene cold boxes with PE coating film or inside bag, Glass other methods (clip seals)	All kind of packaging allowed as per product specificity
9	Solvent for extraction	Water, ethanol, plant and animal oils, vinegar, carbon dioxide, nitrogen or carboxylic acids of food grade quality.	Any solvents are allowed
10	Filtration	Asbestos are not allowed	All filtration
11	Microemulsions	morpholine and triethanolamine are prohibited	Allowed
12	Preparations of Micro-organisms	Genetically modified microorganisms are excluded, Bakers yeast without bleaches and organic solvents	No restriction
13	Marketing	Should be marketed near farm gate at peak ripeness	Distant market also allowed

All harvested fruits and vegetables should be placed as soon as possible in a storage area that is kept at the appropriate temperature. However, organic products need to be stored and transported with proper identification and physically separated from non-organic products. Handlers of organic food must provide adequate separation of organic food products from non-organic food products to ensure that no commingling or misidentification occurs. Materials and chemicals used within the handler's facility must not contaminate the organic food products.

A thorough understanding of materials and ingredients used in organic processing is necessary to interpret the national list (Table1). For example, even though substances such as carnauba wax or wood rosin are allowed, they actually cannot be applied to a fruit as such unless they are formulated into microemulsions. Microemulsions used for the waxes applied to fruits are made with a fatty acid such as oleic, linoleic, palmitic, myristic, lauric acid and a basic counterion such as the hydroxides of ammonium, sodium or potassium, morpholine, or in the past, triethanolamine (Baldwin, 1994). But, morpholine and triethanolamine, while added to steam to prevent pipe corrosion, are strictly prohibited for use in an organic process if the steam is in direct contact with the organic food. Antifoams such as polydimethylsiloxane or silicon dioxide may be added, but they are not absolutely necessary to make a wax emulsion. For instance, a carnauba wax coating is most likely to also contain a fatty acid (10% to 20% of solids), ammonia or morpholine (3% to 10% of solids), and possibly an antifoam (Hagenmaier and Baker, 1997). Manufacturers who desire to sell their products for use in organic food or organic production systems should have their formulations and processes verified by the Organic Materials Review Institute (OMRI). The verification process is strictly confidential, suppliers can have their products guaranteed acceptable for use in organic production, and users may use such products with confidence that organic integrity will not be compromised.'

As with conventional systems, surfaces used for fresh or processed product preparation should be kept clean. However, the cleaning agents can differ between organic and conventional systems. For instance, quaternary ammonia products are not allowed in organic systems on food contact surfaces because they leave a residual sanitizer (Narciso and Pl[illegible]2006). Make sure all practices are documented as per standard sanitation operating procedure. Organic foods can also be processed by drying; with the use of approved processing aids such as: ascorbic acid, citric acid, tartaric acid and salt; blanching with high temperatures to destroy micro-organisms; pasteurizing to destroy micro-organisms that could contaminate the product after blanching; and with heat treatments that conserve products by destroying or inactivating enzymes and killing micro-organisms. Organic pest management, cleaning and sanitation operations should not compromise food safety at any level (Montecalvo, 2004). In addition handler may use substances to prevent pests as required by federal, state, local laws and regulations, provided that adequate measures are taken to prevent contact of the organic product or ingredient with the substance used.

Juice is an ideal product for the organic market. It offers a simple and natural way to process fresh produce, preserves the majority of vitamins and minerals, and largely resolves the problem of storage. Canned produce must be prepared in a way that retains, as closely as possible, the characteristics of fresh produce. Other forms of processing include conservation with sugar which is principally used for fruit jams and purees, and by fermentation which is a chemical change caused by enzymes, bacteria or micro-organisms. There are very few approved organic post-harvest treatments for pests and diseases. Hot-water (45-55°C) immersion, steam and forced hot-air treatments are sometimes used as organic control methods after harvest. Although some root, tuber and bulb crops require a curing period at ambient or elevated temperature to promote wound healing and ensure optimum storage life, there are no specific requirements for curing, storing or transporting organic produce.

Sanitation and water disinfection

For organic handlers, the nature and prior use of water is a special consideration. Postharvest water cannot, at any time, contain prohibited substances dissolved in water. This responsibility applies to the organic producer, handler, processor or retailer. Even incidental contamination from a prohibited material would render product non-certified. Organic producers, packers and handlers are required to keep accurate and specific records of postharvest wash or rinse treatments, identified by brand name and source. Adequate sanitation and disinfection during postharvest processes are vital components of a postharvest management plan. As food safety regulations become increasingly important to the sales and marketing of crops, the establishment of proper measures to ensure the elimination of food-borne pathogens is essential. In addition to mitigating potential food-borne illness, proper sanitation during postharvest handling can also minimize the occurrence of postharvest disease and decay. In sanitation, the following chemicals are used.

Chlorine

Chlorine is a very common disinfectant that can be added to transport flumes or to produce cooling or wash water. Liquid sodium hypochlorite is typically used, with the pH of the water maintained between 6.5 and 7.5 to optimize effectiveness (Suslow, 1998). The National Organic Programme approves chlorine's use (calcium hypochlorite, chlorine dioxide, and sodium hypochlorite) in postharvest management as an algicide, disinfectant, and sanitizer. These regulations restrict the residual chlorine levels in the water at the discharge or effluent point to the maximum residual disinfectant limit under the Safe Drinking Water Act (SWDA), currently established by the Environmental Protection Agency (EPA) at 4 mg/L (ppm) for chlorine. However, the levels of chlorine used to prepare water to be used for sanitation of tools, equipment, product, or food contact surfaces may be higher than 4 mg/L and should be in high enough concentration to control microbial contaminants. Thus, the concentration of chlorine at the beginning of a disinfection treatment is generally greater than 4 mg/L; however, care must be taken to ensure that the effluent water does not exceed this limit.

Ozone

Ozone is becoming an increasingly popular alternative to chlorine for water disinfection. Ozone, through its action as an oxidizer, provides comparable disinfection power to chlorine, rapidly attacks bacterial cell walls and thick-walled spores of plant pathogens. Ozone treatments have the benefit of forming fewer undesirable by-products than chlorine treatments, such as trihalomethane, chloroform, and other dangerous compounds. The use of ozone does require a greater capital investment and ongoing operating costs than the use of chlorine, however. Because of the instability of the compound (20 min in clean water), ozone must be generated on-site, requiring investment in ozone-generating equipment. These generators create ozone through the action of a high energy source (UV light or corona discharge), splitting oxygen molecules that then recombine to form ozone. Small-scale ozone generating units are available for a few thousand dollars.

Peroxyacetic acid

Peroxyacetic acid (PAA, also called peracetic acid on the NOP National List), in combination with hydrogen peroxide, is another popular alternative to chlorine that is allowed in organic production. Like chlorine, PAA performs well in water dump tanks and water flumes. To maximize effectiveness, PAA should be maintained at a level of 80 ppm in the wash water. A post-treatment wash with potable water may be recommended after a disinfection treatment with PAA. Though not a requirement of the National Organic Standards themselves, all allowed inputs must follow label use instructions when used in organic production. Therefore, if the PAA label recommends a fresh water rinse after use, then this rinse should be done.

Other Allowed Cleaners and Sanitizers (Suslow, 2000)

Acetic acid: Allowed as a cleanser or sanitizer. Vinegar used as an ingredient must be from an organic source. **Alcohol, Ethyl:** Allowed as a disinfectant. To be used as an ingredient, the alcohol must be from an organic source. **Alcohol, Isopropyl.** May be used as a disinfectant under restricted conditions.**Ammonium sanitizers**. Quaternary ammonium salts are a general example in this category. Quaternary ammonium may be used on non-food contact surfaces. It may not be used in direct contact with organic foods. Its use is prohibited on food contact surfaces, except for specific equipment where alternative sanitizers significantly increase equipment corrosion. Detergent cleaning and rinsing procedures, often combined with product purges prior to organic production, must follow quaternary ammonium application. Monitoring must show no detectable residue prior to the start of organic processing or packaging (example: fresh cut salads). **Bleach.** Calcium hypochlorite, sodium hypochlorite and chlorine dioxide are allowed as a sanitizer for water and food contact surfaces. Product (fresh produce) wash water treated with chlorine compounds as a disinfectant cannot exceed 4ppm (mg/L) residual chlorine measured downstream of product contact. **Detergents:** Allowed as equipment cleaners. Also includes surfactants and wetting agents. All products must be evaluated on a case-by-case basis. **Hydrogen peroxide:** Allowed as a water and surface disinfectant. **Carbon dioxide:** Permitted for postharvest use in modified and controlled atmosphere storage and packaging. For crops that tolerate treatment with elevated CO_2 (≥15%), suppression of decay and control of insect pests can be achieved. **Wax:** Must not contain any prohibited synthetic substances. Acceptable sources include carnuba or wood resin waxes.

Ethylene

Ethylene treatments may be applied for degreening or acceleration ripening events in fruits harvest at mature but unripe development stages. In organic handling, ethylene gas produced by catalytic generators is prohibited, except for bananas. As the majority of ethylene- responsive organic produce is harvested at a fully ripe stage, this restriction is not currently a significant barrier. In contrast to its role in ripening, ethylene from plant sources or environmental sources ex. Combustion of propane in lift trucks can be very damaging to sensitive commodities. In brief, ethylene producers should not be stored with fruits or vegetables that are sensitive to it.

In addition to providing adequate venting or fresh air exchange, ethylene adsorption or conversion systems are available to prevent damaging levels as low as 0.1 ppm for some items in storage and during transportation. Potassium permanganate ($KMnO_4$) air filtration systems or absorbers are allowed for post harvest handling provided that strict separation from product contact is assured. Other air filtration systems for ethylene removal based on glass-rods treated with a titanium dioxide catalyst and ultraviolet light inactivation are available for cold rooms. Ultraviolet light/ ozone based systems of ethylene elimination are also commercially available. Temperature management also plays a key role in limiting water loss in storage and transit.

As the primary means of lowering respiration rates of fruits and vegetables, temperature has an important relationship to relative humidity and thus directly affects the rate of water loss. Relative humidity of the ambient air conditions in relation the relative humidity of the crop directly influences the rate of water loss from produce at any point in the marketing chain. Water loss may result in wilting, shriveling, softening, browning, stem separation or other defects.

Comparisons of post harvest quality between organic and conventional crops

Candir et al., (2013) compared postharvest quality of conventionally and organically grown 'Washington Navel' oranges and reported higher TSS/TA ratio at harvest and during storage as well as better taste in organic orange compared to inorganic one. Duarte et al. (2012) reported that ascorbic acid concentration in the juice was generally higher in citrus fruits produced in the organic orchards, but the response depended on species and cultivar. Of the six types of fruits (lemons, oranges apples green kiwi, and mangoes) analyzed by Esch et al. (2010), only one lemon demonstrated a significantly higher vitamin C concentration for organically grown field.

Despite the relevance of the issue, few comparative studies have focused on such postharvest issues. Differences during cold storage in incidence of physiological disorders, soluble solids content, firmness, and mineral content have been reported (DeEll et al., 1993; Weibel, et al., 2004). After ethylene treatment, organic banana showed faster peel color changes, and lower gravimetric water balance and pulp/peel ratio, and impedance in comparison to conventionally-grown banana (Nyanjage et al., 2001). During simulated marketing conditions, organoleptic characteristics and resistance to deterioration were higher for organic strawberries in comparison to the conventional fruit (Cayuela et al., 1997). Hasey et al. (1997) reported higher soluble solids content and firmness in organically-grown kiwifruit compared with conventionally-grown kiwifruit. In contrast, Benge et al. (2000) reported that conventional kiwifruit showed higher soluble solids content and similar softening behavior and decay than organic ones, analyzed at the same firmness stage. The levels of calcium in kiwifruit were negatively correlated with the incidence of soft patches. Moreover, higher levels of Ca as well as of NO_3, Mg, Fe, and Zn were observed at harvest and during 25 days of cold storage at 10^{o}C for conventional "Meyer" lemons in comparison with fruits from an organic orchard (Uckoo et al., 2015).

The Post-harvest handling stage

Significant differences exist between organic and conventional agriculture in the options for post-harvest handling and sanitization methods. Decontamination of food by using irradiation, chemical washes, a variety of antimicrobial agents or other synthetic disinfectants is prohibited in organic farming, while other practices, such as the use of chlorinated water and pasteurization are optional. The adoption of sanitization methods varies substantially among organic farmers (Magleby et al., 1998). It is likely not all organic farmers use post-harvest water sanitization methods. When harvesting and packing in the field, the harvest bin and any container or tool should be kept clean and should be sanitized prior to use. After harvest, produce are sorted by hand or machines depending on the farm. Some produce types are washed on the farm. Chlorine (tap water), ozone, and peroxyacetic acid (PAA) are most common ways for washing organic produce. Chlorine (chlorinated in tap water) may be used, within specified limits, 5ppm, in the forms of liquid sodium hypochlorite (bleach), granular calcium chloride within specified limits. PAA is a substance allowed to come in contact directly with produce according to NOS and therefore a good option for small and medium size organic farms. It has good efficacy in water dump tank and flume water sanitation applications in removing and controlling microbial biofilms in tanks and flumes although it is restricted to large bulk units. Storage is a very important stage after washing since temperature is the single most important tool for maintaining produce quality after harvest. The common ways include room cooling, forced-air cooling, hydrocooling, top or liquid icing and vacuum cooling. Clean packaging bags are required to prevent contamination before sale (OEFFA Organic Certification Fact Sheet). Farm managers should establish a protocol for cleaning and disinfecting harvest equipment, cleaning/processing facilities, and transportation. Organic producers, packers, and handlers are required to keep records of postharvest wash or rinse treatments, identified by brand name and source (Suslow et al., 2010).

Several studies have reported that organic produce stores better and has longer shelf life than conventional produce. This, of course, positively affects taste. Better storability appears to be linked to the lower level of nitrate that is usually found in organic produce. Lower nitrate levels have been linked in many studies to better taste. But this comes with a caveat; lower nitrogen also usually means lower crop yield. The Organic Center is sponsoring ongoing research designed to better understand the impact of high levels of fertilization, and high crop yields, on the flavor and nutritional quality of food. Evidence suggests that high yields in some crops can dilute the concentration of vitamins and antioxidants in plants, changes that can reduce nutritional quality and diminish flavor. This is why winemakers look for grapes from vines that have dealt with a certain level of stress during the growing season. Grape vines managed for maximum yields produce more grapes per acre, but lower quality, less flavourful wines.

Organic processing in Andaman

The agricultural sector is predominantly based on plantation and spice based homestead farming systems owing to favourable humid tropical climate (330 cm annual rainfall and 68-85 % mean relative humidity) where spices are grown as intercropping in the coconut and areca nut plantation. Of the 45000 ha cultivated land, plantation crops and spices cover around 61.7 and 3.03% of total cropped area contributing about 54.8 and 2.52% of total horticultural production. The post harvest technology followed for spice is still the traditional labour intensive practices and dried in open sun on floors smeared with cow dung or on bamboo mats. The drying time required varies from 32-45 hours. Quality analyses of these samples revealed that in terms of physical quality, they do not qualify the specified standards. Spreading on unclean surfaces such as soils and also without any supervision is the common method prevailing for drying. The lack of quality consciousness and poor handling of the commodity during post harvest period is the primary factor for quality deterioration. Systematic and effective post harvest processing such as cleaning, washing, drying, packaging and storage of spices and plantation crops is beyond the eye catch of the progressive farmers. Traditional "machan" drying system is inefficient and tedious with respect to profitability. In this connection, CIARI has been developed solar dryer for drying of produce which is the clean and ecofriendly source of energy as per its strategic sub-tropical region of getting intense solar radiation.

The variation of temperature and solar radiation (Fig. 1) indicates light intensity ranging from 186 to 1192 w/m^2 with the temperature anomaly of 10^{0}C. This radiation maybe harnessed using solar dryer for drying the produces. It is the clean form of energy which is ecofriendly and are widely used by developing countries to reduce their energy budget. The use of solar dryers in the drying of agricultural products can significantly reduce or eliminate product wastage, food poisoning and at the sometime enhance farmer's revenue.

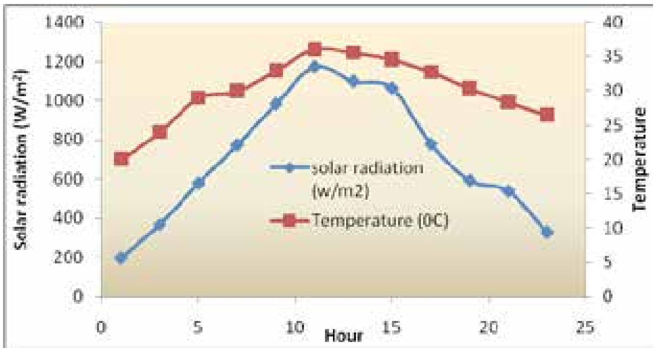

Fig. 1. Variation of temperature and radiation at CIARI campus

Fig. 2. Solar dryer (Garacharma farm)

Solar drying process

Sun drying is called air drying or solar air drying. In the drying process air circulation inside the dryer plays an important role. So the efficiency of the solar dryer is highly dependent on the air circulation across the absorber plate inside the dryer. The products being dried inside the dryer may receive energy direct or indirect. With the receipt of solar energy, the temperature arises that in turn increase the rate of evaporation of the moisture from its surface. Drying rate plays important role in calculation of efficiency of the solar dryer. And some other parameter also affect on the efficiency of the solar dryer like- atmospheric temperature, humidity of the atmosphere, movement of the air inside the dryer.

Solar dryer technology

Solar dryer consists of collector panel (2 no's), solar photo-voltaic cell (*for providing power to the blower*), blower (*for aiding hot air from collector panel to the drying chamber*) and drying chamber (Fig. 2) where vertical stacks of adjustable trays are placed to dry the produce. There is provision of fan to maintain uniform temperature inside the drying chamber. At CIARI, the maximum temperature inside the solar dryer reached up to 65^{o}C compared to outside air temperature of 34^{o}C. The minimum temperature was recorded to be 44^{0}C on partially cloudy day. Studies have indicated that CIARI designed solar dryer takes only 11 hours for cinnamon, 18 hours for black pepper and 26 hours for drying of clove to reduce the initial moisture content of 56-62% to safe moisture content of 4-7 % (w.b). In comparison to sun drying, solar drying on an average saves 30% of total drying time (Fig. 3) with better quality spices. Similarly, for the drying coconut, it took about 32 hours for the production of quality copra.

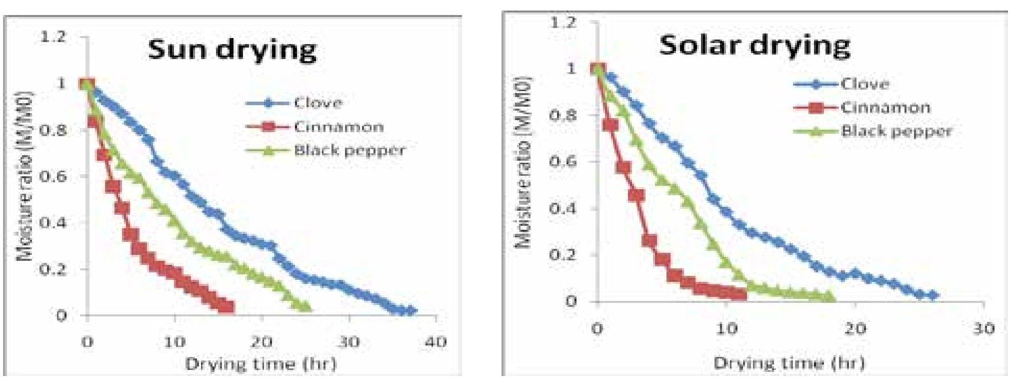

Fig. 3. Drying curve for sun drying and solar drying

So, the successful establishment of solar drying system could certainly help in enhancement of revenue generation to the progressive farmers/farm women/rural youths who are using open yard for drying of spices.

Post harvest handling considerations for important organic products are described below.

Coconut

The nuts ripen during the entire year. As a rule, a harvest is carried out every 1-2 months, when the ripened coconuts are harvested directly from the tree – farmers should not wait until the nuts fall from the tree. The nuts are fully ripened when the coconut water can be clearly heard sloshing against the inside when they are shaken. An average harvest yields around 40-80 nuts per palm and year.

Virgin coconut oil is the oil extracted from the coconut without the application of heat. The main difference between regular and virgin coconut oil lies in their processes of extraction. While the former is extracted by cold compression or cold milling of Copra (another name for dried Coconut kernels) with a moisture content of around six percent, the latter is extracted from the coconut milk obtained from fresh coconuts. Thereafter, using processes such as fermentation, churning (centrifugal separation), refrigeration, and the action of enzymes, the oil is separated from the water or moisture. In some cases, this fresh coconut oil is boiled to obtain the oil by evaporating the water or moisture. Virgin coconut oil extracted by the cold compression method is considered better than that extracted by the fermentation method since the oil extracted by fermentation has higher moisture content and goes rancid quicker.

Banana

Conventionally, the fruit is washed with disinfectant (Na- Bisulfite, Na-Hypochlorite) and/or treated in a fungicide bath. The use of fungicides is out of the question on organic plantations. Either alum salt (potassium alum) or extracts from lemons or orange pips (kernels) can be used to disinfect. So called crown rot (*Colletotrichum musae*) can be prevented by wetting the cut with vinegar. The cleansing water that collects at preparation sites contains many organic compounds, and must therefore be biologically treated before allowing it to flow into a drainage ditch. Organic material that collects during preparation (e.g. unusable, damaged fruits) should be composted and returned to the soil. Cooling equipment must then be used to delay the ripening process during shipping. Optimum temperatures are dependent on the variety, and vary between 12-15°C. At too low temperatures, frost damage can occur, such as lack of ripening, production of tannins, discolouring of the skins, inhibition of starch transformation as well as an increased production of ascorbic acid. An additional delay in the ripening process can be achieved by increasing the CO_2 content and reducing the O_2 content of the storage room atmosphere during shipping.

Mango

If the mangoes are to be sold as fresh fruits, they must be treated with warm bath water to remove any dirt or funguses from the peel. It is recommendable to place them in a 55°C water bath for 5 minutes and then let them cool down slowly. For safety reasons, treatment with warm water is recommended and is absolutely necessary in cases of anthracnose infection. The fruits are packed into sturdy cases. The fruits are generally packed in untreated wood wool, free from harmful substances, to prevent them lying too close to one another. The cases must also be well aerated. Mangoes that are not fully ripened and are to be shipped by sea should be stored at a relative humidity of 90% and not under 12°C. Fully ripened mangoes that are to be shipped by sea should be stored at a relative humidity of 90% and at a temperature of 10°C.

Pine apple

The fruits should be harvested at the ideal time, and this time is dependent upon how the pineapples will be marketed. Because of their low sugar-content, pineapples harvested too early are unpopular amongst consumers (pineapples do not ripen afterwards). This requires establishing a closed cycle of cooling facilities and dependable transport/logistic infrastructure. Unripe, hard fruits that are at present not saleable can be stored at 11-13°C and 90-95% relative humidity for up to 3 weeks. Ripe fruits can be stored at 6-7°C and 90-95% relative humidity for up to 2 weeks. However, temperatures under 5°C cause black-brown spots to appear in the pulp.

Vegetables

Organic vegetable production has gained major importance in many countries, because in vegetables pesticide application is much more "visible" and closer to the final consumer than, for example, cereals or any other agricultural product that receives important post-harvest treatments and further processing. This is the reason why organic vegetables in many countries are the first products demanded by the consumers. Producers, processors and traders recognized this opportunity and started programs of fresh and processed organic vegetables. Today, organic vegetables are the most important items in the organic food assortment.

Leafy greens (spinach, Swiss chard, collards, kale, rape, mustard, turnip)

Leafy greens are very perishable, especially prone to wilting, and therefore harvested leaves should be shaded and cooled immediately. Pre-cooling can be carried out using hydro-cooling, liquid icing, package icing, and top-icing. Leafy greens are not chilling sensitive and they should be kept at 0°C with 95 to 98% RH. Harvest of most leafy greens in the cooler part of the day, rapid cooling, and topping with ice can result in 10 to 14 days of storage. Ethylene production of leafy greens is very low, but exposure to ethylene will cause yellowing of the leaves. Retail outlet stands should be refrigerated or use ice. Use misting if the environment is dry. Turnover is helpful in maintaining quality, so use of small display areas and restocking frequently with refrigerated produce is encouraged. Retail mixing of greens in modified atmosphere packaging or clam shells is risky since some greens will degrade more quickly than others, rendering the entire package unacceptable. Plastic films can be used to reduce water loss from the leaves. Controlled atmospheres with 10 to 40 % carbon dioxide and 10% oxygen have been found to be beneficial in retarding yellowing and maintaining quality. Controlled atmosphere storage can increase the storage life, but it is not used commercially.

Conclusions

Organic versus conventional production system inputs can affect changes in the phytochemical and nutrient content of foods, and even change ripening patterns, which can affect harvest operations, marketing qualities, and consumer acceptance. Switching from conventional to organic production requires a philosophical shift and recognition of different production system inputs plus postharvest handling challenges. First, and most obvious, is the replacement of common and readily available manufactured chemical inputs with approved ''natural'' or ''nature-made compounds'' (i.e., organic) for organic production. Many of these organic inputs may require new knowledge for successful implementation or may be less effective than conventional counterparts. So, post harvest handling of organic crops need greater attention ensuring the health benefiting effects. Chemicals used in organic postharvest operations must comply with the National Organic Program (NOP) rules. Although managements are the same for conventional and organic systems, the treatments and methods of production system inputs radically differ. Currently, the greatest unknown and potentially the most challenging topic to research is to determine whether organically produced crops will inherently have reduced postharvest shelf life problems and perhaps better quality compared with conventionally one. Thus, this may require novel approaches to solving possible issues in an organic system.

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THEME III:
ORGANIC LIVESTOCK AND FISH PRODUCTION

Organic Dairy Production

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Definition

Organic dairy production is an important system of farm systematic plan & design and proper managemental practices for milk production and its dairy products in the absence of antibiotics or hormones, pesticides and synthetic fertilizers or synthetic chemicals as a feed or for treatment. Production of organic milk is by rearing the milch cattle in a completely thorough natural environment like the dairy cattle that are reared on the grazing pastures which is free from chemical fertilizers that fulfil with the normal standards of organic farming system. In the organic dairy farming, the dairy cow is provided only natural fodder/grass/feed and insecticide/pesticide sprayed grass & antibiotics/other synthetic feed are completely avoided. Moreover, the milk is directly sent from the udders to the cooling and pasteurization plants by fully automated systems and this confirms no human/hand contacts/touch that might turn to contamination and/or un-hygiene milk.

It is important to understand that the organic farming method is a system/production pattern and have a set of goals, rules and regulations that permit the organic dairy farmers to adjust the requirement for their own particular situations while managing the organic integrity in a suitable and feasible method. Important standards for organic dairy farming certification rules and regulations for the all organic dairy farmers are followed as:

1. Silage, hay and pasture are grown in the absence of synthetic fertilizers and/or pesticides are considered as the Organic crops
2. Non-natural or synthetic feed additives and other supplements such as vitamins, minerals, probiotics are properly screened as well as approved for use in the dairy farm
3. Genetically Modified Organisms (GMO’s) are strictly excluded or forbidden
4. Land used to cultivate the organic crops/fodder/grass/feed should/must be free from all the prohibited materials for minimum of three years before to the 1storganic harvest
5. In calves, synthetic milk replacers are completely prohibited and calves must be grown in 100% organic milk as well as the 100% organic feed need to be fed to the cows as well the calves
6. All the dairy animals must be permitted to the outdoors depending upon the weather and environmental conditions. The dairy animals with age more than six months must have access to grazing pasture especially during growing season
7. Health care products to be used in organic dairy farms as only approved items; antibiotics are strictly not allowed and only used in ill/sick/emergency or as prescribed by the qualified veterinary doctor.
8. Any slaughter by-products, industrial by-products, manure or urea etc. are strictly forbidden as feed in the feed to the organic dairy animals
9. The welfare of dairy animals need to be considered carefully and protocols like tail docking is strictly prohibited and unless otherwise needed for the health status of the animal or prescribed by veterinarian. Other practices like dehorning must be practised so as to reduce the stress to the organic dairy animals and untoward injury to other animals.
10. Organic dairy farmer must preserve sufficient records, data and note books to study and verify his or her compliance with National Organic Standards or any suitable approved standards
11. Each and every organic dairy farm is must be inspected as well as audited each and every year and also any farm can have an unannounced inspection at any time during the organic production

The interest and important in organic agriculture and organic animal husbandry farming system emerges in recent period is mainly due to increasing concerns on the conventional farming paradigm that depending upon the synthetic inputs to increase yields which inturn threats to the health of human as well animal and environment. Intensive farming system by introduction of species of foreign or exotic, land clearing, fragmentation of vegetation, habitat change and erosion of soil has been one of the main causes of deterioration of biodiversity (Bengtsson *et al.,* 2005; Hole *et al.,* 2005) in places like Andaman and Nicobar Islands and North Eastern Regions of India. But on the other side, organic production system focuses on conservation of soil organic matter and biology to form a sustainable and/or dynamic environment or situation to produce the healthy feed & food and also to beneficial for fauna and flora (Fuller *et al.,* 2005; Gabriel *et al.,* 2010). Quality and quantity of natural resource base is reducing especially in the places where intensive farming system is practising for decades and based on the increasing available evidences, there is presence of residues of toxin/chemicals in food chain due to the result of the chemical intensive farming system by various researchers and investigations. At the same time, consumers are increasingly searching or expecting environmentally safe, health conscious foods which are free from chemical residue/

toxin and a have high quality standard of animal welfare and organic production system can ensure the condition (Chander *et al.*, 2011).Therefore the organic agriculture and organic animal husbandry farming system is gaining importance in the Indian farmers. Further, it is also recognised as only possible and feasible alternative as well as interesting option for constant and sustainable agriculture and its allied sectors in developing countries as because the organic farming provides a unique combination of inputs like low external technology& inputs, input/output efficiency and environmental conservation& protection (Augustine *et al.,* 2013). Concept on practice of organic milk production is relatively new as compared to organic agricultural farming. Organic dairy products introduced into the commercial market in the 1990s and established itself as a major organic category whereas in Indian sub-continent, this became visible in later period of the time (Oruganti, 2011). Organic dairy farming defines the animals are growing only on the organic feed and fodder environmental condition (pastures land developed without the use of synthetic fertilizers and/or chemicals/pesticides or anything) and allowed to access the pasture or outside with the restricted application of hormones and antibiotics. It also purposefully avoids including the use of synthetic inputs like feed additives, drugs and genetically engineered breeding materials in the organic farming system. Animal welfare is also of primary importance in the organic dairy farming system and management (Chander and Subbhramaheswari, 2013). Organic milk production system is a system of production which has a set of goal and object based regulations which allow the dairy farmers to arrange and manage their own organic dairy farming integrity without getting anything from outside (Wolde and Tamir, 2016).

Brief History of Organic Dairy Farming

The organic farming movement is commonly agreed to have begun in the 1940s in England with the writings of Sir Albert Howard, who learned about organic practices in India during the periods of 1920s. In the United States, the origin of the organic movement is commonly credited to JI Rodale. The reasons for producing and purchasing of the organic food are individual choice and can be very complex one. However, most of the organic production and purchasing will fall under three different categories such as community, health and environment. Rachel Carson published *Silent Spring* in 1962 and afterwards there has been an increasing concern about the conventional agricultural paradigm that depends upon synthetic inputs to increase or maximize the yields and posses threats to the forest, environment as well as disconnects the farmers, the land and their communities in conventional farming system. Fundamental principles on the organic movement are such as healthy soils which inturn to healthy crops, animals and healthy planet. Organic agriculture and animal husbandry production system targets on building the healthy soil organic matter as well as biological system to create a constant sustainable and dynamic & favourable environment to produce the healthy feed and food. Organic agriculture system is also observed as a suitable way for the sustainability and support to family farms to faceless, ever-expanding mega and corporate farm models. Organic fruits, grains & vegetables and animal husbandry products have long been mainframe of the organic movement and the organic dairy farming is relatively newcomer to the organic system as compared to organic agriculture. The success of organic dairy farm can largely be depends upon the several critical events, including a response to Monsanto's introduction in 1994 of genetically modified or recombinant Bovine Growth Hormone (rBGH). Use of rBGH coupled with increased consumer awareness on genetically modified soybean, corn and other crops cultivated with administration of synthetic pesticides being fed to animals; the supplementation of slaughter by-products in the feed to the ruminants and worried about mad cow disease and the higher or increased use of synthetic medications such as hormones, antibiotics, drugs and steroids have encouraged number of the consumers to search and seek suitable organic dairy products. These consumers have come to rely on the assurances of certified organic dairy as a trusted source of unadulterated dairy products.

At the same time, the organization and marketing efforts of producers and manufacturers of organic foods have established an infrastructure and market presence that makes high-quality organic dairy products available, affordable and desirable in both specialty natural and mass market groceries. Organic dairy products are often observed as gateway products, in that consumers will make their first forays into organic purchasing by buying organic dairy products and eventually increasing their allegiance to organic products as they become increasingly food savvy.

Prospects of organic dairy farming in India: Traditional and integrated farming system in rural India was/is followed since centuries and rising consumer awareness &demand in domestic as well as foreign market for healthy food products, organic farming system could be a blessing for Indian farmers. In India, crop farming sector, the dairy production is not highly intensive as is the case are observed in other developed countries especially in dairying (Wolde and Tamir, 2016). Some of the agro-climatic regions in India are best suited for organic milk production. These areas include, Madhya Pradesh, the rain-fed areas of Rajasthan,Gujarat, Jammu and Kashmir, hilly areas of Himachal Pradesh, Tamil Nadu, Uttaranchal, whole of North-Eastern region and Andaman & Nicobar Islands. There are some areas in the country especially hilly regions and certain tribal communities, where the green revolution technologies have so far not been reached, not accepted and did not adopt the use of agro-chemicals. These regions have been classified as organic zonal areas (Singh, 2007). The North Eastern region and Andaman & Nicobar Islands of India also have higher potential for organicdairy farming due to least utilization of chemical inputs where it is estimated that more than 18 million hectares of such land is available which can be explored for systematic organic production (Ghosh, 2006). The Trans-Gangetic plains region of Haryana, Punjab,Western U.P. and parts of Rajasthan have evidenced the most intensification of crop husbandry by the way of intensive crop rotations and the heavy use of inorganic fertilizers, pesticides and agro-chemicals. However, even in this region and also in other region, where the dairy farming has not been received much intensification as has been the case with advanced countries and therefore, it is amenable for conversion to organic with little exercise. Organic dairy farming has high scope in the country as it is the small holder's low input, crop residue & fodder based production system contributing 70% of total milk production of the country

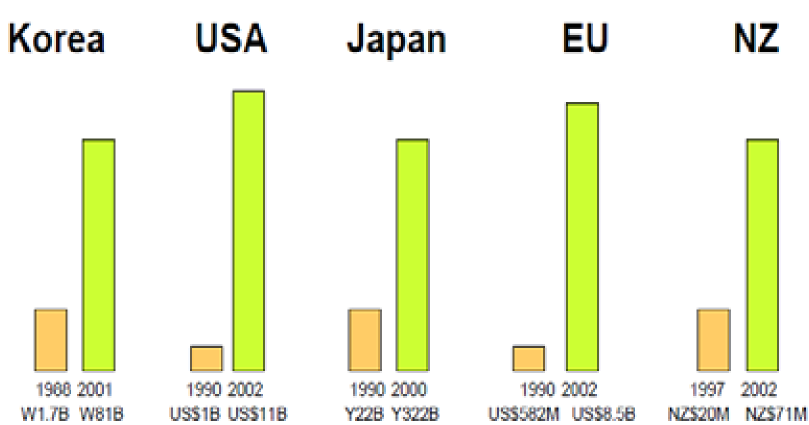
(Kumar *et al*., 2005). Thus these systems are expected to offer a more profitable and sustainable production system based on low input (Hermansen, 2003). But the predominance of small and marginal land holder and landless dairy farmer and labour in this sector is also a source of potential challenge for organic dairy farming especially due to certification difficulties and traceability of the problems. Also these small farmers are producing a few litres of daily milk are not in a position to market it as organic milk due to ignorance and due to unavailability of local market for organic produce and unavailability of premium price. However, the cooperative society or organization can play important roles for promoting of the organic dairy farming in these interior rural places by creating awareness, certification, procurement, processing and marketing of organic milk. But on the other hand, less demand of organic products in domestic market for getting premium price for their products, the farmers definitely need to be depended on export market/foreign market. Animal produces and its by products are still a small share of the organic market as compared to fruits, cereals and herbs and in terms of exports animal products are almost negligible in developing countries like India (Willer and Kilcher, 2011). Therefore the pros and cons are need to be critically analysed the strengths, weaknesses, opportunities and threats (SWOT analysis) related to organic dairy farming system in India in general and Andaman and Nicobar Islands in particular.

Market potential

There has been tremendous growth potential in the number of organic farms around the world in the past two decades. As a result of altered consumer preferences, the organic dairy market growth in developed countries has rejuvenated the agricultural and its allied sectors in developing countries like India also. Around 130 nations produce certified organic products in commercial scales, which consists 30 nations in Africa, 30 in Asia pacific, 20 in Central American countries, 5 in Australia &the pacific and most countries in Europe as well as the United States of America and Canada (ITC, 1999) in worldwide. The total market of organic food as well as beverages in the year 2001 was about USD 21B and is also expected to be increased to USD 80B by the year 2008 with an annual growth rate of 20% (ITC, 2002). The latest estimates suggest that there should be at present more than 0.15×10^6 organic farms worldwide, covering a total surface of 26.3×10^6hectares (Willer and Yussefi, 2004).

- In internationally, the market share of organic produce at present is about 2% of world food markets with the growth rate of 20 to 30% per annum
- The world organic sale in current position is about US$28B.Similarly the world organic dairy market was estimated at US$15B in 2014 and is also expected to increase to US$ 26Bby 2019 with a growing trend at a CAGR of 11.7%.

- Moving to forward, the focus of consumers on the consumption of organic food and beverages increasing and that will compel manufacturers to initiate or launch innovative and exotic organic dairy products efficiently.



- In the recent last few years, some of the innovative organic milk products like organic yogurt along with granola &fruit toppings, Greek yogurt as well as the organic milk containing high quantities of antioxidants and essential healthy fatty acids like DHA as well as omega 3 have been included and introduced into the commercial markets.
- Profitability of Organic Dairy farming: the table representing the example of performance of organic and non-organic dairy herd in Minnesota and Vermont in 2010.

Particulars	Minnesota		Vermont	
	Organic	**Non-Organic**	**Organic**	**Non-Organic**
Cows per herd	79	137	55	66
Milk Price ($/cwt)	26.19	16.26	30.40	13.30
Production (lbs)	12819	21832	13116	19909
Income ($/cow)	3102	3278	4469	4199
Feed cost ($/cow)	1210	1569	1065	1005
Total cost ($/cow)	2346	3057	3555	3286
Net income ($/cow)	756	212	914	925

Europe and North America accounts for over 90% of the total market

- Europe occupies ~50% of the organic milk market worldwide followed by North America and Asia Pacific countries with 40.7% and 6.3% share, respectively.
- The organic milk products market in Asia Pacific countries was estimated at about US$0.9B in the year 2014 and is also expected to achieve to US$1.7B by the year 2019 with a growing trend at a CAGR of ~12.3%.
- With the increase in disposable incomes as well as more awareness on organic food options in emerging current markets such as China, South Korea and India, the consumers are increasingly demanding very high-quality as well as nutrient-rich dairy products.

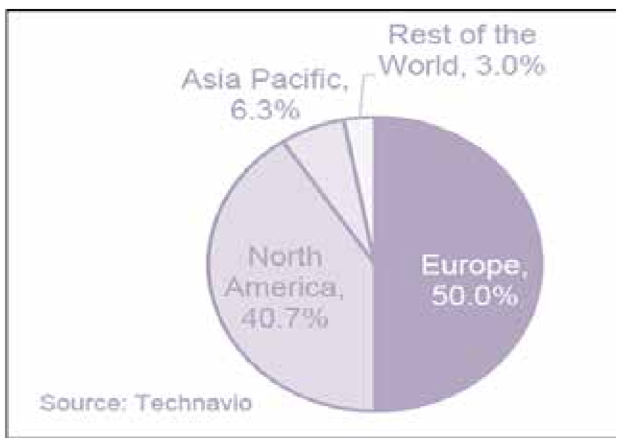


Figure Global organic dairy products market by geography 2014

Indian dairy market

- The increasing demand for fresh as well as packaged dairy milk & its products and ethnic dairy specialties is broadening the base of modern dairy sector of India, which creates accounts for almost 17% of total expenditure on food in India.
- Dairy products market in India is projected to achieve to US$22.5B by the year 2020 with a growing trend at a CAGR of 15.3% during the periods of 2010-2020.
- The organic milk market is less than 1% of the total milk market in India and there is increasing demand and consumption of organic milk & its milk products especially the organic ghee. Niche players like Organic India, Holy Cow Foundation and Vedic Cow have entered the fast growing niche category of the organic cow ghee production and marketing.
- Lucknow based Niche player, Organic India has observed demand for its organic ghee growth at 400% in the last four years since it was launched and also this is when organic ghee costs is increased at least 40-50% than the conventional ghee.
- The unorganized sector consists of small & marginal farmers as well as the cooperatives primarily contribute to the dairy market in India. However, the organized sector has been coming up forward rapidly by providing customized

and innovative products like organic milk & organic paneer to the end consumers in the last few years, therefore there is increasing the organized market share of organic dairy products.

- There is tremendous increase of consumers to move to packaged milk and milk products from unpackaged is mainly due to assurance of consistent quality, hygiene and safety for milk and its products.
- Additionally, organic milk producers have linked with modern trade milk outlets like e-commerce websites as well as gourmet food retail stores (Nature's basket, Le Marche) to boost the sales and increase the visibility of the organic dairy products.
- Market on the organic dairy products is predicted to grow at the rate of 15% per annum in the near future as the customers become more aware and conscious on its health benefits
- The Food Safety and Standards Authority of India (FSSAI) have founded in 2012 that ~70% of milk in all over the country was mixed and diluted with milk powder, water or mixed with impurities like urea, detergent solution and liquid formaldehyde, etc.
- Additionally the consumers are becoming sceptical about tetra Pak milk brands has been increased where there is no transparency regarding where the milk is come from or how the cows are treated, etc.

Entrepreneurs are investing in offering healthy alternatives to store-bought milk through organic farms

1. **Happy Moo:** The company allows the cows to graze freely on organic grass, rest on individual day beds, drink fresh clean water, be treated to daily beer massages, swim on a hot summer's day and listen to relaxing sounds all day long.
2. **Pride of Cows:** The company places extra emphasis on quality milk production by guaranteeing that the milk arrives at consumer's doorstep within three hours and strictly maintaining a cold supply chain of 4ºC to ensure that no bacteria can contaminate the bottling or milking premises.
3. **Sarda Farms:** Fans and fresh water is available throughout the farm, there is no restraint imposed on any cow and they even have access to motion sensitive massage brushes. Sarda Farms not only has automatic milking machines with zero human intervention, but also employs GPS trackers on all their delivery trucks to ensure that the milk is delivered straight to consumers with no deviation.
4. **Astra Dairy farms:** At Astra Farms, 100 cows are fed nearly 35 kg of organic corn, grass and alfalfa every day. They believe in feeding the cows the right food and giving the best care.

Growth Drivers to produce organic milk

1. **Increasing health awareness:** Increase awareness on nutritional values of organic products and growing willingness of consumers to spend on non-conventional milk and its products like yogurts, probiotic drinks, etc., has inturn increased to adopt the organic food. Moreover, consumers are also increasing knowing the ill-effects milk and milk products derived from the conventional dairy farming where use of pesticides.
2. **Favourable macroeconomic factors:** Urban population in India is expected to increase from $420x10^6$ in 2015 to $527x10^6$ by the year 2025, which resulted to increase the demand for nutritious and healthy food. Urban consumers are ready to pay premium prices for organic food and its products.Indian middle class population which is approximately $270x10^6$ with the income of US$4,000–US$20,000 is likely to be doubled over the next one decade.
3. **Innovative offerings from dairy players:** Domestic dairy manufacturers are increasing their main focus about to offer the food products for health and nutritious conscious consumers and inclusion or introducing the packaging innovations to strengthen their market position and potential. For example, MILMA, the Kerala Co-operative Milk Marketing Federation Ltd is partnering with the Netherland company to produce healthy, nutritious and high quality 'organic milk and milk products' that is without using any synthetic feed or fodder or antibiotics or hormones while growing the dairy cattle.
4. **Increasing support from Government of India:** The Indian Government (GoI) is promoting the organic farming as well as the consumption of organic food in the country. Moreover the financial assistance is also provided to the farmers who are interested to adopt the organic farming under different central government schemes like National Mission for Sustainable Agriculture (NMSA), National Food Security Mission (NFSM), Mission for Integrated Development of Horticulture (MIDH) and Rashtriya Krishi Vikas Yojana (RKVY).
5. **Growing penetration of organized retail:** In India, currently the organized retail is in at a nascent stage and its accounts is ~8% share in the retail market and is also expected to increase to ~10% of total retail share by the year 2019. Retail players like Big Bazar, Easy Day and Reliance Fresh has helped to create awareness among consumers on the organic food options available in India. Additionally, availability of wide variety of organic milk as well as its products are due to the growing prominence of organized retail market coupled with increasing world connectivity, that has led to easy availability and alteration in the tastes as well as the preference of domestic organic food consumers.

6. **Evolution of e-grocery segment in India:** In India, the e-grocery market is expected to be grown at a CAGR of 26% during the periods from 2015-2019 which is driven by increasing utilization and penetration of internet connectivity, internet banking as well as growing popularity of mobile shopping without any time and location constraints. Besides the online e-grocery, start-ups like Big Basket and Grofers, existing horizontal marketplaces also see grocery as a viable space. In the year, 2015, Snapdeal has MoU with Godrej Nature Basket whereas Paytm has launched a dedicated application for e-grocery ordering and procurement.

Organic Milk – from farm to table

1. The organic dairy production concept has two different activities such as i) organic dairy production by growing of good & adoptive, healthy and local indigenous breed of dairy cattle in completely adopted organic environment &procedures, therefore the milk produced from that animals can be certified as organic milk and even by recognised international agencies, ii) Production of variety of milk products from the organic milk from the organic farm by using complete preparation process and source ingredients to meet the organic standards as well as the specifications.
2. Each and every dairy cow in the organic dairy farm is carefully selected after properly checking it antecedents and to ensure only the finest make the grade.These dairy cows are quarantined in an external environment for minimum 3-4 weeks before being introduced in a dairy farm for routine operation. These cows are allowed to milk by machines in the automated milking station and the milk is immediately sent to a bulk cooler through properly hermetically sealed pipelines for further processing.
3. The bulk cooler cools the milk gradually to 4°C and at which, the milk is preserved without any degradation.
4. Then the milk has been transported to a processing unit through insulated tankers.The cold chain delivery is followed by strict measures that ensure that the organic milk reaches to the consumers in untouched by hands as well as chilled to maintain quality standards&flavour.

Strengths, Weakness, Opportunities and Threats (SWOT) analysis of organic farming in India

Strengths

1. **Quality indigenous breeds availability:** Cattle breed required for organic dairy farming system is highly location specific (NPOP, 2005). In a diversified country like India has breeds and one breed of dairy animal has not been much successful and not recommended. However, India has a number of good quality local dairy breeds for each specific region unlike foreign country. Cattle breed like Sahiwal, Gir, Red Sindhi, Rathi, Tharparkar and buffalo breeds such as Murrah, Surti, Nili Ravi, Jaffrabadi, Mehsana are best local milk producing breed in Indian sub-continent.
2. **Traditional and integrated farming system:** Organic farming system requires cropping diversity, agro-ecosystem complexity and a transition from monoculture to mosaic and temporal integration and an optimal spatial of the components (Nardone *et al.,* 2004). Integrated livestock–crop farming system is very predominant in country like India with well diversified livestock population is ideal and suitable for organic dairy and livestock farming practice. Most of the Indian dairy farmers still practising a close to natural farming practice with limited external input/resource use including for animal production and maximum on farm reliance bring its further closer to the organic farming. This integration of various forms of crops and livestock ensure input availability for both agriculture and dairy enterprise along with efficient recycling of by products of both for effective utilization. It also offers synergistic and mutual interactions with the greater total contribution than the total of their individual effects (Devendra, 2003).
3. **Resistance to diseases:** Dairy animal breeds of India are highly resistance to disease and stress and also need less allopathic medicine/antibiotics/chemicals which make them suitable for rearing under the organic management. Homeopathic or ayurvedic or siddha medicine could be used for treatment if the animal is suffered such as health problems. Indian continent has the rich biodiversity along with rich indigenous traditional knowledge(ITK) base among farmers has ensure the efficient treatment& control and recovery of animals in case of any health problem. Increasing research effort has also ensured that there is sufficient knowledge, informations and technologies available to prevent the diseases and management on feeding in organic milk production system (Nardone *et al*., 2004).
4. **Animal welfare:** In general, in India, the dairy farming is largely extensive or semi-extensive where animals are not seen as business vehicle like industry or factory type of animal production, which was common in developed countries (Chander, 2014). The welfare of animals is not too much compromised by common Indian farmersdue to religious sanctions and moral obligation in India.
5. **Indigenous technical knowledge:** India is the big basket of the diversified indigenous traditional knowledge and useful for every aspect of farming system. Therefore the ayurvedic and indigenous local ethnic herb based healthcare system are largely used by the Indian farmers for animal healthcare activities. Treatment with allopathic medicine is meagre, which not only reduce the cost but also bring the nation, India in an upper hand overdeveloped countries.

6. **Better performance of dairy animals:** In general, the yields drop by about 10% when converting to organic production system but it is possible to manage a high yield level in organic dairy cows. In National Dairy Research Institute, Karnal, a research has been undertaken that the total lactation yields (2358.33±248.08 vs. 2703.93 ± 237.42 kg), total lactation lengths (323.5±41.84 vs. 347.66 ± 39.722 days) and the 305 day milk yield (2081 ±133.90 vs. 2439.7 ± 156.25 kg) were found to be lower in conventionally or in-organically managed buffaloes as compared to organically managed buffaloes, thus it was proved. Health status of the buffaloes in the organically managed groups was found to be too far better than the health status in the control/conventionally group of buffaloes, that buffaloes were maintained under normal circumstances (Kamboj *et al.,* 2013). Similarly studies undertaken in different European nations reported a range of 80-105% milk yield level of organically managed herd (Padel, 2000; Hermansen, 2003). In general, organic management in dairy cow causes less metabolic stress& free radical formation for the more natural management, but for the same reason, the average milk yield is far lesser and the reproductive performance is often far better. But in a well managed nutrient supply in the form of organic feed/ fodder can ensure the comparable milk production of organically managed dairy cattle in long term (Jakobsen and Hermansen, 2001).

Weaknesses

1. **Small and Marginal farmer:** Dairy farming is dominated as like crop farming by small &marginal farmers in India. Approximately 70% of the total milk production in the country has come from small and marginal farmers. Milk and its products is the main sourced from the large number of small farmers and also making the traceability is a very difficult option in India. Increasing local demand of organic dairy products and considering India's rich experience in co-operative movement especially in dairy sector, promotion of co-operative movement in dairy farming as well as the contract farming can overcome these inherent difficulties of small and marginal holder dominance. Innovative value chain model like Ksheerasamruddhi in Kerala, which is based on forming the Self Help Group (SHG) to produce, package and supply of quality milk in consumer doorstep in surrounding areas could also be explored for organic milk production and marketing (Sreeram and Gupta, 2016).
2. **Incidence of disease:** India eradicated many diseases like Rinderpest (Gangadharan,2010) but prevalence of diseases like Foot and Mouth disease (FMD) and Mastitis in different regions of India is also one of the limiting factors for quality maintenance as well as export of dairy products. Along with prevailing messy and unhygienic condition at production sites and processing units and distribution parlour, India needs to do a lot of arrangements so as to be eligible for exporting the organic milk products and become organic milk producing country in the world (Barbuddhe and Swain, 2008). In organic animal production systems, the animals are particularly at risk due to ban of prophylactic medication and outdoor rearing. But in organic dairy system, parasite infection and infestation are the biggest challenges interms of animal health care and consequently in terms of product quality for the consumer (Kouba, 2003).Therefore, achieving control on these diseases is a main priority factor to increase the acceptability of our products in western countries given their strict organic standards. Though these problems cannot be completely eradicated immediately at one time but can be controlled slowly and gradually by rational grazing management and other suitable management procedures like moving stock to uninfected areas and/or using diluting strategies by alternating or mixing species on same grassland, use of plant extracts, use of homeopathic treatment, use of biological method of control or treatment, use of special forage crops and improved pasture species, which may improve the animal resistance like *Lotus pedunculates*, which contains high quantity of condensed tannin, development of vaccines against parasites, animal nutrition, which are improving resilience and resistance, biological control of parasites like by applying native or exotic natural enemies against nematode parasites, genetic resistance to nematode infections etc(Ronchi and Nardone, 2003).
3. **Production drop and Cost concern:** Various reports around the world has given different accounts on productivity of dairy cattle in organic dairy farming is ranging from 10 to 18% lower milk yields to significantly higher milk yield under favourable situation in comparison to conventional dairy production system(IFAD, 2010; UNCTAD, 2013). It is also reported that the health of the organic cows might be impaired because of a poorer plane of nutrition as affected by the restrictions on feeds used inorganic dairy production (Hermansen, 2003). But many reports has also nullified this concern as no major differences on health aspects in general have been identified in the organic production system. In general, the milk yield dropped during the initial period of conversion from conventional to organic dairy farming. Butas in Indian situation, the lower productivity of indigenous local animal breeds and predominantly presence of small and marginal dairy holders, the scanty loss of production will not be able to withstand by the dairy farmers and thus will be possibly discouraging and demotivating for converting to organic dairy farming. Another important point of concern is that the organic dairy farming involves more intensive use of labour for all the activities of the farming. The organic farming system needs at least 10-20% higher number of the labour to manage than in conventional farms (Wolde andTamir, 2016). The costs of organic inputs are also often higher than conventional farming system. Therefore, the total costs for operating most organic dairy farming systems are far lower than those for comparable with conventional farms and this does not necessarily indicate or

translate into higher net market income per unit of labour because organic farms need more units of labour and inputs to tend the same number of hectares or cows. But these cost and production concerns can be outsmarted given by increasing willingness among consumers to pay premium price, by cutting cost with more evolved market chain and by introduction of subsidy for farmers during transition time for production lost.

4. **Lack of organic farming knowhow and proper training:** In most of the developing countries like India, promotion of chemical based inorganic farming system has eroded/reduced the indigenous technological knowledge base and in current, much of these technical knowledge and supports are oriented by using the technologies that can improve the productivity per unit input as well as time. Moreover, there is lack of extensive promotion of work with regards to the negative impact of products from inorganic farming system (Setboonsarng, 2006). Poor/lack of proper education prevailing in Indian farmers as well as lack of awareness and knowledge on the various important issues of organic farming are the challenging task to promote the organic dairy farming in India. Additionally, there is also lack of proper practice and training especially related with organic dairy farming procedures & standards (Kamboj and Prasad, 2013).However, with the increasing awareness and penetration of ICT among Indian farmers, this problem can be solved and also this will help to reach the information to the farmers where there is lack of qualified manpower among countries of extension as well as the training organizations.

Opportunities

1. **Consumer awareness and demand for healthy food:** There has been an increasing trend over the last few decade for products associated with lifestyle choices as well as the process quality which ultimately justify the payment of premium price for the organic products (Nardone *et al*.,2004). The interest of the consumer in the organic farming systems seems mainly to be associated with to take care of their own health, nutrition and the environmental impact on agriculture and also considerations of animal welfare (IFST, 2001). Increasing per capita income, change of lifestyle & food habits which in turn demand for organic dairy products is increasing in domestic as well as foreign market especially in the developed nations like USA, EU, Argentina, Japan and Brazil. Moreover, the literacy rate is also rising and the media are creating the consumers more aware of& concerned on animal welfare issues as well as the healthy & nutritious foods. These conditions may boost the consumption of organic foods in domestic level.
2. **Grass or crop residue based feeding systems:** In India, most of the animals are kept by the small as well as marginal farmers and they do not have sufficient resources. Therefore these animals are fed grasses as well as agricultural by-products like straw in most of the time. Further, in India, very limited practice of fodder cultivation in rural areas and also in general, these animals are consume naturally grown shrubs and grasses and often are low quality in terms of proximate analysis especially protein and energy and they are thus highly dependent upon seasonal variations and this in turn fluctuation in fodder production and supply throughout the year, affecting the milk supply round the year (Meena and Singh, 2014).It is measured that the crop residues also contribute on an average 40–60% of the total dry matter intake per livestock unit in rural areas of India (Singh *et al*.,2014). But in the integrated as well as in well diversified crop-livestock integrated farming with more production of legumes will enhance the quality of feed and fodder along with other beneficial effects. Presence of native protein rich concentrates like beans and peas also contributes to minimize the necessity of commercial concentrates for dairy cows. Use of self reseeding of annual legumes (*Trifolium* sp. and *Medicago* sp.)can be beneficial to low input and organic farming systems(Caporali and Campiglia, 2001) and available grasslands can also be improved by introducing the species of grasses with high nutritive value and careful grazing management. This procedure can be undertaken by involving the well empowered and developed local Panchayatraj system in Indian continent.
3. **Protecting &enhancing biodiversity and positive social impact:** In general, organic farming system is environmentally friendly and also provides energy for the microbial activity. Chemicals have destroyed many beneficial microbes and insect species which in turn caused environmental pollution and degradation (Bello, 2008). Organic livestock producers have mandate to manage the manure for crop production, thus the contamination of crops, soil or water is reduced and increases the optimization through recycling of nutrients (Chander *et al.,* 2011). This will be particularly useful to improve the already degraded biodiversity in the green revolution areas as well as will help to maintain and improve the natural resource base as in other traditional farming dominated area. Organic milk production has also significant social and economical impact on rural communities. Main benefit as per the some organic farmers in developing countries like China and India is that they now have better standards of living and improved livelihood. Low unemployment, good product prices, dropped rural emigration as well as reduced health risks (from chemicals) are the results from the organic farming system (Wolde and Tamir, 2016).

Threats

1. **Foreign market dependence:** Demand for organic products in domestic market is not still at developing stage and the international trade in organic dairy products is considered a risky business due to existence of diseases, poor sanitary conditions and traceability problems as also self sufficiency in the importing countries, which might discourage the producers in India also. The restriction applied on import of agricultural and livestock products

from developing countries is often due to the political reasons and it is an also important limiting factor to limit the demand and lower premium price in the domestic market.

2. **Polluted natural resources:** Extensive use of chemical pesticides and fertilizers throughout the last few decades leaves water, soil and natural resources contaminated and polluted. Prevalence of pesticide residue is very high in India in spite of the truth that the average consumption in India is far below than many developed nations. Heavy use of fertilizers and pesticides has contaminated and polluted the fodder as well as animal feed concentrates in turn contaminating the milk & its products, eggs and meat and its products consumed by human beings (Prasad and Chhabra, 2001). The presence of residue of pesticide in milk collected from intensive utilization of chemical fertilizers and pesticides in the region of Punjab, Haryana, UP etc. showed a decrease trend over the periods but did not stop to exist in milk. Less popular and fat soluble organophosphorus pesticides like diazinone, acephate, phorate, malathion and chlorpyriphos have been diagnosed in food products with high fat content especially the dairy products (Ivey *et Al.,* 1993). Parathion-methyl, Quinalphos and ethion were also detected in samples from river Ganga and monocrotophos and malathion were also detected from underground water from areas of UP (Bansal and Gupta, 2000).Pesticide with heavy metals such as mercury, cadmium, lead and arsenic are the common heavy metals detected in milk in some locations in India (Dwivedi *et al*.,2001). But it was also reported by many research that the relatively low presence of pesticide residue in the organic dairy products than in conventional dairy products (Kamboj *et al*., 2013). Organic milk may not be completely pesticide free especially due to environmental contaminants if judicial use is not promised (Woese *et al*.,1997). Therefore for organic farming system, application of these chemical inputs must be stopped not only by the organic farmer but also in surrounding fields.
3. **Organic dairy farming standard:** Organic milk farming must face the tough and strict regulations, which need to be planned and monitored by the well developed procedure or mechanism which is lacking in the present condition in Indian nation. Due to totally different characteristics of Indian Dairy farmers, the organic dairy standard of western developed nation will not be totally acceptable and not feasible for Indian dairy farmers.
4. **Fodder shortage:** It is reported that a demand of 1097×10^6 tonnes of green fodder and 609×10^6tonnes of dry fodder in India against the supply of400.6×10^6& 466×10^6tonnes, respectively. Therefore a deficit of63.50% and 23.56% of green and dry fodder against actual demand which will further increase to 64.21% and 24.81% up to 2020 (Planning Commission,2001).The farmers will not be able to delineate more land resources for fodder cultivation due to heavy population pressure and decreasing land availability. But on the other side, grazing lands also keep on declining over the years. Therefore the present situation of limited availability of green fodder will be further aggregated in future (Mishra *et al*., 2009).
5. **Nutrition management challenge:** Milk production systems have face unique nutrient management challenges in the dairy farm. In general, most dairy farms utilize the large nutrient (like NPK) surpluses as a result of high nutrient imports, mostly as feed, relative to farm nutrient exports (mostly as milk). Researches in western countries indicated that some organic dairy farms may develop the deficiencies of phosphorus especially decreasing the top soil phosphorus concentrations (Loes and Ogaard, 2001). Therefore milk fever or hypocalcaemia or grass tetani is more prevalent in organic farming than in conventional farming systems (Patra, 2007). Low application of phosphorous by Indian farmers and deficient nature of Indian soil, this issue can become a potential threat to the fertility of soil in organic dairy farms.

Transition to Certified Organic Milk Production

1. Before You Transition: Make a Plan

The following guidelines are based on the National Organic Program (NOP) final rule (USDA, 2000) for certification to organic milk production. Farmers planning to make the transition to organic dairy production should consider all of the following areas as well as the time and investment that will be required for compliance with certification requirements.

A farmer interested in making a transition to organic production should create a transition plan which includes a timeline from the day that organic practices have been implemented to the day that the farm will ship the organic milk. This process takes a minimum of one year and can take up to three years, depending on the farm, current farming practices and when the last prohibited substance was applied. Fields can be transitioned to organic on a field-by-field basis with each field required to be free of prohibited inputs for 36 months before the first organic harvest. Dairy animals will require a 12-month transition which may overlap with the third year of the land transition. In some situations, the farm may choose to purchase a herd of certified organic dairy animals instead of transitioning an existing herd.

Before starting the transition process, it is important to find an organic milk market and decide which organic certification agency to use. The certifier will provide an application and/or Organic System Plan (OSP) as well as record-keeping forms to document the transition to and management of organic production. During the initial application process, the certifier will require one year worth of production and managemental documentation of the livestock and three years worth of production information for the land. Following the initial transition and first year under certification, the certifier will continue to require an annual OSP and records of management &materials used on the farm.

It is important to choose an organic certification agency early to make sure the certification process can be completed on time. The certifier can provide information about the requirements, record-keeping forms and a list of inputs and materials allowed. All accredited certifiers are required to provide the sufficient information to persons who are seeking certification process to enable them to understand and comply with the requirements. Since there are regional differences in available inputs, climatic conditions, agronomic practices, and so forth, it is always a good idea to work with a certifier who is knowledgeable about the local conditions, practices and inputs used.

Shippers or processors that buy the organic milk may have contract or production requirements in addition to the NOP final rule. Be sure to learn about their requirements before selecting an organic milk buyer and going through the USDA organic certification process. It is important to know that certification process does not assure the organic milk in the market. A contract with an organic milk buyer or organic milk market should be established prior to making investments in the transition and certification process.

2. Dairy Herd Transition Guidelines

During the 12-month transition period, all animals in the dairy farm must be managed according to the NOP. This requires that all the feed to be certified organic, that all animals over the age of 6 months must meet the pasture standard and that all the feed supplements, medications, health management practices and livestock housing must meet the organic standards. There is an allowance where the farmers may use, in addition to certified organic feed, their own feed grown on their own land in its third year of transition. This home-grown feed may only be fed during the 12-month livestock transition period. Once the transition is completed and the herd is certified, the standards require that all dairy animals be under organic management from the last third of gestation.

3. Livestock Feed

All feed must be 100% certified organic at least 12 months prior to selling organic milk or harvested the farm's third year transitional land (i.e., land where a prohibited substance was last applied 24 to 36 months ago).The 100% organic feed ration includes forages and grains as well as any agricultural products that are used as the carriers or bulking agents in feed supplements (e.g.oat bran, etc.).The provision for feeding of farm-raised, third-year transitional feed is only allowed for herds in transition. Once the herd is certified and the farm is shipping organic milk, feed from transitional land cannot be fed. For this reason, it is important to time the transition to have silos, bins and hay storage empty of transitioned crops and full of certified organic crops prior to the completion of the transition process. During the transition, all purchased grains and forages must be certified organic. "In-transition" organic feed (managed organically for 2-3 years) cannot be purchased from other farmers and fed to a dairy herd during transition. You must keep all receipts and organic certificates as documentation of your organic feed purchases, making sure that the receipts provide the seller's name, transaction date, a copy of the seller's certificate of organic status and the amount of feed purchased. These documents will be required to allow the certifier and inspector to verify that the herd has been fed only organic feed. All feed supplements including minerals and salt must include cent percent certified organic feed ingredients or materials on the National List. In addition, they must be pre-approved for use by the certifier. Antibiotics, GMO derived products, animal by products, artificial colors /flavours, synthetic flowing agents and synthetic preservatives are not permitted in any feed products. If a supplement contains soy oil, wheat middling or molasses, for instance, these are agricultural products and must be certified organic. The certifier may provide a list of approved products and suppliers. The Organic Materials Review Institute (OMRI) also provides a list of approved inputs for crops, livestock and processing. There is currently no approved organic milk replacer, so calves must be fed organic milk along with other certified organic feed. The organic standards on pasture are defined that the pasture as a crop and require that farms have a pasture plan in their OSP. The standard requires that during the grazing season, all animals over 6 months of age must receive an average of at least 30% of their dry matter from pasture. Grazing season length will vary regionally. There are specific record-keeping requirements in the organic standards which relate to grazing, feeding and dry matter intake calculations.

4. Livestock Living Conditions

Organic livestock producers must establish and maintain year round livestock living conditions which accommodate the health and natural behaviour of animals. These include year round access for all animals over six months of age to the outdoors and during the grazing season, require pasture. When housed, the livestock living conditions require that the bedding be dry and clean and that when roughages are used as bedding, that they be certified organic. Outdoor areas must be managed to prevent run-off of wastes and water contamination. There are exemptions that allow the producers to provide temporary confinement due to specific situations like inclement weather, risk to soil and water quality, healthcare treatment, breeding and milking.

5. Livestock Health Care Products

The organic standards require that the producer establish and maintain preventive health care practices. The standard states that this includes selection of appropriate species and types of livestock, feed rations, appropriate housing, pasture and sanitation. It also includes conditions that allow for exercise, freedom of movement and reduction of stress. Dairy farmers must follow organic health care requirements during their one year transition prior to shipping to organic milk. This means that all health care products with synthetic ingredients are prohibited for use, unless they are specifically included on the

National List of synthetic materials allowed for use in organic livestock production. The organic standards allow physical alterations such as dehorning as needed to promote the animals' welfare and in a manner that minimizes pain and stress. Docking the tails of dairy cattle is not allowed.

Non-GMO vaccines and biologics are allowed in addition to medications on the National List. Some of the materials on the List have restrictions including milk withholding, and some are prohibited for use in slaughter stock. All health care materials must be listed in the OSP and approved by the certifier prior to use. It is prohibited for a producer to withhold treatment to maintain organic status of an animal. If an animal is treated with a prohibited product, the milk and meat from that animal can no longer qualify as organic and the animal must be sold as non-organic or tracked and managed as non-organic. Records should be kept including vet visit records and health treatments administered as well as records of deaths and culling.

6. Animal Identification and Inventory

An animal identification and inventory system are not specifically required in the organic standards. However the organic standards do require that all the certified operations maintain records which fully disclose all activities and transactions in sufficient detail as to be readily understood and audited. During the annual inspection, the inspector will usually do an audit of some or all of the livestock to verify the identification system, animal records and number of animals. Some certifiers will provide farms with livestock record keeping forms; however most of the computerized record keeping systems will have enough detail in them to allow an audit of the herd records during the annual inspection. When animals are purchased, the invoices and organic certificates should be kept and made available during the next inspection.

7. Dairy Livestock as Organic Meat

If part of the farm plan is to sell cull cows, young stock or steers as organic meat, all the slaughter animals must have been organic from the last third of gestation. This means that the mother cow had to have been on the certified operation, fed and managed organically for the last three months before the slaughter animal was born. If third-year transitional feed is being used to feed the herd, the young stock born that year would not be eligible for organic meat sales. Dairy animals that were transitioned to organic can never be sold as organic meat, but they can give birth to organic meat animals and produce organic milk. Dairy animals that were given parasiticides can never be sold for organic meat.

8. Field Practices

Fields, including pastures, qualify as organic if at least three years have passed since the last application of a prohibited pesticide, herbicide, synthetic fertilizer or any planting of fungicide-treated seeds or GMO crops. If some fields qualify as organic, but others have had recent applications of prohibited products, the farm may still be able to get certified.

The feed from fields that have not yet completed their three-year transition would be considered non-organic transitional feed. First- and second-year transitional feed can be sold on the conventional market or fed to non-organic livestock, such as bull calves to be sold for non-organic meat. Records documenting the sale or use of transitional and other non-organic crops should be maintained. Third-year transitional feed can be fed ONLY during the one-year whole herd transition year.

9. Risks of Commingling and Contamination

The organic standards require that the organic operations have measures to prevent the commingling of organic and non-organic products and to protect organic products from contact with prohibited substances. For farms, this may create the need for buffers on the edges of some fields and it may also create a requirement that equipment which may become contaminated by non-organic crops or prohibited materials be cleaned between uses. If an adjoining farm, golf course, development or other land user applies prohibited substances to their land, an adequate barrier/distance between the certified crops and the neighbouring land needs to be in place. The buffer needs to be sufficient to prevent prohibited substances from contacting the organic crops. The organic certifier can provide detail on the distance needed for buffer zones, depending on the risk of contamination, taking into consideration physical barriers, slope, prevailing winds, substances used by the neighbour and methods of application. If buffer zones are needed, crops grown in those areas cannot be used for organic feed or sold as organic.

If harvest equipment, seeders, sprayers, spreaders or other equipment are used for both organic and non-organic production, they will need to be cleaned so that organic crops will not be contaminated with prohibited substances or non-certified feed. For some types of equipment, this can be done by sweeping or manually cleaning. Other equipment may require washing or a purge. A record of this cleanout should be kept and made available to the inspector during the organic inspection.

10. Soil Fertility and Crop Production Inputs

The NOP regulation states, "A producer must select and implement tillage and cultivation practices that maintain or improve the physical, chemical and biological condition of the soil and minimize soil erosion". The regulation also states that the producer must use management practices to prevent crop pests, weeds and diseases including crop rotation, sanitation and cultural practices. It allows the use of predator species for pest control, development of natural habitat for predator species and non-synthetic controls such as traps and repellents. It allows the control of weeds through mulching with fully biodegradable materials, mowing, mechanical cultivation and grazing.

Soil fertility should be managed through rotations, cover crops, manure, compost, plant residues and the application of approved soil amendments. Approved soil amendments include non-synthetic minerals such as manure, rock phosphate and naturally mined lime, so long as they do not contain synthetic additives and are not on the list of non-synthetic substances prohibited for use. The organic standards also include a list of synthetic substances allowed for use in organic crop production. Use of a prohibited material will disqualify that field from organic production for three years.

All soil fertility inputs, pest control or weed control materials must be listed in the OSP and approved by the certifier prior to use. Records of use should be maintained and product labels or purchase records should be kept and made available during the organic inspection.

11. Seeds

Producers of organic crops are required to use certified organic seed if it is commercially available. Conventional, untreated seed may only be used if organic seeds are documented as not being commercially available. Documentation must be kept to verify that any non-organic seed used has not been treated with synthetic fungicides/insecticides, is not genetically modified, nor inoculated with GMO nitrogen-fixing bacterial inoculants.

Crops grown from treated seeds cannot be sold as organic and the use of treated seeds disqualifies the field from organic production for three years. Seed treatments such as non-GMO legume inoculants and natural clay-based pelletizing materials can be used, provided they are approved for organic use.

Records of seed purchase including commercial availability documentation, statements of non-GMO status and documentation that they are untreated should be kept and made available during the organic inspection.

12. Milk Handling and Sanitation

All types of milking systems are allowed including hand, bucket, stanchions and parlours. The milking system cleansers, sanitizers and teat dips should all be listed in the OSP and should be approved by the certifier prior to use.

Benefits of Organic Dairy Products

Organic products must be from animals that have been under continuous organic management for atleast one year prior to the production of the milk or milk products.

Superiority in terms of quality of products is due to the following reasons:

1. Organic milk is better for health

Milk is a perfect indicator that reflects the level of pollutants and pesticides those contaminated dairy cows and as well as dairy. Variety of dairy products such as butter, butter milk, butter oil, cheese, whole milk, yogurt,s kimmed milk powder, ice cream, ghee etc are used in diet of our daily life. Out of which, milk and its products share a large part. Conventional produced milk may contain residues of hormones, antibiotics, chemicals, drugs those used on the dairy animals for excess milk production and treatment purposes, pesticides, antibiotics, urea, solvents, which have a serious impact on the health of the individual. In conventional milk producing farm, such practices were very common to obtain more milk beyond their natural capacity. Inappropriate protein is fed to cows for stimulating the rapid growth and/or milk production. All these factors can make the conventional milk inferior in quality. Consumption of such milk may lead to early puberty, hyper-sensitivity, hormonal imbalance, various reproductive disorders and certain types of cancer in humans. Milk from organic and non-organic dairies is having difference but organic milk is far superior to non-organic milk in many aspects.

2. The differences which make organic milk superior

a. **CLA**: Milk contains Conjugated Linoleic Acid (CLA). Functional effect of CLA in human body is to enhance or boost the immune system and also reduce the tumours growth. CLA quantities in organic milk are significantly higher because these cows consume higher quantities of grass, silage and hay. Organic milk has significantly higher beneficial Omega-3 fatty acids (Lairon and Huber, 2014), less damaging Omega-6 fatty acids (Benbrook *et al*., 2013). Research report at University of Aberdeen in 2004 revealed that the organic milk contained up to 71% higher Omega-3 than non-organic milk and has a higher ratio of omega-3 to omega 6 than in non-organic milk. The organic dairy farming system produces organic milk that is on average of 68% greater in total omega-3 fatty acids than non-organic milk. CLA is an essential fatty acid, required for healthy growth and its deficiency inturn to various health complications that have increased in recent past years. Regular dietary inclusion of omega-3 fatty acids helps to protect from the different diseases and helps to reduce the incidence of cancer, arthritis, heart disease and inflammatory condition in skin like eczema (Annon, 2014). Organic milk also contains higher amounts of CLA (Mercola, 2014). CLA increases the metabolic rate, immunity to disease and muscle growth and also reduces allergic reactions, abdominal fat and cholesterol (Annon, 2014).

b. **Antioxidants and vitamins:** Organic milk has a 2-3 time higher quantity of antioxidants such as lutein and zeaxanthin than in non-organic milk (Mercola, 2014) and lutein is significantly important for eye health and is more effective in prevention of numerous eye diseases like cataracts and macular degeneration. Zeaxanthin is also more important for eye health. It protects the eye from UV ray damage and the impact of free radicals. It is very beneficial in prevention of cataracts, diabetic glaucoma & retinopathy and macular degeneration and hypoplasia. Organic milk has a greater concentration of vitamins especially Vitamin A as well as Vitamin E than in conventional milk. Because the organic dairy cows graze on fresh grass, fodder and clover, organic milk contains about 50% significantly higher Vitamin E and 75% significantly higher beta carotene in milk (Nielsen and Nielsen, 2004).

c. **Pesticides**: The organic dairy farms are not using any synthetic pesticides on pastures where the dairy cows are grazing. Whereas in the conventional milch farms 500 different pesticides are used on the pasture to cultivate feed and fodder. The main problem with use of the pesticides beside from their individual toxicity is that every research report shows that the way and toxic effect on reaction among the chemicals when combined in the cocktail effect. Additionally, it has more deleterious effects on the children because of their organ are immature and developing immune system. But drinking of the organic milk reduces/minimizes the risk of consuming chemical residues or toxic substances.

d. **Antibiotics**: On conventional dairy farms, the dairy cows are given antibiotics regularly to prevent and control the disease and infection as for treatment as well as for prophylactic measurement. Whereas in the organic dairy farms, natural remedies are used to treat the illness of the dairy cows at first time, if it is not working than move to antibiotics treatment. The treated cows must be separated and keep the isolation centre and then the withdrawal period are preferably longer than that recommended time for conventional dairy farming.

e. **GMOs and Solvents**: The feed and fodder has given to dairy cows that are maintained in the organic dairy farms are must be free from GMOs (genetically modified organism), urea and solvents extracts. So it results in milk that is free from these substances.

f. **Organic** cows are never given any animal derivatives or slaughter products or by-products in their feed and which was the source of the disease, BSE (Bovine spongiform encephalopathy). But till date, no case of BSE has ever been found in an organically born and managed dairy cows or farms.

g. **Hormones**: Fertility hormones are used regularly in conventional dairy farms for treatment and estrus synchronization programmes to ensure that calves are conceived and born within defined management periods and also to synchronize batches of cows or heifers to calve around the same time. Additionally, hormones like rBGH (recombinant Bovine Growth Hormone) and oxytocin were frequently used to improve or increase the quantity of milk or milk production and also cause easy ejection of milk, respectively. Whereas in organic dairy farms, use of these hormones was totally prohibited and forbidden.

Specifications of feeding and management for dairy cows raised organic farming (BCMAF, 2000)

Conditions	Requirements
Feed	Organically certified feed must be fed for one year before to start the milk production
Antibiotics	It must be restricted to minimum period of one month withdrawal or twice the labeled withdrawal time or whichever is greater
Hormones	Strictly not allowed and permitted
Sanitation practices	Teat dips and milking sanitation chemicals approved. However, equipments must be properly thoroughly rinsed at least twice with the clean water before to milking
Vaccinations	Vaccines for all the endemic diseases are allowed and permitted
Living conditions	Breeding & milking stock: Requires free access (weather permitting) to organic pasture for a minimum of 4 months/year Calves: Age: 24 h to 3 months Outdoor system : 64 sq ft/animal (5.95 sqm/animal) Indoor system : 40 sq ft/animal (3.72 sqm/animal) 3 mon-181.4 kg : 80 sq ft/animal (7.43 sqm/animal) 181.4 to breedable age : 100 sq ft/animal (9.29 sqm/animal)
Animals	Dairy herd must undergo one year transition period on organic feed as well as management. Replacement from non-certified sources must undergo a one year transition period. 10% of herd can be replaced in this manner. Bulls are not required and embryo transfer technology in the organic animals is prohibited

Determination of organic milk authenticity

Natural stable isotopes of carbon and nitrogen (12C, 13C, 14N, 15N) have abundances unique to each living creature. Therefore, measurement of the stable isotope ratio of carbon and nitrogen (δ13C = 13C/12C, δ15N = 15N/14N) in milk provides a reliable method to determine the organic milk (OM) authenticity. The authenticity of organic milk was determined by using δ13C and δ15N and reported that mean carbon isotope ratio (δ13C) was higher in organic milk than in conventional milk and mean nitrogen isotope ratio (δ15N) was lower in the former than in the later and the combination of δ13C and δ15N was more effectively distinguished between former and later (Chung *et al.* (2014).

Energy use and green house gas emissions

Organic dairy farming creates better environment for biology. In organic dairy farm, the production of livestock is more in intensive farming practices than in conventional one. In organic farming, pesticides sprays and synthetic fertilizers are prohibited in animal fodder and feed production and also the animals are kept at reduced stoking rates. This condition lowers the pollution risk (Younie and Watson, 1992) and it also reduces the nutrient losses at the farm level (Sundrum, 2001). A study was conducted in Netherlands showed that there was significant contribution of organic dairy farming towards ecological and environmental sustainability. The present study showed that emission of green house gases (GHG; gCO2 equivalents) and acidification potential (gSO2 equivalents) per litre of milk were 14 and 40% less for organic than conventional dairy herd (Oosting and DeBoer, 2001).Organic dairy production system inherently increases methane production and emission and thus, it can be possible to reduce global warming potential only by reducing emission of carbon dioxide and nitrous oxide considerable level (Boer, 2003). Similarly, Bos *et al*. (2014) estimated energy use as well as GHG emissions in Dutch organic and conventional farming systems and reported that energy use and GHG emissions per unit milk in organic dairy are ~ 25% and 5-10%, lower than in conventional dairy farming system. Kimming *et al*. (2014) reported that organic milk producers can become self sufficient in energy production and minimize the total GHG emissions from milk production by 46% in the form of the Biogas system.

Regulating Authorities

Organic standards are the detailed rules and regulations defining a) the production and processing practices that are permitted in the growing and manufacturing of organic food and b) the precautions that must be taken to protect the integrity of an organic product or process (Michaud *et al*., 1994). Standards whether international or regional are linked to a specific philosophy and they are not simply a collection of prohibitions describing what is allowed in organic farming and what has to be done in order to manage the farm in organically. Implementation of organic standards requires inspection& verification and the end product of the inspection and verification is certification. Certification ensures that organic dairy products are produced, analysed, processed and packaged as per the norms of organic standards. Certification also ensures that consumers, producers and traders against fraudulent labelling of non-organic products in the market. The accreditation process, which is conducted by an independent accreditation body, evaluates a certifier's inspection and certification procedures as well as that organization's ability to remain free from vested interests (USDA, 2001).

The farm must be registered with a registered organic control body and production system adopted must meet the organic standards to produce organic milk. The five organic standards are important and accepted worldwide such as European Union Regulation (1804/ 1999), Draft Guidelines of Codex/WHO/FAO, Organic Food Products Act of USA (OFPA), the International Federation of Organic Agricultural Movements (IFOAM) basic standards and United Kingdom Register of Organic Food Standards of UK (UKROFS). Further, it has been reported that in worldwide, there are 468 organizations which provide organic certification process and services to the dairy sector (Yadav, 2008). Highest number of certification bodies are in Europe (37%), Asia (31%) followed by North American countries (18%). The countries which have most certification bodies are United States, Japan, China and Germany. Forty per cent of the certification bodies are approved by the European Union, 32% have ISO 65 accreditation and 28% are accredited under the US National Organic Program.

United State Department of Agriculture (USDA) launched National Organic Programme (NOP) in October, 2002, is an authority to regulate and synchronize the organic production, farming and marketing in the United States. Now, all products sold as organic in the U.S. must be produced, handled, analysed and processed as per a single standard, i.e. the NOP "Final Rule' (USDA, 2000).Considering the rapidly increasing world demand for organic products, the Indian Government approved a national programme for organic production (NPOP). In India, the National Programme on Organic Production (NPOP) under the Agricultural and Processed Food Products Export Development Authority (APEDA) was officially launched in 2000 and notified under FTDR (Foreign Trade Development and Regulation) act in the year 2001. The non-government organisations (NGOs), private sector and public sector like APEDA are making concerted efforts to boost organic food production in India. The NPOP was accorded equivalency by the European Union for its regulation on Organic Agriculture EC 2092/91. That means that any product certified according to NPOP can have ready access to European Markets without the need for separate EU (European Union) certification. The USDA has also recognized the accreditation system adopted by India under (NPOP).

The National Programmes for Organic Production (NPOP) propose to provide an institutional mechanism for the implementation of National standards for organic production through a national accreditation policy and programme. The aims of the NPOP is a) to provide the means of evaluation of certification programmes for organic agriculture as per the approved criteria, b) to accredit certification programmes, c) certification of organic products in conformity to the national standards for organic products and d) to encourage the development of the organic farming and organic processing.

Steps involved in certification process include registration of producers and the processing industries, provision of basic information on the dairy stock, crops & farm and inspection and verification of farm, processing unit, production methods and production practices by the inspector appointed by the certifying agency like APEDA (Agricultural Products Export Development Agency), NSOP (National Standards for Organic Products), USOCA (Uttarkahnd State Organic Certification Authority) appointed by Uttarkahnd Government and ECOCERT appointed by Ministry of Agriculture, Govt. of India etc. These agencies have taken up several steps to improve the supply of organic food products mainly to meet export demands from developed nations. Some sporadic attempts have been made in India to produce organic milk as per the prescribed standards. For example, Institute for Integrated Rural Development (IIRD), Aurangabad based NGO established an organic dairy with indigenous cow breeds and imports training on organic management for organic agriculture school (Daniel, 1999). Besides, some Gaushalas/Ashrams/temples also claims to produce milk in organic ways.

Identified risks to the financial performance of the organic dairyunit

1. Lack of proper & sufficient feed and an inability to supplement with conventional feeds. A key strategy is adopted by organic farmers is to reduce the stocking rate.
2. Access to information, knowledge, resources and strategies about on conversion to organic dairying.
3. Animal health, especially mastitis as it minimizes the number of cows in milk and affects total milk production and health of the amimals.
4. High somatic cell counts in milk create difficulties also in organic producers and in the conventional dairy farms.
5. The ability to maintain soil fertility may affect pasture production at certain times of the year.
6. Weeds as they affect pasture production and its quality.
7. The restriction on using artificial nitrogen can limit the number of options in adverse or crisis situations. Therefore careful planning and monitoring are required and you may have to seek advice of the organic certification bodies frequently.
8. There is a range of allowable responses to fix a problem if the organic status of the animals and their products is to be maintained.
9. To counteract these risks, organic producers need to be forward looking proactive and preventative in management and good planners & managers.

Procedure to start the organic dairy farming

Stage	Description
1	Attend a: ❖ 1 day introduction course, then a ❖ 4 day conversion to organics course. These courses introduce you to the process of converting toorganics and give a structure for managing the process.
2	Read as much relevant material as possible
3	Join a specialist organic dairy discussion group which usually meet monthly. Visit other farms and obtain as much information you can about organics and the conversion process including: ❖ costs and benefits ❖ risks ❖ managing the conversion process ❖ animal health ❖ soil and pasture management ❖ managing the farm after conversion ❖ staff and training issues.
4	Begin preliminary supply contract negotiations with your milk processor. Find out: ❖ expected premiums over the next 5 years ❖ their requirements for supply ❖ any information, support and resources they have available.
5	Start implementing small changes with the information you have learnt (if you haven't already).
6	Complete a preliminary management plan outlining in broad detail: ❖ the changes you will be making during the conversion process ❖ expected costs and income ❖ actions to take for expected and unexpected situations and ❖ details on how you will manage the conversion. Keep reviewing and updating this document during the process.
7	Select an organic certification agency.
8	Have an adviser visit your farm and make recommendations for conversion.

9	Look at your whole farm system against the organic certification standard and identify key areas where you are not compliant. Write these into your management plan with time frames and costing.
10	Start working on the non-complying areas and manage the complying areas.
11	Review your management plan
12	Keep talking and visiting other farmers and experts and obtaining information, knowledge and resources.
13	Arrange the first audit by the certifier
14	Carry out any corrective actions as a result of the audit and obtain certificate.
15	Notify your milk processor and start supplying organic milk.

National standards for Organic Dairy Production

1. Animal husbandry management: The accredited certification programme shall ensure that the management of the animal environment takes into account the behavioural needs of the animals and provides for

1. Sufficient free movement within the pasture and shed
2. Sufficient fresh air as well as the natural day light according to the needs of the animals
3. Protection from the excessive sunlight, temperatures, rain as well as wind as per the withstanding capacity of the dairy animals
4. Enough lying and/or resting area as per the needs of the animals and for all animals, sufficient bedding and natural materials must be provided.
5. Ad libitum access to fresh water and feed as per the needs of the animals
6. Adequate facilities must be provided as per the biological and ethological needs of the dairy cows.
7. No components used for the construction materials and/or production equipment shall be used which might have detrimentally effect on human and animal health.
8. All animals must have to access open air and/or grazing appropriate to the type of animal and session taking into account and the age and condition are to be specified by the accredited certification programme.
9. The accredited certification programme shall be allowed exceptions in cases where:
   a. The specific farm or settlement structure prevents such access provided the animal welfare can be guaranteed
   b. Areas where feeding of animals with carried fresh fodder
   c. Is more sustainable way to use land resources than grazing providing welfare of the animals is not compromised.
   d. The accredited certification programme may allow exceptions like male animals, sick animals and those about to give birth.

2. **Length of conversion period:** Milk and its products may be sold as product of organic dairy only after the dairy farm or relevant part of it has been under conversion for at least 12 months and providing the standards of organic animal production have been met for the appropriate time. The accredited certification programme shall specify the length of the time of which the animal production standards shall have been met. With regards to dairy production, this period will not be less than one month. Animals present of the farm at this time of conversion may be sold for organic meat when the organic standards have been met for one year.
3. **Brought in animal:** When organic dairy animal is not available, the accredited certification programme shall allow the brought in conventional animals. In this case, the calves up to 4 weeks old have received colostrums and are fed a diet containing mainly of whole milk. Accredited certification programmes will set time limits (not exceeding 5 years) for implementation of certified organic animals from conception for each type of animal. Breeding stock may be brought in from conventional farms in the absence of sufficient or suitable animals. A yearly maximum of 10% of adult animals of the same species on the farm is brought in. The accredited certification programme shall allow maximum 10% for brought in breeding stock in the following cases and with specific time limit like unforeseen severe natural or manmade events, considerable enlargement of the farm and establishment of a new type of animal production on the farm or smallholdings.
4. **Breeds and breeding:** The accredited certification programme shall ensure that breeding system is based on breeds that can both copulate and give birth naturally. Artificial insemination is allowed only upon veterinary necessity. Embryo transfer techniques are not allowed. Hormonal treatments for induced heat/birth/pathological conditions are not allowed unless applied to individual animals for medical reasons and under veterinary advice. The use of genetically engineered species of breeds is strictly not allowed.
5. **Mutilations:** Mutilations are not allowed in organic dairy farming. The accredited certification programme shall allow the exceptions like castrations, tail docking, dehorning, ringing, etc.

6. **Animal nutrition:** The accredited certification programme shall draw no standards for feed and feed ingredients. The prevailing part (such as at least more than 50%) of feed shall come from the farm unit itself or shall be produced in co-operation with other organic farms in the region. The accredited certification programmes shall allow exceptions with regard to local conditions under a set time limit for implementation. The feed produced on the farm unit during the first year of organic management be classed as organic. Where it proves impossible to obtain certain feeds from organic farming sources, the accredited certification programme shall allow a percentage of feed consumed by the farm animals to be sourced from conventional farm and should be a maximum of 15% of dry matter intake (DMI) for ruminants and 20% of DMI for non-ruminants and these percentages should be reduced to 10 and 15% of DMI for ruminants and non-ruminants, respectively within 5 years. The accredited certification programme shall allow exceptions to these percentages with specific time limit and conditions in the following cases like unforeseen severe natural or manmade events, extreme weather or climatic conditions, etc. The following products shall not be included/not added to the feed such as synthetic growth promoters and/or stimulants and synthetic preservatives, appetizers, except when used as a processing aid, artificial colouring agents, urea, slaughter house waste as well as all types of excreta & droppings even if they processed by using sophisticated technologies and the feed is subjected to solvent extraction or the addition of chemical agents. Chemically engineered products or organism thereof are not included. Nutritional supplements such as vitamins, trace elements and other supplements are included from natural origin which is maintained in organic farming. Young stock shall be reared by using systems that mainly depends on organic milk, preferably from their own species. But in emergencies, the accredited certification programme shall permit to use the milk from non-organic farming systems of dairy based milk substitutes as long as they do not contain antibiotics or synthetic additives or drugs or hormones.
7. **Veterinary medicine:** The well fare of the animals is the primary consideration in choice of illness/sick treatment. Use of conventional veterinary medicines is allowed when there is no other justifiable alternative is available. If conventional veterinary medicines are used, then the withholding period will be double the legal period as per the standard norms. Use of synthetic growth promoters, hormones or drugs, synthetic substances for production& reproduction, stimulation or suppression of natural growth promoters are prohibited unless used for individual animal treatment or justified by veterinary indications. Legally required vaccines and for those endemic, prevalent and expected diseases, the vaccines are allowed. Genetically engineered vaccines are strictly prohibited.
8. **Transport:** Throughout the different steps of the process and procedure, there will be a person responsible for well fare of the animals. Handling of animals during transport will be calm as well as to be gentle.

Important areas where the policy initiatives need to be taken are

1. Improvisation of organic standards: the present standards for organic production, which is based on IFOAM-Basic standards, should be modified as per to the regional agro-climatic conditions.
2. Development of regional standards to bridge the gap between the national and international standards. Regional standards should be developed to promote the marketing of organic products within the regions.
3. Establishment of a low cost certification agency that the farmers can afford and easy to certify
4. Development of strong domestic market: without a developed suitable domestic market, the benefits of the organic-products produced by producers cannot be protected as international markets are always fluctuating. As such, the urban milk consumers pay significantly higher price (70-80 percent more) for milk, collected from cows of free range or local cows milk which is a fair indicator of their willingness to pay more premium price for quality products.
5. Establishment of a Growth Centres for organic dairy production: Some potential and possible areas of the countries like hilly areas, forest areas and rain fed areas, where agriculture is not so well developed and animal rearing is not intensified, we should be identified and some nodal agencies should be established. These agencies will provide the technical supports to the farmers and will make arrangements for certification as well as will help in marketing. The success of these areas will be a model for the rest of the country.
6. Research and development: organic dairy farming requires research and development in order to apply the most modern knowledge and improve its performance. Universities as well as the research centres should initiate the research programme together with dairy farmers.
7. Training, awareness programme and extension course should be provided to all types of categories of stakeholders of organic farming system starting from producers to consumers in very elaborative way.
8. Government have to make legislation in order to ensure the much needed regulatory framework, where all stakeholders can play on a fair-levelled ground.

Conclusion

India has some excellent indigenous breeds of cattle and buffaloes, possessing higher natural resistance against many prevailing diseases. These breeds are well adapted and adjusted to Indian climate and food availability situations. The Indian livestock owners possess a wealth of indigenous practice and traditional knowledge to treat their animals with locally available herbs or materials. Therefore, they need a little bit training and some incentives for organic dairy farm management that may help them to qualify for organic dairy production. Additionally, converting to organic milk production may be far easier for Indian dairy farmers as compared to their European counterparts where conventional production has increased to very high level of input dependence, overuse of antibiotics, medicines, hormones, pesticides, feed additives, feed preservatives etc. the low external inputs based Indian dairy sector has better opportunities to convert to organic production since majority of Indian farmers are organic dairy farmers not by choice but by tradition. The government policy support, incentives, creating awareness, training, development of strong markets for domestic and export may turn the constraints into a big opportunity.

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Organic Poultry cum Duck Production

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Concept of organic production

FAO/WHO Codex Alimentarius Commission defines organic farming as “a unique production management system which promotes and enhances agro-ecosystem health, including biodiversity, biological cycles and soil biological activity’’. According to livestock standards, birds for slaughter designated as organic must be raised under organic management. Preventive management practices, including the use of vaccines to keep animals healthy, are used; however, antibiotics cannot be used for any reason, and federal regulations prohibit the use of hormones in all poultry. Organic management standards prohibit producers from withholding treatment from a sick or injured animal, but animals treated with a prohibited medication may not be sold as organic. All organically raised animals must have access to the outdoors; they may be temporarily confined only for reasons of health, safety, or to protect soil or water quality. It is a careful and gradual approach to change from conventional to organic management system. In organic poultry local breeds are given due preference. Animal must be born to organically managed dams if they are to be slaughtered for organic meat production.

Status of organic farming in India

Due to the increased health awareness and consumer preferences, organic land area as well as organic poultry farming is increasing day by day throughout the world. Chicken has become the most important organic meat due to its short production cycle, which permits producers to quickly increase supply. Poultry organic meat production has comparatively lower cost of production than other livestock meat. It is of interest to note that organic chicken is only about 20% higher priced than conventional, compared to 30-40% price premiums for other organic meats (Heller, 2006). The demand for research and development efforts in poultry sector is also going up as the world trade in organic poultry products is growing.

India even if a small shift from current conventional production to organic animal production can create a huge market to domestic consumption as well as export. Currently, 130 countries are producing certified organic products. Some developing countries like Argentina, Brazil and Mexico are now exporting organic animal products to the developed countries. Our country has a vast scope for promotion of organic farming in the export market, without compromising with the national food security as farming by tribals and under rainfed conditions is generally organic, since very little chemical inputs are used (NAAS, 2005). Presently, research studies on organic poultry in India are almost nil.

Why organic farming?

The main aim of organic poultry farming is to establish and plant-animal and animal- soil interdependence and to produce a sustainable agro-ecological system based on the local resources. Management of eco system is of important in this farming. Domesticated livestock are integral part of the agriculture cycle that plays a major role to establish organic poultry production. Conversion period is very much required to establish this organic poultry farming.

Strategies for organic farming

Breeding : Breed should be chosen which are adaptable to local conditions. Breeding should be done under natural behaviour and reproduction technique should be natural. Artificial insemination is allowed only upon veterinary guidance (Chander, *et.al*., 2006). Genetically engineered breeds should be avoided. Hormonal treatment for higher meat and egg production should be banned. Availability of appropriate breeds, transport costs and suffocation losses and non availability of hatcheries supplying required small number of chicks are the three major constraints with organic poultry breeding in India.

Housing : Housing in organic poultry production should provide stress free environment for poultry bird to exhibit all its normal behaviour patterns. Stress free birds will stay healthy and has more production capacity. For organic poultry production in European and American countries mobile houses are very popular as compare to fixed housing system. The main advantage of mobile housing is that the birds can be moved to fresh grass areas so that the risk of soil-borne parasites in the outside area can be kept low. However, the costs of mobile housing per unit are likely to be higher than the fixed systems. Further, the scope of mobile housing system in India is very limited due to financial constraints.

Housing should protect the birds from predators. Regular cleaning of poultry sheds is of paramount important to maintain good sanitation. Cage and deep litter rearing is strictly prohibited in organic poultry production. Artificial light might be used as prescribed by the certification agencies. The growing period for organic poultry is 81 days. Poultry must have easy access to an outside grazing area, fresh air, clean water, balanced ration, dust-bathing facilities and an area for scratching. Welfare of poultry is emphasised. De-beaking and beak trimming are usually prohibited practices however, it is permissible and if done, more than 5mm of the upper beak should be removed.

Feeding and watering: Feed for organic poultry production should have the source of 100% organically grown feed ingredients of good quality. All ingredients must be certified as organic, except vitamin and mineral supplements. Poultry should be fed under natural feeding behaviour in accordance to their digestive needs. Chicken are accustom to digest insects, seeds and grain rather than forage. Therefore, the formulation for concentrated balanced feed rations should comprise of organically produced feed ingredients at required level. Maize contributes to the largest component of organic poultry diet. Legumes are supplemented in the feed. Peas, beans and rape seed grown under kitchen garden can be used for feed formulation. Peas have lot of scope in organic feed formulation at 250 and 300g /kg for table chicken and 150 to 20g/kg for laying hens. Oily fish meal is an another protein source as it had higher essential amino acid content as compared to full fat Soya. However, it is costly as well as organic products will have sense of fishy taints. Synthetic amino acids are better replaced with sprouted grains as source of vitamins. Mineral source for organic ration is met through limestone and phosphate rock which will provide needed calcium for egg production. Hence, sound and healthy birds need a balance ration. The birds should be accessed to continuous and quality water without any antibiotic and bacteriological residues. The water should be free from any contamination.

Health management in organic production: Birds will be highly immune towards many infections if all management practices are appropriate. Prompt and adequate treatment should be given to sick birds. The cause for the illness should be found out to prevent the outbreak of disease in future. Management practices must be directed accordingly. Antibiotic should not be used. Vaccinations might be done if diseases cannot be controlled by changing the management. Emphasise must be given on herbal medicines. Coccidiosis and parasitic problems will be highly common in organic poultry production under hot and humid climate. Species specific feed, good housing conditions with proper ventilation and ample space to express natural behaviour along with establishing clean grazing system and dry litter will prevent all health related problems.

Behavioural changes and interventions in organic production: The care and management given by the farmer are important factors to prevent behavioural changes. Observance of behaviour is of more importance in free range/organic production system when hens move around in large flocks. Ample space is very much essential for normal behaviour that is visible in the form of wing flapping and stretching under the suitable areas viz., sand, dust and sun bathing. Sand and dust-bathing are helping in maintenance of hygiene and reduce the number of external parasite considerably. Chicken have a strong pecking ability of recognizing each other in flock of 50-60 birds on the basis of their head form. However, larger groups pose a risk of pecking problems making groups unstable leading to formation of subgroups. Breeding ratio is maintained at one cock for about 4-6 hens in flock. The major behavioural problem is feather pecking and cannibalism. Finding food is another social behaviour of the birds. So, pecking and scratching are the part of normal feeding behaviour. They pass acoustic signals of pecking and scratching acting as a stimulant for other birds in the flock. Sense of test is though poorly developed, the structure and colour of the food influences feeding in birds. Housing system with appropriate space is the main determining factor of these activities.

Record keeping in organic production: Record keeping in organic poultry production includes systematic observance of activities and things with respect to time, evaluation and monitoring for future. This is a potential aid to keep tracking of financial position of the farm business. Important organic farm records are breeding records, purchase registers, formulated organic feed ration record, purchased organic feed record, feed supplements and additives inventory, organic poultry pasture record, health care inventory, sanitation products inventory, organic egg layers monthly flock record, organic meat poultry flock record, organic poultry slaughter/sales summary and monthly organic egg packing/ sales record.

Constraints for organic farming in India

1. Poultry farmers are lacking in clarity of what organic poultry farming.
2. Awareness should be intensified at the production and marketing level.
3. Inadequate Infrastructures like lack of adequate financial support, inadequate local certifying agencies and lack of marketing channels.
4. Obstacles for small and marginal Indian poultry farmers to export organic products are strict measures viz., sanitary conditions, quality and traceability followed by developed countries.
5. In adequate training facilities for poultry farmers.

Important points to be considered in organic production

- *Soil type:* The soil needs to be relatively free draining. Heavy, wet land not only makes access difficult, it also creates more challenges for the birds.
- *Shelter:* Poultry need a sheltered environment.
- *Labour:* Organic poultry production is more labour intensive than conventional systems. The birds are housed in smaller groups, often in mobile housing.
- *Infrastructure:* Water should be available in the house (both at the brooding and rearing stages), and preferably also on the range.
- C*apital:* A considerable amount of capital investment is required to establish a successful and efficient organic poultry production unit of any reasonable size.
- *Feed:* The move towards 100% organic ration, increasing feed prices and the emphasis organic principles place on home grown feed mean that feed is a major consideration when considering setting up or converting to an organic poultry system.

Policy interventions for promotion of organic poultry and ducks

Required regulations should be developed for the development of the organic poultry sector fulfilling the overall objectives of organic farming. Further, national and regional marketing and processing grant schemes for the development of centralized packing and processing facilities must be sanctioned by the government. The capital investment on housing and stocking rate requirements of organic standards must be considered by the government. Except few prescribed standards by international agencies, there are no any formal standards at national level for organic poultry production in India. Indian products are labelled as organic poultry complying with the international / IFOAM standards. However, the IFOAM standards do not specify much detail relating to poultry production, but deal more with general principles. Hence it is necessary for a more critical review of some of these standards with respect to organic poultry for India. Further, it is the need of the hour for the development of the processing and marketing standards for poultry, including the optional use of indications concerning the type of farming (specifically: extensive indoor (barn-reared), free-range, traditional free-range and free range: total freedom).

Researchable issues in organic poultry and duck production

Existing scientific knowledge and practical experience of Indian poultry producer can resolve many of the organic poultry farming issues. However, the following specific research requirements are need to be addressed.

1. Standardise the feed formulae to the nutritional requirements of poultry.
2. Develop slow growing breeds
3. Methods to alleviate the behavioural problems in poultry like feather pecking and cannibalism.
4. Evaluation of production performance under organic production system through examining the relationship between growth potential and productivity, finishing periods and food conversion efficiency under free-range and organic conditions.
5. Tapping the market and fixing premium for organic poultry products are the concern of study of market strategists.

Organic swine production in Andaman & Nicobar Islands

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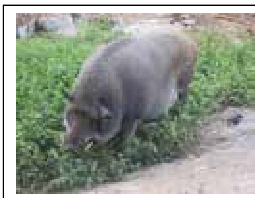
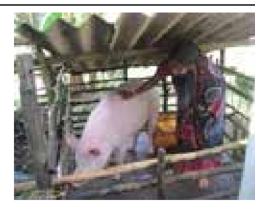
The Andaman and Nicobar group of Islands form the southernmost tip of the Indian subcontinent. These islands are beautiful and unique. The indigenous plants, animals, livestock, and marine life contribute to this uniqueness of these Islands. Animal husbandry and livestock sectors play crucial role in the economic development of the rural India. A quarter of agricultural GDP is contributed by the livestock sector. Livestock are central to rural livelihood and culture. India is endowed with large livestock population, some regard it as an asset provided by nature, but most of the policy makers consider it as a burden. Since 1971, livestock development has been considered as an important tool for eradication of poverty. However, the aim of the programme was to increase the production of livestock commodities for income generation. In these programme it was assumed that the ideal conditions will be provided as followed in the western countries. But the western model was not compatible with the livestock and livestock keeper. As a result, it gave mixed results. Impact assessments of livestock development reports showed no clear mark on eradication of poverty and the adoption of technology by the resource poor farmers had been negligible (Rangenakar, 2006). However, small holder livestock production systems improve livelihood and food security for the poorest people specially the tribal who rear mostly pigs and poultry.

In Indian pigs (*Sus scofra domesticus*) are reared mostly under traditional small scale subsistence production systems with low input and it provide value added output to the farmers using feed which would otherwise be lost. As per the 19th Livestock census, India pig population is recorded to be 10.294 million of which 2.456 million are exotic/ cross bred population. The total livestock population of Andaman and Nicobar Islands as per 2012 livestock census is 154.75 thousand. The pigs constitute 23.06 per cent of the livestock population i.e. 35.68 thousands. However, in Lakshadweep Islands, no pigs were found due to presence of Muslim population only. Four different genetic groups of pigs are available in these islands (i.e. Andaman wild pig, Nicobari pig, crosses of Large White Yorkshire breed and local pig). The Andaman wild pig is not under domestication and is distinctly different from the other three groups.

			
Nicobari Pig	Andaman local Pig	Andaman wild pig	Large White Yorkshire

The indigenous pig named as Nicobari are mostly available in Nicobar group of Islands, having distinct breed characteristics and are mostly preferred by the tribes. Recently the Nicobari pig has been registered as a breed by ICAR-CIARI at ICAR-NBAGAR, Karnal. This breed of pig is unique in nature and is well integrated into the livelihoods of the Nicobari tribes.

Organic Swine Farming

Industrialization of pig production demands confinement of animals with feeding of optimized diets with supplementation of synthetic amino acids along with other nutrients (Dourmad *et al.,* 1999). Most of the feed ingredients are imported as these types of farms are lacking sufficient land to grow the feed required for the farms. Moreover due to insufficient land the slurry are not being used in the farm itself, rather it is being exported. The biological productivity in this system is obviously high. The animal welfare, loss of nutrient and environmental deterioration always remain in question. Organic pig farming emerged as an alternative to this system. It addressed all these issues like animal welfare by allowing the pig's natural behaviour thereby increasing the soil fertility. It helps to integrate the crop-livestock production system for better agro-ecological perspective. Fundamental difference exists in organic and conventional pig production. It is not similar like dairy or beef industries as less numbers of organic pig farms present in even in European countries. Organic pig production requires the use of feedstuffs originating entirely from organic production system. Besides feed, housing poised major challenge for organic pig production. The sows required field for grazing, the grower animals require minimum area for outdoor run. Space requirement for indoor housing is also higher than the conventional production. Organic pig production may be considered as sustainable alternative to conventional system of rearing particularly on consumer point of view. Hence, a need was felt to understand the role of livestock and livelihoods of the resource poor using their production system and perceptions. Mellor (2004) opined that development of small holder production system has better impact on livelihood of the resource poor compared to introduction of western model for development of commercial enterprises.

Organic farming is a type of agriculture that benefits from the recycling and use of natural products. Present day the term 'Organic' is getting popularity among the different sectors. Even increasing population pressure and economic affluence demands more and more animal product. This leads to intensive type of production with the use of fertilizers, pesticides, hormonal compounds and feed additives. Organic livestock system of production differs from conventional systems. In organic systems animals are allowed on a larger housing area (including outdoor areas) having obligatory straw bedding and are with fed organic feed and roughages. This deals with management of livestock and poultry farms, pasture management, feed production and parasitic control. Use of feed additives, chemicals, growth regulators and pesticides are to be avoided. It is based on minimum use of off farm inputs like veterinary drugs for animals' health care and non use of fertilizer and pesticides for fodder production. Use of high input in agriculture resulted green revolution in India. This has reached a plateau and is now sustained only with diminishing return. Thus, a natural balance needs to be maintained at all cost for existence of life. Organic livestock based agriculture may be preferred to reclaim productive land.

Organic pig production refers to use of natural resources for production, rearing and supporting biological cycles within the farming system. However, there was quantum jump in production and productivity in pig due to intensive system of rearing. The use of high end external input supports maximisation of profit from the pig farming. But the current intensive pig production is often associated with environmental pollution. The chemicals and pesticides used in agriculture and pig rearing have ill effects not only on soil health but also on human and pig health. Hence, the conflicts appear how and what degree the innate behaviour of the pigs need to be harnessed for production of sufficient quantities of pork. The Indian piggery has been organic form the very beginning and around 85 percent of the country's piggery are *"organic by default."*

An overview of information on the current state of the art and to support the development of free range systems for fattening pigs with regard to the increasing demand for organic pork is detailed below.

Source of Animals

1. Organically produced pigs must compliance with the regulations prescribed for organic farming.
2. The pigs will be called as organic when the piglets born from the sow or gilts managed organically at least during the last third of gestation.

Feed

Organic pig production requires the use of feedstuffs originating entirely from organic production system. In house or local production, are preferred over the imported feed. However, the following guidelines are broadly indicative for supply of feed in organic pig production.

1. Organically grown feed ingredients like grain and protein sources should be used.
2. It is more cost effective to grow grains than to purchase them from the open market.
3. Synthetic vitamins and minerals could be added in the organic pig ration. Some premixes and supplements contain prohibited substances and thus excluded.
4. It is essential to confirm that ingredient included in the ration should not contain any prohibited substances.
5. Feed ingredients originated from animal origin like tallow, grease, meat and bone meal, feather meal and spray dried plasma are prohibited. The synthetic amino acids like L-lysine, DL-methionine, l-threonine and L-tryptophan are not allowed. Similarly, the exogenous source of enzyme like phytase, some antibiotics and hormones are to be excluded for organic feed ingredient.

Health care

1. Prevention of diseases and maintenance of health of the organic pig is a challenge. Treating diseases with antibiotics are prohibited. However, preventive vaccination with the non-genetically produced vaccines are allowed and encouraged for vaccination to the organically reared pigs.
2. To prevent piglet anaemia, injection of iron is allowed.
3. Feed additives used for health promotion must be avoided in organic production. However, the feed additives such as organic acids, probiotics can be used for animal health.
4. Artificial insemination could be done but the hormones are not allowed for oestrus synchronization.
5. Only the approved parasiticides could be used when the other preventive measures failed or ineffective. Paraciticides should not be used for the breeding stock. If it is required on exigency, it may be used before the last third of gestation.
6. Under emergency condition the parasiticides can be used for the lactating and market animals but the sow, her nursing piglets and market animals would lose their organic significance.

Production System and breeds:

Andaman and Nicobar Islands followed traditional small scale system of pig rearing as has been seen in other tropics. This system of rearing is characterized by high mortality rate, low off take, absence or minimal health care, lack of supplementary feeding and poor housing. Mostly the pigs are reared on scavenging followed by tethering and few are on confinement. In free range system the pigs are supplemented with grass, coconuts, pandanus and bread fruits. In Nicobar group, kitchen waste are not offered to the pigs as it is considered as abusing to the animals.

Figure 5 Difference in health among exotic and indigenous pigs

Figure 6 Tethering system of pig rearing

Figure 7 Pig sty at Nicobar

Tethering system is not followed in Nicobar groups but it is prevalent in Andaman groups of Islands. Intensive system are not followed in these group of Islands but few farmers rear exotic / crossbred pigs fed with supplementary feeding have mixed type of performances. The intensive pig production is economically viable but mixed/ integrated pig farming with cropping system provide good future prospects for economic and sustainable agriculture based on organic agriculture. In these groups of Islands, the pig production has not been fully exploited, among the reasons are, poor sanitation, abysmal health care, disease control and poor nutrition. Indigenous breeds available in these Islands are having valuable traits *viz;* disease resistance, high fertility and early maturity. They can survive in the stressful environmental condition. These are the basis of sustainable agriculture. That is why the traditional pig rearing becomes profitable in these areas. On the contrary, the exotic breeds are unable to cope with the harsh environmental condition and become susceptible to different diseases. They require high quality feeds for their rearing on economical way.

Prevalent Feeding practices

Like many small tropical islands, the main agricultural crops available in Andaman and Nicobar Islands are coconut. The livelihood of these population mostly depends on the income that comes from the coconut plantation. The essential vegetables are being cultivated in their home gardens like yam, bananas and varieties of colocasia. Cereals produced are not sufficient to feed the human population and depends on the imported food grains from the mainland India.

It puts hurdles in production of indigenous pig feeds. The pigs are mostly fed on coconut and its water (Jeyakumar *et al.,* 2007).

Figure 8 A Nicobari tribe going inside forest with incense stick made up of coconut sticks to make their pigs to recognize that their owner are coming to feed them.

Figure 9 Calling the pigs for feeding, by beating the bamboo drum

Figure 10 A member of Tuhet is feeding the pig

They do not prepare any feed (ration) separately for feeding the pigs. However, with this available feeding, the pigs are well grown and fattened. The Nicobari tribes feed the coconut to the pigs by making it in the slice form or breaking the coconut with stone /hammer and mixed it with the kitchen waste (Kundu *et al*., 2009). One member of the Tuhet (In Nicobari language Tuhet means joint family) is assigned to feed the pigs in the morning as well as in the evening. This is the important routine work of the day.At the time of feeding the tribal have very different and distinct ways of calling the pigs e.g. by beating bamboos, producing different sound by shouting at a peculiar high peak or singing particular number of songs etc. These animals soon respond to their owners and come to their respective place of feeding. After feeding, the animals wander back to the jungle for scavenging on ripe pandanus fruits, locally available tuber crops and roots only to return to village/ household premises during night hours. Fish waste is another source of protein, available in these islands but not in sufficient quantities for conventional use, e.g. fish meal production. However, poor quality fish and fish waste, snails and meaty portion of snails are also fed to the pigs by the tribal (Srivastava *et al*., 2002). During low tide, the pigs also scavenge on the sea shore in search of fish, snails, shell fishes, sea faunas and other sea animals. These Nicobari pigs are very much trained to dehusk the ripe coconut and then break the hard nut to eat the coconut kernel.

Housing

In the Islands, it was observed that the pigs were reared under a free range system. During day time, pigs roamed freely in jungles in search of food and in evening, they returned to their respective owners. Two types of night shelter were provided for pigs. In 58% of households, the pigs were housed underneath the tribe's hut. The huts were made in appropriate height from the floor to protect the pigs from heavy rainfall and other inclement weather. On the other hand, in 42% of household, separate indigenous pig sties made of bamboo or other indigenous plant material were provided. The size of the sty varied according to the size of the pig and population. It was observed that, before farrowing, the pregnant sow went to jungles and prepared nests with wild leaves, grasses and some other plant materials.

Figure 11 Pigs are reared under the Nicobari hut

Figure 12 Pig sty made up of locally available materials used for night shelter

Economically important traits of Nicobari Pig

Mature Nicobari pig weighs about 150-200 kg; normally at the age between 12- 15th months. Age at first farrowing, litter size and farrowing intervals are 10-12 months, 6-12 numbers of piglets and 8-10 months, respectively. The colors of body coat are generally Black, black with white patches and some time with brown rusting colour. Two distinct varieties viz, long and short snouted are found. They are relatively resistant to most of the diseases. It is easily managed under open range systems. Pigs are housed below the raised houses of the Nicobari community. But the growth rate of indigenous pig is low probably because of various reasons such as the poor quality of the feed, parasite infection and other diseases as well as the genetic make up.

Prevalence of diseases

Good animal health is a precondition for suitable market in organic pig production. Organic pork mostly produced from small scale production system. An analysis of status of health in organic pig production is required for understating of the health and welfare problems in different organic herds. Parasitic infection is a problem in organic pig production. Prevalence of helminth infestations has been reported in organic pig production. Post weaning problems with endo and ecto-paracitism become the main concern in organic pig production. Lameness was the common clinical symptom found in sow and other type of pigs and respiratory diseases and pleuritis are less in organic pigs than in non-organic pigs. Poor body condition and reproductive problems are frequently encountered in sows. Sometimes diarrhoea caused a problem in the weaned pigs. The major bacterial and viral diseases like swine fever, FMD and swine erysiphalus have not reported in these islands.

Quality of pork: Organic *vs* conventional

Organic foods are considered as healthier than conventional because these are wholesome, absence of chemicals, environmentally-friendliness and better taste. In India, about eighty five percent pork are being produced by the small holder. Hence the pork produced in India is organic by default. But due to lack of organize marketing and proper infrastructure it failed to fetch premium price. The quality of pork both in terms of its physical appearance, taste and method of production determines the price. The quality of pork produced in the organic production system showed lower dressing percentage (76%) in comparison to the intensive concentrate-rich intensive system which is around 80% in most of the cases. The lean meat content is too low in castrates but in case of sows acceptable lean meat are produced which is well comparable with the intensive system. The content of macro-elements such as Na, K, Mg and Ca and some trace elements such as Ni, Fe, Zn and Sr in organic and conventional meat samples showed no difference. However, few trace element concentrations in organic pork were significantly higher compared to conventional pork such as Cr, Mn and Cu.

Conclusion

It may be stated that under the scarcity of feed, the indigenous pigs such as Nicobari pigs are sustainable under present back yard system which is one of the best way of organic production. More efforts should be taken to increase the population size for its conservation and to improve feeding system for higher growth rate and disease control using traditional methods to safe guard from natural calamity.

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Organic goat production in Andaman & Nicobar Islands

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The domestication of animals was carried out by humans during the Neolithic era which started with cultivation of cereals. Goats were considered to be the one of the oldest animal to be domesticated by humans followed by sheep, cattle, pigs, draft animals, horses and asses. The present domesticated goat (*Capra hircus*) is adapted from the wild bezoar ibex (*Capra aegargus*) in western Asia during the Neolithic era between 10,000-11,000 years ago. The farmers of the Neolithic era started keeping small herds of ibexes for their milk and meat, and for their dung for fuel, as well as for materials for clothing and building: hair, bone, skin and ligaments. The evidence of domestication of goat also found in the Harappa toys contains representations of a goat. Two seals from Mohenjo-Daro show a wild bezoar goat with enormous curled horns, and a bearded domestic male goat with side-spreading horns. The Gaddi goat, which greatly resembles the ancestral wild goat, was used as a beast of burden in the mountains and is still used in the Himalayan region of India for carrying salt and food grains.

There are more than 1000 million goats scattered throughout the world and they are found in nearly every country. They are found in all the continents except Antarctica and in a quite astonishing range of environments, from humid tropical rain forests to dry hot desert regions and cold, hypoxic high altitude regions. In India, 28 goat breeds have been characterized and recognized and are registered as separate breed. There are more than a thousand adapted breeds in existence. Almost 90% of the goats are found in developing countries and are considered as the poor man's cow.

Goat production in India

India possesses the second-largest goat population in the world (135.2 million) 2012 census. The population of goat has been increased from 47.2 million in 1951 to 135.2 million in 20I2 with overall growth of 186%. The present agrarian system where the landholding has been decreasing and it is hardly 0.2 ha per capital, goat rearing becomes an important component on the mixed farming system. It is recommended as the best choice for rural and poor people in the developing countries because of less investment, wide acceptability, wide adaptability, high fertility and fecundity, low requirement of nutrients, high feed conversion efficiency, immediate return to the farmers etc. Goat also provides opportunity for livelihood security through income generation, capital storage, improving household nutrition. Goat rearing is also considered as backbone of the marginal and small farmers where more than 40% of the farmers are directly dependent for livelihood security. With the present population of goat, it provides supplementary income to almost 70 million farmes of over 5.0 lakhs remote villages. The meat production of goat has also increased from 0.47 to 0.59 million tons during the last decade (2002 to 2011) with overall growth rate of 2.4%. Similarly, the growth of milk was also recorded to the tune of 3.6 to 4.7 million tones with 2.6% growth rate. India records first in goat milk production and second largest goat meat production in the world. Goat contributes approximately 8.4 % to the livestock GDP through milk, meat, hides, skin and manures. It also generates about 4.2% of the rural employment to the small, marginal and landless labourers.

Goat production in A & N Islands

Goat (65324) constitutes about 42.21% of the total livestock population (154733) in the Andaman & Nicobar Islands and is an integral part of the livestock system and are mostly owned by settlers and distributed in different island (19th Livestock Census;2012). However, there is decrease of 3.18% (67472) population over that of the previous census (2007). There are four distinct populations of goats in these islands, *viz*. Andaman local goat, Teressa goat, Malabari and its crosses and Barren Islands goats. All the goats available are of meat type and there is high demand for chevon in these islands. The price of the goat meat ranges between □ 600-700 per kg and this shows great demand for goat and its products. The goats constitute an important productive asset of landless, marginal, and small landholders of these islands and it generates a flow of income and employment throughout the year. Majority of goats in these islands resemble Black Bengal and were brought from Bengal and adjacent areas in different phases of inhabitation and rehabilitation of migrated/settled people. These goats are well adapted to the island condition and are widely distributed throughout Andaman Islands. These goats are locally called as Andaman Local Goat. Andaman Local Goats (ALG) is an indigenous goat of this islands and are usually reared by the settlers under extensive/semi intensive system. Teressa goats are being reared by the Nicobari tribal farmers and are mostly found in the Nicobar Islands.

The population of the Andaman local goat is approximately 57480 and Teressa goat is about 8000. Flock size ranges from 5 to 35 with average of 8.38 per family. The percentage of singles, twins and triplets were 57.14, 75.71 and 4.28 respectively in the present population under study. Age at first mating, weight at first mating, age at first kidding, weight at first kidding, service period, kidding interval and gestation period was 260 ±15.0 days, 8.49±0.89 kg, 420.0 ±12.0 days, 13.26±1.61kg, 101.20±11.23 days, 300.0 ± 20.0 days and 147.0± 2.0 days respectively. The common disease observed in the goats was contagious ecthyma (orf), tetanus, coccidiosis, pox etc. Mortality % ranged from 2.28 % to 10.06 %. The risk of extinction of the breed is increasing in these islands due to decrease in the number of breedable male and reduction in the total population. Generally, farmers are selling goats (irrespective of male and female) at the age of 7 months onwards due to which there is lack of superior breeding animals for improvement in the breed status.

Teressa goats are reared mostly under free range system and for days together they reside in the forest and after some time they come near the shelter. Limited numbers of tribes maintains these goats under semi-intensive system. All the tribal farmers allowed their goats for free range / open grazing in the coconut plantation and inside the thick forest. The goats were mostly fed with coconut leaves, tree fodders, dried coconut and oil extracted coconut. Teressa goats are reared under free range or semi intensive system. They are mainly resting underneath the tribal's hut/ shelter.

Production systems

In India goat is being reared by mostly small, marginal and landless laborers mainly by the women. The production system varies with the region to region and with socio, cultural and economic condition of the goat farmers. Basically the following production system is being followed. *Tethering:* This is a common practice mainly followed in the humid and sub-humid zones, where because of intensive cropping; it is convenient to rear the goats in controlled conditions with minimum requirement of labour. It is thus a sedentary system. It is mainly practiced by women and children's and where the herd size is low (5-10). *Extensive production*: This system of rearing is mainly practiced by farmers of low rainfall region where the land is marginal and is plentiful. In this system, goats are mainly let loose for grazing and browsing the plants and are mainly followed by the nomadic people. The system is used by nomadic people, usually in very low rainfall areas or during winter months when crop residues are available. *Intensive production:* In this system, the goats are reared in confinement and fed with feed and fodders with limited access to the grazing land. This system involves high input cost with labour, shed and feed cost. The main advantage in the system is control over the animals. *Semi-intensive production*: This is the main system followed by most of the farmers with nature and extends to integration depends upon the type of crops grown and their suitability to the goats. The advantages of this system are increased fertility of land via the return of dung and urine, control of waste herbage growth, reduced fertilizer usage, easier crop management, increased crop yields, and greater economic returns.

Organic goat production

The definition of "organic" would include something along the lines of, not using pesticides, artificial fertilizers or any addition that mother earth does not provide the food we eat today. The history of organic goat production dates back to the Neolithic era when the goats were reared in a small herd for the requirement of meat, milk, hides, skin bone etc. During this era, the goat farming was purely based on organic. However, with the revolution of mechanical (1880-1930) and chemical (1920–1950) agriculture greatly influenced the modern day livestock farming predominantly in non-organic form. Rudolf Steiner (1861–1925) is considered to be one of the founders of organic farming. He proposed the concept of biodynamic agriculture in 1924. Biodynamic agriculture comprises an ecological and sustainable farming system that includes many of the ideas of organic farming. Biodynamic agriculture emphasized the individualization of the farm by bringing in no or few outside materials. Modem day organic farming started in 1950s and major development taking place in 1970s. Certification agencies for organic started in 1980s. Creation of certification bodies occurred in the 1980s. During the last decade the growth of organic farming has been very tremendous with overall global turnover of US$ 40 billion in 2006. Sixty-nine countries have a regulation on organic agriculture, while 21 are drafting one. There are currently more than 468 organic certifiers in the world. A recent and significant development in organic agriculture is the increase in wild collection.

Area occupies under organic agriculture production is largest in Australia with 12.4 m ha and smallest in Africa with 0.4 m ha. In terms of land use in organic agriculture, permanent grassland represents more than 60% globally, implying the significance of organic livestock production. Arable land, permanent crops, cropland, and land without information of use make up the rest. There has been considerable increase in the land area under organic agriculture from 7 m ha in 1998 to more than 37 m ha in 2009. This development is particularly significant in extensive livestock production, including goats. It provides a rapid transition to organic production and expands opportunities for farmers in marginal land areas. Data on organic goat production are very little. European Union certified almost 2.4 m goats or 2.4 % of the total sheep and goat population as organic. The majority of the goat population in the Europe is in Greece and Italy. The international federation for organic farming is the International Federation of Organic Agriculture Movement (IFOAM) which certifies and promotes the organic brand. Presently, 108 countries are member in this forum. There are many other seals used throughout the world for similar distinctions and purposes such as USDA Organic, Australian Certified Organic, INDOCERT in India, Organic Farming in Europe, JAS in Japan, Bio Gro Organic Certified in New Zealand, BIO in Germany, and Organic in China. One of the most important aspects of organic goat production is the certification process which means certain industry standards are compulsory. These standards may vary from country to country, although the guiding principles appear to be similar.

Production system in organic goat farming

Rotational system where housing/ shelter is provided in different paddocks. Goats are moved frequently or seasonally. This prevents building up of parasites to the environment from overgrazing. Provision of shelter and a large exercise area, where feed and browse are brought to the animals. Goat should always be allowed plenty of space for running and jumping. A goat barn with access to different grazing areas. In winter animals are confined to a smaller outdoor exercise area. Barns should be well ventilated and be kept dry with plenty of bedding. Goats are generally quite hardy animals if fed adequate fiber. If shed are too well insulated the goats will never develop the winter undercoat and will prefer to be indoors rather than outside.

Important aspect of organic goat production

The essential elements for a successful organic goat production include feeding, breeding, reproduction, health, welfare environment, vegetation and workers.

- For a successful organic goat production, pastures must be certified organic and maintained in a purely organic way, i.e. without the use of pesticides, herbicides, insecticides, chemical fertilizers and other restricted materials.
- The feed (hay, grain, milk replacer etc) given to the does and kids must be organically certified and free from chemical residues. Therefore, the feed/fodders should be given which are being grown in organically and free from synthetic hormones, antibiotics, coccidiostats, urea, or other restricted materials.
- Even the care must be taken to provide the bedding material (straws etc) should be free from any chemical residues.
- The animals should not be treated with antibiotics, anthelmintics, growth implants, or other prohibited materials. However, breeding does can be dewormed with ivermectin only based on the faecal egg count but not on a routine preventative does.
- Pregnant does during the last third of gestation and does during lactation should be avoided. Vaccinations are acceptable.
- Records must be maintained on feed and health care.
- Identification of animals is required throughout the life cycle.

Organically-produced animal is not the same as naturally-raised, free-range, or grass-fed. In Europe, the use of deworming of small ruminants with targeted use of anthemlminitc and cocodistats is allowed due to the fact that the total natural control of internal parasite is difficult. It is generally more expensive to produce products organically in goats. The producers must recognize that organic feeds are not always readily available, and more land is generally needed. Organic dairy goat production can be productive and sustainable. Studies suggested that higher yields are possible in organic dairy goat production subject to pasture condition. The pasture should be free from the worm eggs and free from any chemical residues. It is also possible to control intra-mammary infection and improve the quality of milk without the usage of drugs and maintain optimum level of milk production with quality.

Management of disease and infection

Foot infection: make sure shelter and yards are clean and dry. Good drainage is important. Trim feet regularly once in every six weeks

Mastitis: Homeopathic remedies like Belladona, Aconite, Apic mellifica, Bryonia Alba, Arnica Montana, Phytolacca etc can be used. Herbal product like Mastilap cream can be used externally.

External parasites: Neem oil and Ash can be used.

Skin infection: Aloe Vera as a food additive can be used. Some herbal cream or capsules can be used.

Poisoning: Goats with regular access to a wide variety of plants will be selective and not eat excessively of poisonous plants. However, those which break out from confinement are more likely to be poisoned.

Effect of organic goat production

Meat production: Studies suggested that there is no obvious difference in the production efficiency or carcass quality between organic and conventional goat production. In case of organically produce meat there is less chance of accumulation of internal fat around the heart and kidneys. There is slower rate of weight gain but heavier market weight.

Fiber production: Very little information is available on the effect on fiber production. Studies suggested that yield of meat and cashmere could be improved by feeding the kids until 20 months (19 kg) in organic production system. There is possibility of high value cashmere production and biological control of weeds.

Nutritional implications: **N**utrition plays an important role in the organic goat production. The synchronization of protein and energy in the feed to achieve optimal microbial synthesis in the rumen is very important. Studies suggested that supplementation of protein can improve the resistance of goats against the parasites. The supplementation of protein boosts the immune system to fight against the parasites in the organic goat production. In the organic production system this can be challenging when goats are on pasture and rely mainly on grazing. Understanding of nutrition, eating behavior and seasonal interaction can also be beneficial to improve production efficiency. The role of secondary metabolites such as tannins and tanniferous plants has implications in organic goat production. Anthelmintic effect of neem was also reported by many workers in the organic goat production system. Cultivation and feeding of legumes can be important in organic goat farming systems because of its abilities to fix the nitrogen in the soil, increased soil fertility, stability, nutrient recycling, and control of weed species and also provides a high protein diet to the goat.

Since the use of chemicals is prohibited in the organic goat production, alternatives such as plants and its derivatives are useful for treatment and control of many diseases without any side effects. Some of the important plants which are useful in the organic goat production are :black cumin, black walnut, boundary tree, common mugwort, common wormwood, crucifers, custard tree, eucalyptus, Eurasian wormwood, fargara, fennel, fern, fumitory garlic, Gambian mahagony, goosefoot, Indian lilac, kamala tree, neem tree, papaya, pinkroot, pumpkin, pyrethrum, sacred basil, southern wormwood, tansy, tarragon, wild carrot, and wild ginger, legumes (sainfoin, sulla, lotus corniculatus, lotus pedunculatus, dorycnium, chicory) and woody plants (heather, oak, hazel tree, brambles). These plant species can be promising in parasite and disease prevention, control and treatment in organic goat production.

With the grazing management the internal parasites and diseases can also be controlled. These include preventive (turning out parasite free animals on clean pastures), evasive (worm challenge is evaded by moving animals from contaminated to clean pastures) and diluting (worm challenge is relieved by diluting pasture infectivity) strategies.

Post-harvest processing: Care should be taken to avoid the contamination of organically produced meat and milk at the time of processing. No chemical preservatives, flavoring agents etc should be mixed while processing the organically produced meat and milk. Organic meat cannot come into contact with non-organic meat during processing and no synthetic materials can be used during the processing of organic meat and meat products.

Marketing: The main considerations by the consumers for purchase of the organically produced products are its quality, price, appearance/freshness, taste and family health. More than 40% of the consumer population identified quality and price as important consideration. In just about every member of the EU-25, more than 50% of consumers worried about the welfare of farm animals, implying consumers' willingness to pay a premium to improve animal welfare.

Food security: There has been a concern that shifting towards organic production may results in decrease in food security, decrease in production and productivity. It has been projected that there may be modest impacts on global commodity prices, production, and trade by organic farming. In an international conference it was concluded that organic agriculture could actually contribute to global food security but its potential to do so depends greatly on political will. The organic production will definitely lessen the impact of climate change through carbon sequestration, improve drinking water quality and security through decreased irrigation needs in organic soils, increase agro-biodiversity, enhance nutritional adequacy with more diverse and micronutrient rich organic foods, and achieve rural development generating income and employment in areas where people have no alternative other than using labor, local resources and indigenous knowledge.

Sustainability and animal welfare: The issues of animal welfare mainly for treatment against disease, injury, veterinary aid etc are some of the concern which could be a challenge in the organic goat production. The standards for animal welfare in organic goat production are yet to be defined. A number of issues related to sustainability that included landscape degradation, degradation of communal pastures, abandonment of marginal lands, low levels of integration between agriculture and livestock, land fragmentation, great dependence of farmers on purchased feedstuffs, reduced diversity and increased specialization in monocropping, numerical reduction of local breeds and populations, large incidence of parasite disease and necessity of preventive and curative chemical treatments, high incidence of clinical and subclinical mastitis, high incidence of other diseases, and high variability of milk quality. To improve sustainability of organic small ruminant production identified breeding strategies, feed management and disease control for small ruminants as important focus. Possible alternatives to chemoprophylaxis should be available to control helminth diseases, such as the use of homeopathic treatment, and the improvement of genetic resistance to parasite infections.

Opportunities and challenges

There are several opportunities for the organic goat production:

- Promising for the goat production in the marginal land.
- Enhance in income generation.
- Opportunity for global market for organically produce cheese, meat, fibre etc.
- Investment and input cost on energy is low.
- Scope for alternative medicine as a result of restriction on the use of chemicals.
- Research opportunities such as emerging health issues, welfare and production constraints; epidemiological surveillance of key production diseases; breeding studies on disease resistance and commercial traits, nutritional deficiencies in organic systems, livestock breeding, biological control and the use of novel plants and plant extracts, development of animal welfare assessment methods, and development of welfare-friendly production systems.

Challenges

- Challenge will be to prevent and control the disease.
- More land will be requiring for grazing and use of organically grown fodder and pastures.
- Due to the extensive use of grazing for organic goat production, mineral deficiencies as a result of soil characteristics and pasture management system should be important considerations
- Prevention of fraud and quality assurance for organic goat dairy, meat and fiber products will continue to be a concern for consumers.

Conclusion

Organic goat production can improve animal welfare, protect the environment, and in long run may change the lifestyle. Traditional goat faming with use of alternate medicines, homeopathy, ayurveda, medicinal plants for treatment and growth holds the promise for alternate prevention and treatment of diseases. The future of organic goat production is totally depends upon the alternatives that are environment friendly, safe without any residual effects. The goat farming in India is being generally reared by marginal and small farmers in rural areas and are directly dependent for their livelihood. Therefore, shifting towards organic farming should be done by understanding and considering the socio-economic, livelihood, ecological and animal welfare perspectives issues and political will.

Organic Fodder and Feed Production

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Crop- Livestock Farming- Legacy & New Era

Indian agriculture can largely be characterized as rainfed small holders production system, putting a special significance to livestock in attaining sustainability, resilience (hedging risk) and creation of livelihood. Crop livestock system is one way of optimizing output from limited land and other resources of production. In mixed crop-livestock production system, dairy production contributes 20 to 50% of family income. The share of livestock for under privileged marginal and landless livestock owner is as high as 70 to 80% during drought year. Livestock rearing is drought-proofing strategy for farmers of arid and semi-arid region. It also provides input for crop production, transport of produce and people as well as fuel cakes, which largely remains, unaccounted. This calls for priority to take up research to improve livelihood and income under these mixed farming situations.

Crop and livestock are raised in close vicinity and symbiotically in our country. Since the domestication of animals, their products and by-products have been used as food, fuel and fertilizer. Indian farmers were basically organic farmers before the advent of inorganic fertilizers and pesticides. Over the years, the use of these synthetic inputs has come to the level of causing concern to the environment and human health. Consequently, it was felt necessary to advocate the use of age old practice of organic farming not only to ensure uncontaminated food production but also to sustain the agriculture by keeping the land healthy. Consumers have started demanding organic food and to meet the growing demand, it is essential to develop eco-friendly technologies, which can sustain or increase the agricultural productivity and be made available to the farmers. With the increase in population, the demand of food, feed and fodder also increases which necessitated the increased use of fertilizers and pesticides to boost production which resulted in negative side effects like development of secondary salinity, decreasing soil fertility, growing insect resistance to pesticides and increased cost of production. Consequently, interest in organic agriculture as an eco-friendly system of cultivation is growing at both national and global levels. This shift towards organic production is supported by health conscious consumers who are ready to pay extra price for certified organic products.

With the advance pace of development, the livestock productions need to be more efficient. Very fast changes that are being introduced into farming environment, creates imbalances in natural regulation, i.e. in the mechanism of animal organism which negatively influence their health and efficiency. Meat or milk produced from intensive system contains chemical residues causing threat to consumer health. Such concerns of modern day livestock production system gave birth to various new concept like organic livestock farming, natural farming, do nothing agriculture, biodynamic agriculture or greener pasture meat/milk production etc. Organic food grain production is gaining momentum in India by the efforts of different agencies, but organic fodder production has not yet taken off all through as an integral part of livestock production. Organic livestock production towards organic agriculture, is slowly gaining momentum because of increasing consumers awareness and the increasing demand for organic milk and meat.

Feed and fodder scenario

Livestock is an integral component of farming in the country since it is a regular source of income, employment of the farm family and finally leads to improvement in livelihood of 60-70 percent human population of the country. But the productivity of Indian livestock is low mainly due to poor availability of fodder, feed and concentrates. Due to huge livestock population (512 million numbers in 2012), demand for feed and fodder resources are increasing. At present, India faces a net deficit of 35.6% green fodder, 10.95% dry crop residues and 44% concentrate feed ingredients and the demand for green and dry fodder will reach to 1012 and 631 million tonnes by the year 2050 (IGFRI Vision 2050). Further, there are also seasonal and regional imbalances in the fodder production in the country. This gap in demand and supply may further rise due to consistent growth of livestock population at the rate of 1.23% in the coming years. Composition of livestock is also changing with shift towards small ruminants due to high growth in meat sector. Buffalos and goats are attaining major importance.

A vast array of fodder crops viz., pearl millet, sorghum, cowpea, maize, rice bean, lucerne, berseem, oat and different perennial grasses namely guinea, BN hybrid etc. may be taken up in intensive fodder production system or in suitable crop rotation to supply regular and quality fodder. The total area under cultivated fodder is only 8.4 m ha (5.23%) which is static since last two decades. The fodder production in the country is not sufficient to meet the requirements of the growing livestock population and also the forages offered to animal are mostly of poor quality. By adopting suitable crops/ cropping system, economical green fodder may be ensured for the livestock during whole the year.

Organic Farming and Peri-urban Dairy's

Urbanization has brought a marked shift in feeding habits of people towards milk, meat and eggs with the consequential increase in demand of livestock products. Meat and milk consumption will grow at 2.8 and 3.3 per cent per annum, respectively, in developing countries like India. The human population in India is expected to reach over 1531.4 m and 30% urban population is poised to increase by over 75% by 2050. The demand for milk and meat will be around 400 and

14 m t, respectively in the year 2050; whereas the production in 2011 was about 122 and 6 m t, respectively. Global organic food demand is accelerating day by day, so is the demand of organic milk, meat and poultry. Urbanization has also brought a marked shift in the lifestyle of people and people tend to change their food habits towards organic food with resultant increase in demand for more organic livestock products. Peri-urban livestock production and commensurate increase in demand of fodder and changing scenario of small-unorganized fodder market into large organized fodder market need attention of R&D in forage crops.

Concept of organic fodder production and development

The organic fodder and feed production connotes the definition of FAO "Organic agriculture is a unique production management system which promotes and enhances agro-ecosystem health, including biodiversity, biological cycles and soil biological activity, and this is accomplished by using on-farm agronomic, biological and mechanical methods in exclusion of all synthetic off-farm inputs" In Indian context, "it is a method of farming system which is primarily aimed at cultivating the land and raising crops in such a way, as to keep the soil alive and in good health by use of organic wastes (crop, animal, farm waste and aquatic wastes) and other biological materials along with beneficial microbes (bio-fertilizers) to release nutrients to crops for increasing production in an eco friendly, pollution free environment" (RBDC, Imphal, 2006). Organic fodder and feed production is undertaken with following major objectives:

- To produce fodder and feed of high nutritional quality in sufficient quantity.
- To work with natural systems rather than seeking to dominate them.
- To encourage and enhance the biological cycle within farming system involving soil microorganism, soil flora and fauna, plants and animals.
- To maintain and increase the long term fertility of soil.
- To maintain genetic diversity of Agricultural system and its surroundings.
- To use, as far as, possible renewable sources of energy.
- To avoid all forms of pollution that may result from conventional agricultural technology.
- To give all livestock conditions of life that may allow them to perform all aspects of their innate behaviours.
- To allow agricultural producer adequate return and satisfaction from their work and safe working environment.

Organic farming standards, guidelines and regulations

Organic forage and livestock production is not new in India. It is successfully being practiced in rainfed, tribal and hilly tracts of the country since time immemorial. However, it gained momentum and attention among consumers, farmers, corporates, policy makers and agricultural scientists in recent times due to marketing opportunities, health consciousness and ecosystem services.

Presently the organic forage production is practiced at limited scale due to limited scope of organic dairying in the country. However, with more demand of organic milk, meat and dairy products from health conscious elite consumers, organic forage production gaining momentum in the country. Large numbers of farmers started opting organic forage and livestock production either individually or in groups in Rajasthan, Gujarat, Tamilnadu, Maharastra, Haryana, Punjab, Chattisgarh and North Eastern states. Now the organized organic way of livestock rearing is gaining popularity particularly in peri-urban areas.

The (IFOAM) Basic Standards define how organic products are grown, produced, processed and handled. These are presented as general principles, recommendations and basic standards and provide a framework for certification bodies and standard setting organization worldwide to develop their own certification standards. The country specific certification standards take into account specific local conditions and provide more specific requirements than IFOAM Basic Standards. The Codex Alimentations Commission (FAO, 2001), a joint FAO and WHO Food Standards Programme, began in 1991 elaborating guidelines for the production, processing, labelling and marketing of organically produced food. The requirements in these Codex Guidelines are in line with IFOAM Basic Standards and the EU Regulation for organic food. This Codex document is an important step in the harmonization of international rules in order to build up consumer trust.

Indian guidelines

To provide a focussed and well directed development of organic agriculture and quality products, Ministry of Commerce and Industry, Government of India launched the National Programme on Organic Production (NPOP) in 2000, which was formally notified in October 2001 under the Foreign Trade and Development Act. This document provides information on all aspects of organic production in India. These standards and procedures have been formulated in harmony with international standards such as those of Codex and IFOAM and keeping Indian requirement in mind. In 1999, the Codex Ad Hoc Intergovernmental Task Force on Animal Feeding was established with a view to develop a code of practice on safe animal feeding. At present, variety of organic products grown and production increased on a large scale, which included agricultural as well as livestock products with low residue levels (Table 1).

Table1: Maximum Residue Limits (mg/kg) of pesticides in milk and meat

Pesticide	MRL in milk	MRL in meat
Total DDT	0.05	5.0
Endosulfan	0.004	0.4
Cypermethrin	0.05	1.0
Chlorpyriphos	0.01	2.0
Carbaryl	0.1	0.2
Cyfluthrin	0.01	-
Dicofol	0.1	-
Fenpropathrin	0.1	0.5
Fenthion	0.02	2.0

Source: Dairy India: 2003

Key characteristics of organic fodder production

The Ministry of Commerce under the "National Programme for Organic Production" has prescribed National Standards for Organic Production applicable in India. These standards are grouped under following six categories: 1) Conversion; 2) Crop production; 3) Animal husbandry 4) Processing and handling; 5) Labelling and 6) Storage and transport

Conversion

The time between the start of organic cultivation and management of crops or animal husbandry is known as the conversion period. The whole farm including the livestock should follow the standards over a period of time. All standard requirements should be met during conversion period. Regular inspections during conversion period should be carried out. Full conversion period is not required where organic farming practices are already in use. But this has to be verified by the inspection agency. Organic certification is based on continuance. The certification programme should certify the production, which is likely to be maintained on a long term basis. The converted land and animals shall not get switched back and forth between organic and conventional management. The certification programme shall set standards for a minimum percentage of the farm area to facilitate biodiversity and nature conservation.

Crop Production

i. *Choice of crops and varieties*: All seeds and planting materials should be certified organic, well adapted to local climatic conditions and resistant to pests and diseases. If certified organic seed or planting material is not available then chemically untreated conventional materials can be used. Uses of genetically engineered seeds, pollens, transgenic plants are not allowed. The minimum conversion period for plant product produce annually is 12 months prior to the start of the production cycle. For perennial plants, the conversion period is 18 months from the starting of organic management. Depending on ecological situation, the certification agency can extend or reduce the minimum conversion period.

ii. *Diversity in crop production*: It is achieved by a combination of versatile crop rotation with legumes and by appropriate coverage of the soil with diverse plant species during the year of production. Cropping systems should be selected in such a way that it should also help in stability and sustainability of soil fertility in long run, minimize harbouring of insect-pest and diseases.

   a) Guinea grass / NB hybrid + (Cowpea – Berseem/ lucerne): Punjab, Haryana, Himachal Pradesh, Jammu & Kashmir, West Bengal, Jharkhand, Uttar Pradesh, Uttarakhand, Madhya Pradesh, Chhattisgarh, Orissa

   b) Guinea grass /NB hybrid + (Rice bean/Cowpea – Lucerne/Berseem): West Bengal, Jharkhand, Andhra Pradesh, Maharashtra, Rajasthan, Karnataka, Goa, Tamil Nadu, Kerala, Costal/islands regions

   c) Other cropping systems :Rice-Berseem, Sorghum-Berseem, Sorghum + Cowpea –Berseem + Mustard, Maize/rice/sorghum/green gram/soybean – Lucerne, Cowpea + Maize (fodder) – Lucerne, Sorghum (grain) – Lucerne - Maize (fodder), Rice/maize – Shaftal , Maize + Cowpea - shaftal , Sorghum – Lathyrus + mustard, Sorghum –Oat + Lathyrus, Rice – Lathyrus, Sorghum + Cowpea – Oat, Sorghum – Oat + Berseem, Maize + Cowpea – Oats – Maize + Cowpea, Sorghum – Oat (multicut).

iii. *Nutrient management*: Biodegradable material of plant or animal origin produced on organic farms should form the basis of fertilization policy. Emphasis should be given to generate and use own on-farm organic fertilizers. Brought in fertilizers of biological origin should be supplementary but not replacement. In case of deficiency, mineral fertilizers can be used as supplementary source and should be applied in their natural composition. Biofertilizers can be used safely under all ecosystems and in all the crops.

iv. *Pest disease and weed management* : Weeds, pest and diseases should be controlled by a number of preventive cultural techniques, such as suitable rotations, green manuring, balanced fertilization programme, mulching, mechanical control and the disturbances of pest development cycles. Botanical pesticides prepared at farm from local plants, animals or microorganisms are allowed. Use of synthetic chemicals such as fungicides, herbicides, synthetic growth regulators and dyes are prohibited. Use of genetically engineered organisms or products is prohibited.

v. *Contamination control*: All attempts should be made to minimize contamination and from outside and with in farm.

vi. *Soil and water conservation*: Soil and water resources should be handled in a sustainable manner to avoid erosion, salinization, excessive and improper use of water and the pollution of surface and ground water.

Animal Husbandry

i. *Maintenance/ rearing of animals*: The certification programme shall ensure that the management of animal environment takes into account the behavioral needs of the animal and provides for sufficient free movement, sufficient fresh air and day light, protection against excessive sunlight, temperature, rain, wind etc., enough lying and resting space, ample fresh water and feed and proper environment for their biological and ethological needs. Landless animal husbandry system shall not be allowed.

ii. *Length of conversion period*: The whole farm including livestock should be converted to organic according to the standards. Animal products may be certified organic only after the farm has been under the conversion for at least 12 months and the required standards have been achieved. Length of the conversion period can be extended at the discretion of the certification agency. In case of dairy, the conversion period shall be 30 days at minimum.

iii. *New animals*: All organic animals should be born and raised on the organic holding. When organic livestock is not available the certification programme shall allow brought in animals according to the specified age limits e.g. calves up to 4 weeks old which have received colostrum and fed a diet consisting mainly of full milk.

iv. *Breeds and breeding:* Breed should be chosen which are adapted to the local conditions. Breeding goals should not be in opposition to animal's natural behaviour and be directed towards good health. Artificial insemination is allowed but embryo transfers are not allowed. Hormonal heat treatment and induced birth are not allowed. Use of genetically engineered species or breeds is not allowed.

v. *Mutilations*: Mutilation of animal in any form is not allowed except castration, tail docking in lamb, dehorning and ringing etc.

vi. *Animal nutrition:* The livestock should be fed 100% organically grown feed of good quality. All feed should come from the farm itself or be procured from the region. Where it proves impossible to obtain certain feed from organic farming sources, the certification programme shall allow a percentage of feed consumed by animal to be sources from conventional farms subject to a maximum prescribed limit. Synthetic growth promoters or stimulant, synthetic appetizers, preservatives, artificial coloring agents, urea, farm animal by products to ruminants, droppings, dung or manure, pure amino acids and genetically engineered organisms or their products are strictly prohibited in feeds. Vitamins, trace elements and supplements shall be used from natural origin. For fodder conservation bacteria, fungi and enzymes, by products of food industry and plant based products can be used.

vii. *Veterinary medicines:* Prevention is better than cure. Common vaccination shall be used and legally required vaccine is allowed. Genetically engineered vaccines are prohibited. Natural medicines and methods including homeopathy, ayurvedic, unani medicines and acupuncture shall be emphasized. Conventional veterinary medicines are allowed when no other justifiable alternatives are available, but in all such cases withholding period should be double the legal period. Use of synthetic growth promoters, stimulants or suppression drugs and hormone inducers are prohibited.

Processing and Handling

Organic products should be protected from co-mingling with non-organic products. For storage controlled atmosphere viz. cooling, freezing, drying and humidity regulations are allowed. Prevention methods such as disruption, elimination of pest habitat, mechanical, physical and biological methods are allowed. Processing method should be based on mechanized, physical and biological processes so that the qualities of organic ingredients are maintained through the processes.

Packaging

Materials used in packaging should be eco-friendly. Recycling and reusable systems should be used. Packaging material should be biodegradable and it should not contaminate the product.

Labelling

If full standard requirements are met, the product can be sold as organic. Certification agency can permit the use of "India Organic" logo on the product.

Storage and Transport

Product integrity should be maintained in storage and transport of product. Organic products must be protected from co-mingling with non-organic product in storage.

Nutrient management in organic fodder production

Organic nutrient management is a prerequisite of organic forage, milk and meat production which avoids or largely excludes the use of synthetic inputs (such as fertilizers, pesticides, hormones, feed additives etc) and to the maximum extent feasible rely upon crop rotations, crop residues, animal manures, off-farm organic waste and biological system of nutrient mobilization and plant protection.Organic manure will be the main source of nutrients in the system. Following components are very important for organic fodder and feed production: 1) Use of FYM on the basis of nitrogen requirement for fodder production for animals under organic production system; 2) Liquid manure through fermentation of green leafy materials, and cattle urine from the system; 3) Use of compost dung, vermi-compost and vermin-wash; 4) Biologically derived nutrients- mulching, composting, N-enriched Phospho-composting, biological pesticides etc. and 6) Green manuring (*Sesbania*, Sunnhemp, cowpea). As per the National Standard, the following (Table 2) are some of the materials allowed either fully or in restricted way under organic production.

Table 2: Organic nutritional inputs as permitted/restricted by National Standard

S.No.	Origin	Materials	Production level	Status of acceptance
1	Plant	Crop residue Green manure Plant residue compost Sea weed extracts Saw dust	On farm unit On farm unit On farm unit On farm unit On farm unit	Permitted Permitted Permitted Restricted Restricted
2	Animal	Dung and urine of livestock Poultry manure FYM and slurry Blood, meat, bone and leather meal	On farm unit On farm unit On & out farm unit ---	Permitted Permitted Out farm restricted Restricted
3	Microbial	Bio-fertilizer	-	-
4	Minerals	Rock Phosphate Trace Elements Basic slag	-	Restricted Restricted Restricted
5	Others	Industrial by-products Saw dust Organic house compost		Restricted Restricted Restricted

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Parasite management - Green" Ruminant Production System

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Initially we are bound to endorse organic farming wherein the soil, plant, animals and human beings are linked with each other. In philosophical terms, organic farming means "farming in sprits of organic relationship". In this system all the components are linked with other. Therefore, its goal is to create an integrated, environmentally sound, safe and economically sustainable agriculture production system. Since organic farming means placing framing on integral relationship and therefore, we should be well aware about the relationship link:

- Between soil, water and plants.
- Between soil-soil microbes and waste products, between the vegetable kingdom and the animal kingdom of which the apex animals is the human being.
- Between Agriculture and Forestry.
- Between soil, water and atmosphere.

Therefore, this is the totality of these relationships that is the bedrock of organic farming.

On the other hand organic animal husbandry is defined as a system of livestock productions that promotes the use of organic and biodegradable inputs from the ecosystem in terms of animal nutrition, animal health, animal housing and judicious animal breeding. The output of organic livestock productions systems are organic milk, meat, eggs and leather products.

Global scenario suggests that organic agriculture is being practised in 170 countries of the world covering 43.1 million ha with annual market of US $72 billion. In India too, the cultivated area under certified organic farming have grown almost 17 fold in last one decade. With over 6,50,000 organic farmers, India ranked 1st in the world in terms of producers. India exported 135 organic products during 2013-2014 with the total volume of 194088 tonnes including 16322 tonnes organic textiles. After getting the encouraging result in XIIth V year plan, Government of India launched *Paramparagat Krishi Vikas Yojna*, under which Rs. 300 crores (union budget 2015-16) have been allocated to promote organic agriculture including organic animal husbandry. Further the organic livestock and poultry standards have also been notified for implementation since 1st June 2015.

When we look into the details of organic livestock production system we find that there are some primary and obligatory characteristics of organic livestock production systems which includes:

- Well defined standards and practices which can be verified.
- Greater attention has to be paid to animal's welfare.
- No routine use of growth promoters, animal offal, prophylactic antibiotics or any other additives.
- At least 80% of the animal feed should be grown according to organic standards, without the use of artificial fertilizers or pesticides on crops or grass.

In normal Animal Husbandry practises, this has been seen that internal parasitic infection especially Nematodes parasites are responsible for severe economic and production losses to ruminants livestock producers. To overcome the issue livestock producers used synthetic dewormers which are a hindrance for organic livestock production system. To overcome the issue two approaches are in vogue namely: Host – stage – directed – Non chemical approaches to parasite control and Free-living-stage-directed- non-chemical approaches to parasite control.

Host – stage – directed – Non chemical approaches to parasite control

a) **Development of genetically resistance hosts:**

This is one of the approaches to come up with solution for green ruminant production system which does not require extra resources and additional cost. But unfortunately resistant livestock population does not have desirable economic traits in terms of either wool or meat production. The resistant breed is mainly seen in the tropics where animals suffer from malnutrition, environmental stress, long term and often massive larval challenge and also undergo limited anthelmintic therapy. This phenomenon actually proves the well known theorem of survival of the fittest

Now-a-days scientist and researchers are trying their level best to identify candidate genes which encodes resistance phenomenon against parasites in laboratory models. With the help of comparative genetic maps scientists and researchers are trying to identify and characterise genes in ruminants which are responsible for resistance phenomenon against nematodes parasites. Thus ultimately the main aim will be to develop transgenic animals in which genes for resistance are inserted into economically productive breeds.

a. **Immunoprophylaxis**

Till date vaccines against nematode parasite has been shown to have limited success except the development of irradiated vaccine against cattle lung worm and sheep lung worm infection. But due to some technical and scientific obstacle the vaccines have been discontinued and era has come to develop vaccines using the aid of recombinant DNA technology. This is really a misfortune that recombinant vaccines against nematodes couldn't be developed successfully due to some hurdles which includes difficulty in production of antigenic fractions of parasite materials on commercial basis. Besides due to complexity of host immune response to parasite seems to be another obstacle for development of successful nematode vaccines. In simple language of immune programming this involves a combined response of local hypersensitive reaction; both cell mediated and humoral immune response as well as inflammatory reactions. This is further complicated by natural unresponsiveness that exists in the young animals (<6 to 9 months) and in the dam around parturition.

b. **Host nutrition**

The profitability of any grazing livestock industry is driven largely by product output. This translates into raising more animals on any given area to produce more meat, fibre and hides. Thus, man – made changes to herd or flock structure result in more reproducing females and their progeny. For ruminant livestock, both the lactating female and the young animal are the most susceptible to nematode infections. Depending on the age and metabolic condition of animals, food resources are allocated among their body functions such as maintenance, growth and reproduction, but also additional functions which are a direct consequence of parasite infection. Studies on the patho-physiology of internal parasite infection show a metabolic drain cost by an increasing endogenous loss of protein and a reduced efficiency in the utilization of metabolizable energy due to parasite infection.

Clearly, the increase in parasite challenge associated with contemporary livestock production systems must come at a price with regards to animal productivity, particularly at times of sub – optimal nutrient supply, when the animal has to prioritize the allocation of scarce nutritional resources. Strategic feed supplementation, particularly to young and peri-parturient animals, can have long term benefits, and research is now targeted at fine - tuning the ways, means and timing of doing this that would be practical, profitable and, if needed, acceptable to the organic standards.

c. **Herbal anthelmintic**

Anthelmintic medication has its origin in the use of plant preparations. In general, these were hazardous concoctions with low anthelmintic efficacy especially in ruminant species, and they rapidly disappeared from human and veterinary use with the discovery of synthetic anthelmintic compounds.

Although a large and diverse range of herbal de-wormers is used throughout the world, particularly in Asian and African countries, generally there is a lack of scientific validation of the purported anthelmintic effects of these products. In ruminants, the claimed efficacy is often associated with farmers observing the occasional elimination of tape worm segments which has little bearing on production, let alone parasite control.

There is considerable and apparently expanding interest worldwide in traditional health practices in both the industrialized and developing countries of the world, including herbal de-wormers. A role for these compounds in the green farming movement of developed countries is difficult to envisage because marketing of products with a high level of efficacy will inevitably be accompanied by regulatory requirements on residue levels, human safely, and so on, and will then, particularly in the organic farming context, become quasi-natural and regarded as medical prevention. However, for resource- poor farmers in developing countries, traditional herbal remedies based on local plants offer an alternative to the expensive and often in accessible commercial anthelmintic studies are now under-way to evaluate some of the "best candidates" used as livestock de-worming preparations by resource- poor communities in east Africa or Asia.

A particular group of compounds, the cysteine proteinases, has been mentioned as having potential for a noble group of anthelmintics, as they might damage the cuticle of nematodes. The parent compounds are present in plants such as papaya, pineapple and figs and have a documentated effect in several host species against variety nematodes. However, their mode of action is not very specific and the safety index (maximal tolerated dose/recommended therapeutic dose) is expected to be low.

d. **Nutraceuticals**

This refers to crops containing plant secondary metabolites (or nutricines) , which are considered for their beneficial effect upon health rather than their direct contribution to the nutrition of animals. The crops are either grazed or fed after preservation, with the main purpose of reducing parasite infections, and ideally they can be incorporated inot crop rotation schemes.

A specific group of plant polyphenols, the condensed tannins, has attracted attention in recent years. Initial studies in sheep showed that grazing leguminous crop rich in these compounds resulted in reduced levels of GI-nematode infection. The main effect of dietary condensed tannins in both sheep and goats reduced in faecal egg counts, often in the order of 50 to 60%, based on a combination of reduced worm fecundity and elimination of adult worms. They might also play a role in reducing the establishment incoming larvae. The effect on worm burdens is variable and apparently species dependent. For example, the administration of quebracho, an extract of condensed tannins, might reduce nematode burdens of the small intestine (*Trichostrongylus colubriformis*), but those of the abomasum (*Haemonchus contortus; Teladorsagia circumcincta*). The epidemiological importance of reduced faecal egg counts continues to be investigated.

Grazing of chicory (*Chichorium intybus*) by infected sheep has shown some promising results, particularly with regard to reduction in abomasal worm burdens. Chicory is not a tannin – rich crop but it contains other compounds (e.g. sesquiterpene lactones), which have demonstrated anti-parasitic properties *in-vitro.*

The variable outcome of many studies using nutraceuticals is probably related to many factors affecting the production (quantity and composition) of secondary metabolites in the crops: soil type, climate, season, cultivar, cutting, grazing, and so on. More knowledge on these factors and on interactions with host nutrition is necessary for future utilization. However in certain areas(e.g. the Mediterranean region of Europe), there is along tradition of growing tannin-rich legumes such as sulla (*Hedysarum coronarium*) and sainfoin (*Onobrychus viciifolia*); thus, the nutraceutical approach to parasite control is worth pursuing.

2. Free-living-stage-directed non-chemical approaches to parasite control

a. Grazing management

It's important to put calves on ground that hasn't had cattle on it for at least six months. Rotating them through pastures so they aren't overexposed to larvae, keeps infestation to a minimum. Having pasture heights in the 6-10 inch range, removing them when grass is no shorter than 2 inches and not forcing the calves to graze close to manure piles will also prevent infestation.

A better way of grazing these pastures, and one that will also allow more utilization of forage is to have the young calves graze through, followed by older cows whose immune systems are fully developed. Calves will be more selective than older cows, grazing the most nutritious and most palatable forage. Older cows will still get excellent nutrition but will eat more of the available forage. The rest period will allow forages to regrow and soil organisms to degrade and remove manure. Calves under the age of 5 months should not regraze those pastures that year. Further these concepts became established in the applied veterinary parasitology jargon, with the epithet of 'dose-and-move strategies'. Although this combination of anthelmintic treatment with a move of animals to pastures with low infectivity proved to be highly effective from a parasite control standpoint, it later became apparent in certain localities that these procedures selected strongly for anthelmintic resistance in surviving parasites. However, it has been shown that not all grazing management strategies to control parasites need to be accompanied by anthelmintic treatment to achieve extremely good levels of parasite control for either young cattle or sheep. A word of caution also needs to be raised on relying on long-term sheep/cattle interchange systems: there have been reports that parasites primarily of cattle might show an increased ability to infect sheep and cause clinical disease.

In comparison with the temperate regions of the world, there are relatively few examples of grazing management schemes in the tropics/subtropics, even though their potential might be even greater in this region. This is because, despite the fact that development of the free-living stages of parasites is generally faster and more successful than in the temperate regions, their longevity is much shorter. Highly successful grazing systems have been developed whereby sheep (or goats) are moved to a new area of pasture after 3-4 days of grazing and are not returned to this area for approximately one month.

b. Biological control

Currently, the work on biological control of nematode parasites of livestock is almost exclusively associated with the nematode-destroying microfungus *Duddingtonia flagrans*. The microfungus has three very important attributes: (i) The ability to survive gut passage of livestock; (ii) The propensity to grow rapidly in freshly deposited dung; and (iii) The possession of a voracious nematophagous capacity. This fungus thus breaks the life cycle by capturing infective larval stages before they migrate from dung to pasture, where they would otherwise be acquired by grazing animals.

Field evaluation of this concept for a range of livestock species, in a variety of geo-climatic regions, has been under-way for the past decade. At the same time, several potential stumbling blocks on the path towards product registration have been overcome. First, it is now possible to produce large quantities of *D. flagrans* spore material; second, long-term field trials using *D. flagrans* have shown no adverse effects on the environment; and third, it has been established that *D. flagrans* is ubiquitous and that very close genetic similarity exists between isolates from all regions of the world.

The commonly used means of development of *D. flagrans* spore material is by a feed additive. To achieve optimal results, the fungal spores need to be continuously shed in the dung of animals at the same time that contamination of pasture with parasite eggs occurs. Thus, daily supplementation of fungal material is recommended during the predetermined period of time that biological control is to be effected. Clearly, much greater opportunities for this innovation would occur if effective methods of *D. flagrans* depot delivery were available. Although work has been conducted aimed at developing fungal feed blocks, and fungal-controlled release devices, at this stage none of these prototype devices provide the effective parasite control (continuous spore release) for the minimum required time of at least two months in temperate environments.

The Future

Most of the farmers in the globe will opt for organic farming because organic produces are costly and for the future generation consumption of organic product will lead to good health. Inevitably, animal productivity will suffer, which might well lead to serious animal welfare problems, due principally to pasture-borne nematode parasites. Livestock owners need to be well informed or willing to seek expert advice, on ways to manage their flocks or herds in relation to the epidemiology and impact of parasite infections in different ages or classes of animals.

The range of non-chemical approaches to nematode parasite control outlined in this brief review varies in their utility, stage of development, practicality and relevance. Also, the type of livestock enterprise and the country/region of the world will have a bearing on their adoption. However, one thing is certain: no single method on its own can be expected to provide satisfactory, Sustainable parasite control more-or-less indefinity. The challenge therefore is to utilize a combination of these strategies, yet importantly to recognise that there should be pragmatic flexibility in these programs, allowing for the possible need of occasional, selective use of effective anthelmintics.

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Organic Aquaculture

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Aquaculture is growing more rapidly than all other animal food producing sectors in the world. Aquaculture gains momentum over capture fisheries owing to the dwindling harvest obtained from capture fisheries. On the other hand, intensive aquaculture practices generate profit and also lead to various environmental impacts and increased risks to food safety owing to high stocking density of fish, increased use of commercial formulated feed containing synthetic product, antibiotic and other harmful pharmaceuticals products (Holmer et al., 2008; Tacon and Metian, 2008). Concern on health and environmental awareness, food safety and growing demand in developed countries are the driving forces for the development of organic products. Indiscriminate use of chemicals and pesticides in conventional food production technology along with increased health consciousness of the consumers strongly demands the emergence of organic farming methods in agriculture and aquaculture.

The fish that are produced under natural conditions according to the organic agricultural principles, not exposed to any protective additives or genetic modification, fed with completely natural materials and certificated by a control agency are called as organic fish (Otles et al., 2010). Organic aquaculture is the farming of aquatic animals without using antibiotics, chemicals and fertilizers by preserving the ecosystem and biodiversity (Dube and Chanu, 2012) and also every stage of the production process is controlled and certified by the control or certification agency according to the regulations of organic agriculture (Otles et al., 2010). It ensures that the farming activity is in harmony with the nature, with due care for good health and welfare of the cultured organisms.

The total global organic aquaculture production has been increased from 5000 tonnes during 2000 to 53,500 tonnes during 2008 with a market value of US$ 300 million and dominated by salmon, shrimp and common carp, produced by 240 certified organic aquaculture operations in 29 different countries (IFOAM EU Group, 2010; Bergleiter et al., 2009). It was also estimated that the production of certified organic aquaculture products will reach 1.2 million tons by 2030 (Tacon and Brister, 2002) which further reiterate the ever growing importance of organic aquaculture.

Standards on Organic Aquaculture

Organic fish production was started with the earliest standard established for common carp (*Cyprinus carpio*) during 1994 by Bio Entre, a certification company in Austria and the first organic trout entered the market in England during 1998 (Xie et al., 2013; Otles et al., 2010). The first national general standards for organic aquaculture were established by France and the United Kingdom during 2000 (Bergleiter et al., 2009). Apart from these standards, the guidelines for organic aquaculture production have been privately developed in various countries such as Switzerland's Bio-Suisse, Austria's Bioernte, Germany's Naturland, Norway's Debio, UK's Soil Association, New-Zealand's Bio Grow, Sweden's KRAV, Europe-Gap Aqua-Gap, Australia's NAASA and China's OFDC (KRAV, 2001; NASAA, 2001; Naturland, 2002; OFDC, 2002; Dube and Chanu, 2012; Otles et al., 2010). The International Federation of Organic Agricultural Movement (IFOAM) is a global umbrella body for organic food and farming. IFOAM's Organic Guarantee System (OGS) is designed to facilitate the development of organic standards and third-party certification (Dube and Chanu, 2012).

At present, around 80 different organic aquaculture standards exist with a major stack of 18 are present in the countries of the European Union (EU) and the standards vary considerably between country, certifier and species (Bergleiter et al., 2009; Xie et al., 2013). Organic farming areas are mostly limited to Europe (46.7%), Asia (35.5% mainly China) and Latin America (13.1%) (Prein et al., 2012) and the organic aquaculture production is primarily dominated by Europe where certified organic salmon, carp and trout are cultured and traded. Likewise, certified organic mussels, tiger shrimp, white shrimp and tilapia are also cultured in various places like Vietnam, Peru, Ecuador, Chile, New Zealand and Israel (Datta, 2012).

Principles of Organic Aquaculture

The main principles of organic aquaculture standards include the absence of genetically modified organisms in stocks and feed prime material, limitation of stocking density, origin of vegetal feed and fertilizer from organic certified enterprise, no artificial feed ingredients, no use of inorganic fertilizers, no use of synthetic pesticides and herbicides, restriction on energy consumption like aeration, preference for natural medicines, intensive monitoring of environmental impact, protection of surrounding ecosystem and integration of natural plant communities in farm management and processing according to organic principle as basic requirement for a final product to be certified as organic (Dube and Chanu, 2012).

Organic Aquaculture in India

The organic aquaculture was first initiated in India during 2007 through India Organic Aquaculture Project (IOAP) by Marine Products Export Development Agency (MPEDA) with the technical consultancy from Blueyou of Swiss Import Promotion Programme (SIPPO), Switzerland. The project was implemented in Andhra Pradesh and Kerala with Naturland of Germany as the certifying agency and INDOCERT in Kerala as the inspection body (Dube and Chanu, 2012). The project has also successfully developed certified stakeholders in organic aquaculture such as certified organic scampi hatchery

(M/s Rosen Fisheries, Thrissur), certified organic feed mill (M/s Waterbase Limited, Nellore) and certified organic seafood processor (M/s Jagadeesh Marine Exports, Bhimavaram).

Under the IOAP, scampi or giant freshwater prawn (*Macrobrachium rosenbergii*) farms with a water spread area of 20 hectares in Kuttanad, Kerala owned by four individual farmers have been stocked with 3,40,000 organic scampi seeds. Organic farming operations have been successful and the world's first organic scampi harvest has taken place during 2008 at Kuttanad, Kerala with a production of atleast 1,000 to 1,500 kg from each farm (Dube and Chanu, 2012). Likewise, another study conducted at Kuttanad, Kerala under IOAP on organic farming of rice and freshwater prawns in rotational cropping system revealed 20% higher revenues (Nair et al., 2014).

In Andhra Pradesh, organic scampi farming was carried out by the farmers of two societies in West Godavari District with the support of National Centre for Sustainable Aquaculture (NaCSA) and IOAP, MPEDA. A total of 27 farmers from Sri Venkateswara Aqua Farmers Welfare Society, Matsyapuri and Sri Sainadha Aqua Farmers Welfare Society, Velivela were involved in the project covering 31 ha area. Both the societies were cluster certified by Naturland for organic scampi farming which is the first of its kind in aquaculture. A total of 12.6 tons of organic scampi was produced during 2009 with an average production of 407 kg/ ha and profit of Rs. 55,495/ hectare from these societies (Anonymous, 2010).

An experiment on the efficacy of organic carp farming found that feed conversion ratio, specific growth rate and total production of Indian major carps (IMCs) were significantly higher in organic culture system than conventional and normal culture systems. Water quality parameters were found to present in the desirable range in organic culture system which indicates that carp farming in organic culture system will improve the fish production and also maintain good water quality (Beg et al., 2016).

Status of Aquaculture in ANI

Freshwater aquaculture is the most accepted and demanding sector among the fish farmers in Andaman and Nicobar Islands (ANI) owing to high local demand and reasonable price in the local markets. The total water spread area for pisciculture of 152.98 ha is occupied by 2,237 ponds. The major cultivable species like Indian major carps namely, catla (*Catla catla*), rohu (*Labeo rohita*), mrigal (*Cirrhinus mrigal*), Chinese carps namely, silver carp (*Hypophthalmicthys molitrix*), common carp (*Cyprinus carpio*), grass carp (*Ctenopharyngodon idella*), other fishes like magur (*Clarias batrachus*), singhi (*Heteropneustes fossilis*) and giant freshwater prawn (*Macrobrachium rosenbergii*) (Fig. 1) are also being reared along with tilapia, puntius, murrels and the populations of several invasive species such as pangas catfish, *Pangasianodon hypophthalmus* and pacu, *Piaractus brachypomus* were also recorded (Rajan and Sreeraj, 2014). The potential freshwater resources in the form of rivers, reservoirs and streams in the bay islands are not utilized fully for the purpose of aquaculture. There are 7 reservoirs covering an area of 367 ha in the Islands, which meet the freshwater requirement of the Islanders for domestic as well as farming purposes including aquaculture. The total inland fish catch of ANI during 2012 was 193 tons mainly contributed by carps, catfishes and other miscellaneous species of less importance (Anonymous, 2014).

Fig. 1: Cultured species in freshwater aquaculture of ANI. (a). Rohu; (b). Freshwater prawn; (c). Catla

Fish culture of these islands are extensive based, due to which the production and productivity is low. Ponds are rain fed unlike pump fed in mainland conditions which has certain limitations in management and preparation aspects of ponds for fish culture. Scientific interventions are much required in case of fish seed availability, feed requirement and water quality management aspects. An integration of agriculture with aquaculture has been achieved through land shaping activities, which offered additional profit to the farmers.

The seeds of IMCs are produced through induced breeding by ICAR-CIARI, Fisheries Department of ANI Administration and also by a few farmers (Fig. 2) in North and South Andaman to meet the requirement of freshwater fish farmers of these islands. Many household have backyard ponds and integrated farming systems, in which fish place an important component (Fig. 3). The major issue is the non-availability of ponds (nursery, rearing and stocking pond) to the farmers for fish culture to be followed throughout their life stages in such ponds, from spawn to adult stage. Because farmers had only one backyard pond, their demands were mostly to stock the spawns obtained from external sources and to practice extensive management, in as much as the spawns would be dependent on naturally available food. Also, relaxation in stocking densities of the spawns or fry in ponds led to overcrowding and non-availability of natural food through competition further causes less production or mortality.

Fig. 2: Fish seed production by the farmers of ANI

Fig. 3: Integrated fish farm in North Andaman

Prospects of Organic Aquaculture in ANI

The use of on farm biological and mechanical methods and exclusion of synthetic off farm inputs forms the central dogma of organic farming. Since Indian major carps and Chinese carps require plankton as source of food, the essential nutrients for the phytoplankton growth are nitrogen and phosphorus and their accessible source are organic and chemical fertilizers. Application of cow dung, compost, animal excretes are known organic sources wherein chemical fertilizers like urea, SSP/ TSP are other available sources. Inorganic fertilizers are not being used generally as ponds are managed under extensive system which purely depends on the naturally available food source.

Pond management practices such as insect removal, weed removal are the other areas for which chemicals are used. In India, soap oil emulsion being a popular remedy for eradicating insects wherein chemical treatments are available for weed removals. In both the cases, manual removal of weeds by hands and use of repeated netting to remove insects are to be recommended. To a large extent, weeds and insects are not removed in ponds except some nursery ponds where insects are removed through netting to avoid mortality of spawns by insects. Hence recommendations of using manual methods to remove weeds, insects and weed fishes through netting could be the best way to avoid using chemical treatments. Use of potassium permanganate as disinfectant is one of the important chemical applications being used in island aquaculture. Use of synthetic hormones for induced breeding can also be replaced by use of pituitary gland extracts. However, collection of pituitary glands in requisite quantity could be cumbersome due to availability of fishes in the islands and their shelf life is also limited. Necessary interventions in this area to replace synthetic hormones for induced breeding could be thought of as an alternative.

Integrated fish farming systems with animal and agri-based systems can take care of nutritional requirement and pond productivity as cow dung and manure provides huge quantity of organic inputs necessary for fish culture. There is also a vast potential available for rice-fish/ prawn culture practice in ANI (Fig. 4). Mariculture activities such as cage farming and other coastal aquaculture practices mainly depend on animal protein as major feed ingredient and inclusion of other plant based ingredients could supplement their growth and resolve the use of off farm inputs. However, alternative method needs to be thought for shrimp farming as they are normally reared in high density intensive practices and depends more on artificial feeds to satisfy their nutritional need and high harvest. Shrimp farming in ANI is currently not being practiced and in future, if shrimp farming takes off, then they are to be hugely dependent on artificial feeds only and suitable plans are to be evolved for such scenario in future if the islands are to be under organic farming. Hence organic aquaculture could be well implemented in the islands as the existing fish culture practices are in tune with the mandate of organic aquaculture with few required interventions will supplement the production cycle.

Fig. 4: Rice-fish culture farm in Middle Andaman

Advantages of Organic Aquaculture

- Sustainability.
- Food safety.
- Environmental responsibility.
- Traceability.
- Optimized productivity.

Disadvantages of Organic Aquaculture

- Time and cost of the certification process.
- More labour intensive.

- Higher production cost.
- High risk of disease during culture process.
- Low volume of production.
- Uncertain benefits and premium marketing tie up.

Conclusion

Organic farming advocates several benefits in terms of product quality, health and environmental protection. As compared to organic agriculture, the development of organic aquaculture is still in its infancy. Various issues in organic aquaculture need to be resolved on priority basis. A lot of scope exists for further development due to efficient production, low stocking density, restricted chemical application and certified production, which is very well received by the consumers all over the world. With increased purchasing power and heightened ecological awareness, the demand for organic aquaculture products by major importing countries such as Europe and USA is on the rise. With constant emphasis, organic aquaculture will emerge as the most eco-friendly and efficient form of agriculture and contributes to sustainable development.

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Mangrove and their utility to farming

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Mangroves act as a buffer zone between sea and shore, protecting the shore from erosion and also play a valuable role as a shield from disasters like cyclone and tsunami. Mangroves are unique ecosystems occurring along the sheltered inter-tidal coastlines, mudflats, riverbanks in association with the brackish water margin between land and sea in tropical and subtropical areas. They sustain diverse flora and fauna species in large proportion and provide many ecosystem services such as coastal protection from storm, reduction of shoreline and riverbank erosion, stabilizing sediments and absorption of pollutants. Mangroves are the breeding and nursery grounds for many wildlife species including many fishes, crustaceans and mollusc population. Thus the habitat loss of this unique ecosystem has direct repercussions in the fishery of the region. India has approximately 7,00,000 ha of area covered by mangroves along the estuaries and major deltas. Mangrove biodiversity and conservation has received significant importance in the recent past as research has increased the understanding of values, functions and attributes of mangrove ecosystems and the role they play in providing important ecological services and livelihoods for the mangrove associated communities. Besides ecological importance in trapping and accreting sediment material to reduce the erosion, mangrove ecosystem plays a significant role in Aquaculture. The fishery potential of these areas is tremendous and provide livelihood to the coastal population as well.

Mangrove

Mangroves are extraordinary tropical forests with unique ecosystems that grow at the mudflats, riverbanks and the edge of the land and sea. According to (Lalji Singh, 2012) mangroves are specialized marine ecosystem of a group of salt tolerant plants found in tropical and subtropical intertidal regions of the world. The specific regions where these plants occur are termed as 'mangrove ecosystem' and are highly productive but extremely sensitive and fragile.

Mangrove Biodiversity

Mangroves represent a rich and high diverse natural resource. Mangroves are home to many uniquely adapted biodiversity. The mangrove ecosystem plays a key role by providing the link between marine and terrestrial ecosystems. This link provides and maintains the stability, not only to the mangrove habitats itself, but also to the other related coastal ecosystems, such as sea grass beds, coral reefs. This ecosystem plays a significant role in replenishing various fish populations for the coastal and lagoon fish industry. The nutrients given to the lagoon as a detritus from the mangrove ecosystem is carried in to the coastal waters by the tidal currents. They become food for marine micro-organisms, which is the first step of the marine food chain. The shallow inter-tidal reaches that characterize the mangrove wetlands offer refuge and nursery grounds for juvenile fish, crabs, shrimps, and molluscs. Mangroves are also prime nesting and migratory sites for hundreds of bird species. Additionally, fishing cats, monitor lizards, sea turtles, and mud-skipper fish use the mangrove wetlands as their habitat. The major genera that represent mangrove species are *Avicennia, Rhizophora, Bruguiera,* and *Sonneratia.* According to mangrove abundance and distribution, they can be categorized as very common, common, and rare. The common category of mangrove species include *Aegiceras corniculatum*, *Avicennia officinalis*, *A.marina*, *Bruguiera cylindrica*, *B. sexangula*, *B. gymnorrhiza, B. parviflora, Ceriopstagal*, *Heritiera littoralis*, *Lumnitzera littorea*, *L. racemosa, Rhizophora apiculata*, *R.mucronata, R. stylosa, Pemphisa cidula*, *Xylocarpus granatum*, *Sonneratia alba*, *Nypa fruticans, Phoenix paludosa*. Out of 45 mangrove species occurring in India, 34 true mangrove species are accounted in Andaman Islands (Dam Roy *et al.,* 2009) while others are considered as 'associated' flora. The most dominant mangrove species found along the east and west coast of India are; *Rhizophora mucronata, R. apiculata, Bruguiera gymnorrhiza, B. parviflora, Sonneratia alba, S. caseolaris, Cariopstagal, Heretiera littoralis, Xylocarpus granatum, X. molluscensis, Excoecaria agallocha, Lumnitzera racemosa, Avicennia officinalis, A. marina.*

Social Benefits of Mangrove

The mangrove ecosystems stabilize coastlines, protect communities from storms, provide critical habitats for many animals, and store vast amounts of carbon. In many coastal areas, communities are still critically dependent on the ecosystem services mangroves provide. However despite their numerous benefits, mangrove forests were once considered wastelands of little value, and forests all over the world have been cleared for aquaculture, agriculture, urban infrastructure and coastal development. The result is that today, mangroves are a rare and increasingly threatened habitat.

Commercial and Economic Benefits of Mangrove

Mangrove forests are extremely important coastal resources and are vital for the socio – economic upliftment of the coastal population as they depend on the available resource for their livelihood. The mangrove area are the sources for highly valued commercial products and fishery resources besides giving scope for development eco – friendly tourism activities (Katheresan and Bingham, 2001) whereas Barber and Strand (1998) have reported 70 direct human activities ranging from fuel wood collection to fisheries from the mangrove forest areas.

In India, mangrove trees are used for house building, furniture and certain household items. Mangrove trees have been the source of firewood in India since ancient time. Tannin is extracted from the bark of some mangrove species like

Rhizophora mucronata, Bruguiera gymnorrhiza and Ceriopstagal. Indian mangrove trees have 35% tannin in their bark which is higher compared to other countries. Extracts from mangrove bark are used by Indian fishermen to dye their fishing net and enhance its durability. Honey collection from the mangrove forest is a promising business in India. It has been estimated that Sundarbans mangrove alone produce 111 tons of honey annually and this accounts for about90% of honey production among the mangroves of India (Krishnamurthy, l990). In Bark and roots of *Aegicera corniculatum and Derris heterophylla* are used as mild fish poison. *Avicennia* spp., *Phoenix paludosa and Sonneratia caseolaris* are used for human consumption and as cattle feed. *Nypa fruticans* is tapped for an alcoholic drink.

The mangroves also supply forestry products (firewood, charcoal, timber, honey *etc*.) and fishery products (fish, prawn, crab, mollusc *etc*.).

The mangrove wood with high content of tannin is used as timber for its durability. The pneumatophores are used to make bottle stoppers and floats. *Nypa* leaves are used to thatch roofs, mats and baskets. Shells of mangrove molluscs are used to manufacture lime.

Mangrove extracts are used in indigenous medicine; for example, *Bruguiera* species (leaves) are used for reducing blood pressures and *Excoecaria agallocha* for the treatment of leprosy and epilepsy. Roots and stems of *Derris trifoliate* are used for narcotizing fishes, whereas *Acanthus ilicifolius* is used in the treatment of rheumatic disorders. Seeds of *Xylocarpus* species have anti diarrhoeal properties and *Avicennia* species have tonic effect, whereas *Ceriops* produce haemostatic activity. Barks of *Rhizophora*s species have astringent, anti diarrhoea and antiemetic activities. Tender leaves of *Acrostichum* are used as a vegetable and a beverage is prepared from the fruits of *Sonneratia* spp.

Mangrove and fishery

The mangrove areas have shallow water levels, warm water temperatures due to various decaying activities and the water flow is slow and hence ideal place for growing of algae and for spawning for fish and marine animals. They are breeding, feeding and nursery grounds for many estuarine and marine organisms. The penaeid prawn life cycle involves the estuarine or near shore habitat phase in the post larvae to juvenile where they spend 6-20 weeks and then migrate to offshore where they breed. The mangroves are the nursery grounds for most of the penaeid prawns. Mangroves provide nursery habitat for many wildlife species, including commercial fish and crustaceans, and thus contribute to sustaining the local abundance of fish and shellfish populations (Lal, 1990). In Selangor, Malaysia 119 species were recorded as associated with mangrove ecosystems while 83 species were recorded in Kenya, 133 from Queens land Australia, 59 species in Puerto Rico and 128 from the Philippines (Chong, 1990). In the Pichavaram mangroves alone nurture 30 species of prawns, 30 species of crabs, 20 species of molluscs and 200 species of fish were recorded (Kathiresan, 2000). Seventy-five percent of the game fish and ninety percent of the commercial species in South Florida are dependent on mangrove ecosystems (Law and Pyrell, 2006).

In the mangrove area the fishery is dominated by detriti vorous species of fishes, crabs, crustaceans and molluscs. Nearly 80% of the fish catches are directly or indirectly dependent on mangrove and other coastal ecosystems worldwide (Kjerfve & Macintosh, 1997). Some of the most common fishes in Indian mangrove waters are Liza. Mugil, Lates, Lutjanussp, Hilsa sp, Etroplussuratensis etc. A special group of fish species found abundantly in the mangroves are the mudskippers (Family Periopthalmidae) which are physiologically and morphologically adapted to an amphibious existence in this intertidal zone with variable environmental conditions.(Clayton, 1993). Prawns are represented by *Penaeus indicus*, *P. merguiensis* and *P. monodon* and *Metapenaeus* species while the crabs are represented mainly by *Scylla serrata*, *Uca* sp**.**, *Thalassina,* etc. The molluscans of mangrove waters are mainly represented by *Crassostrea madrasensis*, *Gelonia* sp and the gastropod *Cerethedia* sp.

Mangroves provide two noticeable facilities for fishes. The aerial roots establish a protected habitat for larvae and early juveniles and secondly the litter fall forms the source for the detrital food web on which many fish depend. The fish larvae in the marine plankton when it meets a suitable habitat will metamorphose into their juvenile forms within mangrove and sea grass habitats and thus recruits to the fishery. As juveniles grow into young adults they often continue to forage in mangrove and sea grass communities, until final migration back to open reef environments, where they will spawn and renew the cycle. The fishes are represented by several species like the mud skippers, carangids, clupeids, serranids, mullets, hilsa, seabass, milkfish etc.

Mangrove and coastal aquaculture

Many methods of mariculture have been practised in the mangroves areas which included the bottom culture of bivalves and seaweeds in the open bays, floating cages and pen culture, raft, stakes and cultch for mussels, oysters and sea weeds in the open bays and estuaries, pond culture of finfishes and prawns in the intertidal region and shore based fish and prawn hatcheries close to the mangrove areas. Many of these have very limited adverse impacts on the mangroves as these were practiced for centuries and were sustainable and thus providing sustainable livelihood for rural populations. The major issues were concerned with the clearing of the mangroves for construction of ponds and other infrastructure (FAO, 2000).

Mangrove swamps and other low-lying areas along the estuaries are generally preferred for brackish water fish farming. The species cultivated are *Liza parsia, L. tade, Mugilcephalus,Chano schanos, Penaeus monodona* and *Fenneropenaeus indicus*.

The traditional tidal prawn ponds known as tambaks in Indonesia which traped fish and prawn seeds in mangrove areas are similar to the pokkali ponds of Kerala. Later these ponds were converted to intensive form of cultivation. Mangrove soils being acid sulphate soils are mostly not favourable for mariculture. Hence many countries have prohibited the conversion of these inter tidal mangrove into pond culture.

Mangroves protect coastline from cyclones, flash floods, tsunamis and surges. Mangroves reduce the velocity of wind and wave thus enabling agriculture practice in the coastal areas too.

Mangrove Litter fall, Litter Decomposition and Nutrient leaching

Mangroves shed and drop about seven and a half tons of leaf litter per acre per year Litter fall quantity is a valuable index of mangrove productivity since it is a major fraction of mangrove net productivity which supports aquatic organism (Bunt *et al*, 1979).Mangrove leaves, wood, propagules, flowers, bracts, and other organic materials fall continuously to the intertidal forest floor. These leaves and other litter cannot be digested by herbivores and are thus unavailable nutrient sources for higher tropic levels. When bacteria and fungi metabolize the leaf litter, however, it releases nutrients via a pathway that has been called the detrital food loop. The detritus is eaten by shrimp, mullet, and numerous organisms within the mangrove prop root community and thus passed into the food web.

The dissolved organic matter (DOM) is produced due to the decay of the litter and the recycling of the leached nutrients reaches the mangrove floor and the adjoining habitats. Thus the nutrient contribution in clear tropical waters is enormous as the concentrations are usually on the lower range. The role of grapsid crabs in burrowing affects soil aeration which in turn affects the productivity and reproductive output of *Rhizophora* (Smith *et al*, 1991).

Acts as Sediment trap

The mangroves have specially-adapted aerial roots and salt-filtering tap roots that enable these trees to occupy the fluctuating intertidal zones where other plants cannot survive. These resilient forests are literally living in two worlds at once. Thousands of kilometres of tropical and sub-tropical coastline are stabilized by their interwoven roots giving shelter to myriads of fauna and flora forming a unique biome in the process. A mangrove acts as a buffer zone between sea and shore, protecting the shore from erosion and also plays a valuable role as a shield from disasters like cyclone and tsunami.

Coastal protection

The dense root systems of mangrove forests trap sediments flowing down rivers and off the land. This helps stabilizes the coastline and prevents erosion from waves and storms. In areas where mangroves have been cleared, coastal damage from hurricanes and typhoons is much more severe. By filtering out sediments, the forests also protect coral reefs and sea grass meadows from being smothered in sediment. Coastal tracts of any country are more prone to tsunami and cyclonic disasters. Mangroves are the natural protective defensive natural resource that protects the coastal areas from natural hazards.

Tourism

Given the diversity of life inhabiting mangrove systems, and their proximity in many cases to other tourist attractions such as coral reefs and sandy beaches, it is perhaps surprising that only a few countries have started to tap into the tourism potential of their mangrove forests. Places as diverse as Bonaire and offer snorkelling expeditions in and around mangroves to witness a marvellous variety of baby fish, jellyfish, and urchins against a magical background of interwoven roots delving deep into the sandy substrate. Great potential exists elsewhere for revenue generation in this manner, which values the mangroves intact and as they stand.

Ecological Benefits

Reduction in UV – B radiation

Mangroves possess mechanisms to deal with intense sunlight rays and solar UV-B radiation.

Reducing the Green House effect

Mangroves are known to remove CO2 from the atmosphere through photosynthesis. This perhaps reduces the problems that go with the green house gases’ and global warming. They fix greater amounts of CO2 per unit area, than what the phytoplankton do in the tropical oceans (Kathiresan & Bingham, 2001). The mangroves are capable of accumulating and storing carbon in the soil in large quantities.

Minimizing the fury of cyclones & Mitigating Tsunami

Mangrove forests protect all types of coastal communities from the fury of cyclones, storms and Tsunami. The best example on finds is the super-cyclone which occurred on the 29th October 1999 with a wind speed of 310 km hr-1 along the Orissa coast (India) and played havoc largely in the areas devoid of mangroves. Andaman and Nicobar Islands also witnessed the effect of Tsunami, 2004, where huge loss to human lives, households, crops and animals occurred in the places having less or without mangrove forest.

Controlling of flood

Mangrove systems offer protection to the coastline against the flood, which are often caused by tidal waves or due to heavy rainfall associated with storms.

Prevention of coastal erosion

The mangrove systems minimise the action of waves and thus prevent the coast from erosion. The reduction of waves increases with the density of vegetation and the depth of water.

Threats to mangroves

The direct and indirect anthropogenic activities have considerably altered the nature of wetlands especially mangroves of tropical countries in the world. The importance of mangroves has been underestimated despite being a critical and fragile ecosystem. Mangroves are rich in biodiversity so, they provide shelter for the various aquatic microorganism and animals. But various practices by the local people cause degradation of mangroves. Mangroves are continuously under the threat by the local population.

The categorization as 'waste lands' has led to the conversion of mangroves to agricultural, industrial or residential uses. This erroneous description made it easier to exploit mangrove forests as cheap and unprotected sources of land for urbanization and other economic activities. However, the havoc created by the Tsunami of 2004, has created the occasion for realizing the ecological significance of mangroves. The reports from across the globe confirmed the storm protection function of this coastal bio-shield (Das, 2009; Kathiresan, 2010).

Shoreline development has replaced mangroves with marinas, dredged channels, airports, seawalls and other commercial and residential construction. Other threats are illegal dumping, beach renourishment, and oil spill, agricultural run-off that contains herbicides, pesticides and sugarcane wastes. Globally mangrove forests are disappearing at a rate of 1-2 percent per year, a pace that surpasses the destruction of adjacent ecosystems, coral reefs and tropical rainforests. The U.N. Food and Agriculture Organization estimates that mangroves are critically endangered or approaching extinction in 26 out of the 120 countries in which they are found. Indian mangroves have been deforested and reclaimed to such an extent that the mangroves along the west coast are very much degraded. This has not only affected the coastline but also the fisheries to a large extent.

Mangroves are invaluable treasure of our biodiversity with immense ecological and economical significance. Mangroves serve as a critical nursery for young marine life and therefore play an important role in the health of fisheries and the economic well-being of fishermen. The ecosystem is also considered as most productive and biodiversity providing significant functions in the coastal zones as buffer against erosion, storm surge and tsunamis. Aforestation of mangrove areas on a large scale is the most urgent need of today, if the coastal environment is to be brought back again to its earlier pristine glory.

Conclusions

Indiscriminate destruction of mangrove compounded by a lack of management capacity in the coastal regions where the mangrove forests remain needs immediate attention. If managed in an effective and sustainable manner, mangroves can provide a reliable source of income, protection, and food for local populations, alleviating poverty, contributing to food and social security, and ultimately, the economic development of the countries in which they are situated.

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THEME IV:
ORGANIC CROP PRODUCTION

Agronomic Tools for organic crop production

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Organic agriculture is practiced in 170 countries with total area of 78 million ha (both in the form of cultivated and wild harvest). Emerging from 42,000 ha under certified organic farming in 2003-04, the organic agriculture has grown many folds and by 2014-15, India has brought 4.89 m ha area under organic certification process. Out of this, cultivated area accounts for 1.18 m ha (24.1 %) while remaining 3.71 m ha (75.9 %) is wild forest harvest collection area. Currently, India ranks 10th among the top ten countries having the cultivable land under organic certification. Around 6.50 lakhs organic producers are engaged in the country in various forms.

Different parts of India have developed their own local or regional systems for ecological agriculture that are now gathered in one umbrella term 'JaivikKrishi' or 'JaivikKheti'. India has a sizable cropped area in different states, which is more prone to weather vagaries; especially those located in rainfed, dryland and hilly areas. Increasing the agricultural productivity and income of the farmers as well as sustaining soil resource in these agricultural systems has always been a challenging task for researchers and policy planners. Use of fertilizers and pesticides is minimal and much below the national average in these areas. At first instance, these are the areas which need to be targeted for organic production by devising proper strategies and identifying niche crops (crops which yield higher under organic production systems and have adequate market demand).

Nutrient Management in Organic Farming

The management of nutrient in organic farming system is a challenge as the use of inorganic fertilizer which feed the plant directly and are thought to bypass the natural processes of the soil, is not permitted.Effective nutrient management is essential in organic farming systems. Nutrient supply to crop plants is supported through recycling, the management of biologically related processes such as nitrogen fixation and the limited use of unrefined, slowly soluble off- farm materials that decompose in the same way as soil minerals or organic matter.Nutrient sources commonly used for organic farming are green manure, farm yard manure (FYM), vermicompost (VC), compost, enriched compost, bio-gas slurry, non-edible oil cakes, poultry manure, Azolla, biofertilizer, biodynamic compost and Panchgavya.

Green Manure: The crops to be taken for green manuring should be fast growing, rich in nutrient like legumes, resistant to biotic and abiotic stresses, has smoothening effect against weeds and with more foliage. Crops that are commonly used for green manuring are *Sesbania aculeata* (suitable for rice-wheat, 55 days old crop producing 17-30 tonnes green matter per ha), *Sesbania speciosa (*suitable for wet lands, when raised on field borders along the bunds, 90 day old crop contributes 2-4 tonnes green matter per ha) and *Crotolaria juncea* (suited to almost all parts of country and adds 15-25 tonnes fresh biomass in 50-60 days). They can be grown together with crops or alone. Because the C:N ratio of green manure crops increases as they age, it is generally recommended that green manure crops be harvested or incorporated into the soil when close to full bloom (but prior to seed set) to assure a C:N ratio of 22:1 or less so that net mineralization occurs.The 60-day-old crop can contribute approximately 100 kg N/ha, 25-30 kg P_2O_5/ha and 75 kg K_2O/ha and these can meet the requirement of organic rice crop (Chandra, 2005).

Farm Yard Manure (FYM): Farm yard manure is partially decomposed dung, urine, bedding and straw.The nutrients from urine become readily available.Dung contains about 0.50 per cent of the nitrogen, 0.15 per cent of potash and almost all of the phosphorus that is excreted by animals. FYM contains approximately 5-6 kg nitrogen, 1.2 to 2.0 kg phosphorus and 5-6 kg potash per tonne. If properly preserved, the quantity of manure that can be produced per animal per year would be as much as four to five tonnes containing 0.5 per cent nitrogen. If available, well decomposed FYM should be applied @15-20 t/ha for cereals and 5-10 t/ha for pulses, which can supply about 75-100 kg N, 35-40 kg P_2O_5 and 75-100 kg K_2O per ha. FYM should be decomposed by adding *Trichoderma* powder.

Vermicompost: Vermicomposting is a simple biotechnological process of composting in which certain species of earthworms enhance the process of waste conversion and produce a better end product i.e. vermicompost. It provides all nutrients in readily available form and also enhances uptake of nutrients by plants.Vermicomposting converts household compost within 30 days, reduces the C: N ratio and retains more N than traditional method of preparing compost.The African species of earthworms, *Eisenia foetida* and *Eudrilus eugenae* are ideal for the preparation of vermicompost. For the preparation of vermicompost, pits are made of 1 m deep and 1.5 m wide, however, the length varies as required and bottom of thepit is covered by polythene sheet on which 15-20 cm layer of organic waste material (it helps in improving nutritional quality of compost) and finally cow dung slurry should be sprinkled. Culture of *Pseudomonas fluorescens* may also be added (@ 200g/100kg). Pit is filled completely in layers as described and finally the top of the pit is pasted with soil or cow dung and material is allowed to decompose for 15-20 days.Selected earthworms (500 to 700) were released through cracks and water is sprinkled every three days to maintain adequate moisture. Vermicompost is ready in about 2 months if agriculture waste is used. This processed vermicompost is black, light in weight and free from bad odour.

Compost: Compost is organic matter (plant and animal residues) which has been rotted down by the action of bacteria and other organisms, over a period of time. The biodegradation process is carried out by different groups of heterotrophic microorganisms like bacteria, fungi and actinomycetes etc. Organic materials undergo intensive decomposition under thermophilic and mesophilic conditions in heap, pits or tanks with adequate moisture and aeration and finally yield a brown to dark brown coloured humified material called compost. Materials such as leaves, fruit skins and animal manures can be used to make compost.

For enriching the compost with rockphosphate, rockphosphate is added at the rate of 12.5 per cent in a mixture of plant residue+ FYM+ soil in ratio of 8: 1.0: 0.5 in the form of slurry on plant residue during composting. Likewise, for enriching the compost with pyrite, pyrite is added at the rate of 10 per cent in a mixture of plant residue+ FYM+ soil in ratio of 8: 1.0: 0.5 in the form of slurry on plant residue during composting. While for enriching the compost with inoculums, a mixture of FYM (10 kg) + soil (2kg) + inoculums (1 kg Azotobacter + 1 kg PSB + Pseudomonas + 1 kg Thiobacillus + 1kg Beauveria + 1 kg Pant biocontrol agent 1, 2 & 3) in a 100-150 litre of water was added on the top of layer while composting which is sufficient for 1 ton of enriched compost.

Bio-gas slurry:Bio-gas slurry is a good source of organic manure. Anaerobic digestion of raw animal dung by microbes in the bio gas plant offers more advantages in improving the manorial value of the slurry as compared to the manorial product of aerobic decomposition. All chemical elements except carbon, oxygen, hydrogen and sulphur contained in animal dung are conserved in bio-digested slurry which is reported to be rich in plant nutrients both macro & micro nutrients compared to FYM. Nutrient content of Bio-gas slurry approximately is 1.43-1.21-1.01% N-P-K on dry weight basis. In general, 10 t/ha bio-digested slurry is recommended to be applied once in three years to maintain organic content in soil, besides providing nitrogen, phosphorus and potassium in form of organic fertilizers to the crop.

Non-edible oil cakes: Non-edible oil cakes have higher nutrient content as compared to other organic manures. Many oil cakes such as castor, neem, mandus, karanja, linseed, rapeseed and cotton seed may serve as good organic source. Neem cake contains the alkaloids-nimbin and nimbicidine which effectively inhibits the nitrification process and increasing the yield, nitrogen uptake and grain protein content of rice. Mahua cake has been successfully used in coastal saline soils for cultivation of rice.They are insoluble in water but their N become quickly available to plants about a week or 10 days after application.Commonly available non-edible oil cakes used as organic nutrient and their nutrient content is presented in Table 1.

Table 1. Non-edible oil cakes and their nutrient content

Oil cakes	N (%)	P_2O_5 (%)	K_2O (%)
Groundnut cakes	7.3	1.53	1.33
Linseed cakes	5.6	1.44	1.28
Castor cakes	4.4	1.85	1.39
Neem cakes	5.2	1.08	1.48

Poultry manure: Poultry manure is concentrated organic manure used as a nutrient source in organic farming particularly for vegetables comprising of 2.9-2.9-2.4 % N-P-K. Broiler litter also contains 23-125 ppm copper, 125-667 ppm manganese and 106-669 ppm zinc. Poultry waste manure is highly complex and challenging because of associated problems like nitrate and heavy metal contamination in soil, crops, surface and ground water, air quality and odour, disposal of dead and diseased poultry and food safety.

Azolla: Inoculation of Azolla bio-fertilizer at 7 days after transplanting of rice crop @ 2 t/ha in standing water and its growth during the rice crop adds organic matter and nitrogen to the soil. The Azolla incorporation at the time of puddling of rice soil @ 6tonnes per ha can also provide about 25-30 kg N per ha to the rice crop in organic farming system. For Azolla incorporation we need to produce required amount of biomass in multiplication tanks/ponds.

Biofertilizers: Biofertilizers means the product containing carrier based (soild or liquid) living microorganisms which areagriculturally useful in terms of nitrogen fixation, phosphorus solubilization or nutrient mobilization to increase productivity of the soil and/or crop. Biofertilizers are live materials hence should be handled carefully and a favourable environment in the field should be assured for desired results.In case of carrier based formulations, the product should have 30-50 per cent of moisture throughout the shelf life period to sustain microbial population and the microbial population should be in the range of 10^7 to 10^9 cells/g of moist product. In case of liquid formulations, the cell load should be in the range of 1×10^8 to 1×10^{10} during the entire period of shelf life. Three types of biofertilizers are used i.e. Symbiotic N_2 fixers such as Rhizobium culture for legumes; free living N_2 fixers (non-symbiotic bacteria) such as Azotobacter and Azospirillum spp. for cereals, blue green algae and Azolla for rice and P solubilizers such as Pseudomonas sp. While symbiotic N_2 fixers inoculated in legumes can fix substantial amount of atmospheric N_2 to feed the host plant, free-living N_2 fixers contribute much less, usually 10-30 kg/ha. P solubilizers enhance the availability of native inorganic P.

Biodynamic Compost (BD): There are eight known biodynamic composts, namely biodynamic preparation (BD) 500(Cow horn manure), 501 (Horn silica), 502 (Yarrow), 503 (Chamobile), 504 (Stinging nettle), 505 (Oak bark), 506 (Dandelion), and 507 (Valerian) and Cow-Pat Pit (CPP). These preparations are easy to formulate and can be done by farmers at their own farms. Out of these, formulation-500 (Cow-horn compost) and formulation-501 (horn silica) can be used directly in soil and plants. These BDs are very popular and are being used by large number of organic farmers. Formulation 502 to 507 is compost enrichers and promoters, while formulation 508 is of prophylactic in nature and helps in control of fungal diseases **(Steiner, 1974).**

BD-500 (Cow- horn manure) usually increases humus in soil and after dilution in water, it is sprayed directly on land during early spring (March-April) and autumn September-early October) concentration 30-35 gms in 12 litres of boiled cool water and stirred for 1 hour in the evening before sowing or transplanting. Mixing of PSM, Azotobacter, Azospirillium and *Bacillus subtilis* 100 ml each in solution ensures better yield in all crops.

Panchgavya: Panchgavya, an organic product has the potential to play the role of promoting growth and also provides immunity in plant system. Physico-chemical properties of Panchgavya revealed that they posess almost all the major nutrients, micronutrients and growth hormones (IAA and GA) required for crop growth. Predominance of fermentative microorganisms like yeast and lactobacillus might be due to the combined effect of low pH, milk products and addition of jaggery/sugarcane juice as substrate for their growth.

Panchgavya consists of nine products viz., cow dung, cow urine, milk, curd, jaggery, ghee, banana, tender coconut and water. When suitably mixed and used, these have miraculous effects. Here for its preparation, the product of local breeds of cow is said to have potency than exotic breeds. For this mix 7 kg cow dung and 1 kg cow ghee thoroughly both in morning and evening hours and keep it for 3 days. After 3 days mix 10 litres of cow urine and 10 litres of water and keep it for 15 days with regular mixing both in morning and evening hours. After 15 days mix cow milk-3 litres, cow curd- 2 litres, tender coconut water – 3 litres, jiggery- 3 kg and well ripened poovan banana-12 nos. and Panchgavya will be ready after 30 days. All the above items can be added to a wide mouthed mud pot, concrete tank or plastic can as per the above order. The container should be kept open under shade and covered with a wire mesh or plastic mosquito net to prevent house flies from laying eggs and formation of maggots in the solution.

Panchgavya is sprayed on crops at a concentration of 3 per cent (3 litres panchgavya to every 100 litre of water is ideal for all crops). The solution of panchgavya can be mixed with irrigation water at 50 litres per hectare either through drip irrigation or flow irrigation. Also, 3 per cent solution of panchgavya can be used to soak the seeds or dip the seedlings (20 minutes before transplanting). Rhizomes of turmeric, ginger and sets of sugarcane can be soaked for 30 minutes before planting. Panchgavya is used at pre-flowering phase (once in 15 days, 2 sprays depending on duration of crop), flowering and pod setting stage (once in 10 days, 2 sprays) and fruit/ pod maturation stage (once during pod maturation).

Weed Management in Organic Farming

In weed management approach under organic system, the central goal is to reduce weed competition and reproduction to a level that the farmer can accept. In many cases, this will not completely eliminate all weeds. Weed management should, however, reduce competition from current and future weeds by preventing the production of weed seeds and perennial propagules - the parts of a plant that can produce a new plant. Consistent weed management can reduce the costs of weed control and contribute to an economical crop production system.

Cultural practices

Crop Rotation: Monoculture, that is growing the same crop in the same field year after year, results in a build-up of weed species that are adapted to the growing conditions of the crop. When diverse crops are used in a rotation, weed germination and growth cycles are disrupted by variations in cultural practices associated with each crop (tillage, planting dates, crop competition, etc.).

Cover Crops: Rapid development and dense ground covering by the crop suppress weeds. The inclusion of cover crops such as rice bean, groundnut, rye, red, clover, buckwheat, wintering crops like winter wheat or forages in the cropping system can suppress weed growth. Highly competitive crops may be grown as short duration 'smother' crops within the rotation. Cover crops offer many benefits to an organic farming system, including protection against soil erosion, improvement of soil structure, soil fertility enhancement, and weed suppression. Cover crops can be used in a variety of ways to suppress weeds. Cover crops can suppress weeds, reduce weed populations in the subsequent crop, and reduce weed seed contributions to the soil seed bank.

Intercropping: Intercropping involves growing a smother crop between rows of the main crop. Intercrops are able to suppress weeds. However, the use of intercropping as a strategy for seed control should be approached carefully. The intercrops can greatly reduce the yields of the main crop if competition for water or nutrients occurs. Intercropping of soybean and groundnut in upland rice, maize or sorghum greatly reduces the weed problem.

Mulching: Mulches reduce weed competition by limiting light penetration and altering soil moisture and temperature cycles.Living mulch is usually a plant species that grows densely and low to the ground such as clover.Living mulches can be planted before or after a crop is established.A living mulch of *Portulaca oleracea* from broadcast before transplanting broccoli can suppress weeds without affecting crop yield. Often, the primary purpose of living mulch is to improve soil structure, aid fertility or reduce pest problems and weed suppression may be merely an added benefit.

Organic mulches include many materials that can be produced on farm such as hay, straw, grass mulch, crop residues, and livestock or poultry bedding. Other materials, such as leaves, composted municipal wastes, bark, and wood chips, may be available from off-farm sources. Farmers must consider both the quantity and type of mulch to be applied, and the cost of the mulch and the equipment needed to manage it. Degradable plastic mulches are either photodegradable, breaking down after 30 to 60 days of exposure to sunlight, or biodegradable, broken down by soil microorganisms. Degradable materials do not need to be removed from the field following the growing season, and some may be incorporated into the soil to speed degradation. Reusable materials such as black polypropylene mulch can be used for long- term weed management in nurseries and some high value crops (such as strawberry). Reusable cloth mulch has also been used in lettuce production to promote seed germination and prevent weeds (Finney and Creamer, 2008).

Stale Seedbed Preparation: This weed management strategy consists of preparing a fine seedbed, allowing weeds to germinate (relying on rainfall or irrigation for necessary soil moisture), and directly removing weed seedlings via light cultivation or flame weeding. Seeds or transplants can then be planted into the moist weed-free soil. This technique helps to provide an opportunity for crop emergence and growth before the next flush of weeds. If time allows, this can be done twice before planting.

Soil Solarization: Solarization consists of heating the soil to kill pest organisms, including fungi, bacteria, and weed seeds. It also reduces populations of various pathogens and nematodes. Soil is covered in summer with clear or black polyethylene plastic and moistened under the plastic, which is left in place for six to seven weeks or longer. Weed seeds and young seedlings are killed by the heat and moisture and through direct contact with the plastic, which causes scorching. Research has demonstrated that solarization from July to October with clear or black plastic provides effective weed control without reducing crop yield (Rieger et al., 2001). Solarization can also be used to produce weed–free soil or potting mix for container production in warm climates (Stapleton et al., 2002), and it has been used in Mediterranean climates to reduce weed competition and increase yields of field-grown cauliflower and fennel (Campiglia et al., 2000).

Planting Strategies: Date, density, and arrangement for many row and horticultural crops, rapid growth and early canopy closure can result in the suppression of weeds. For this reason, using transplants when possible for horticultural crop production is advantageous. Use of transplants will increase production costs, so the economic benefit of using transplants must be weighed against cost. When it is economically viable, as is the case with many vegetable crops, use of transplants should be considered.

Use of manure and compost: Use of organic manure can affect the competition between crops and weeds and in the subsequent crops. Quality of organic manure and method of application affects weed population in crop fields. Broadcasting favours to weed than crops. Similarly improper decomposition of composts promote weeds in fields. Use of legume residues are opposed to chemical nitrogen fertilizer to supplement nitrogen needs of the crop can enhance weed suppression. Legume residues release nitrogen slowly with less stimulation of unwanted weed growth. Applying organic manure near the rows where it is more likely to be captured by the crop will suppress weed growth. Expensive bagged organic fertilizer may be applied in low rates at planting or side dress, relying on mid-season release of nutrients from compost and / or green manures for primary fertility.

Water management: Effective water management is key to controlling weeds in crop production. Time and method of irrigation influences weed growth in field. In drip irrigation water is applied in crop root zone and hence weed growth are minimum. There are a number of ways that careful irrigation management can help reduce weed pressure on crops. In rainfed farming water management practices such as mulching, intercropping etc. helps to reduce weed problem.

Mechanical Weed Control

Mechanical removal of weeds is both time consuming and labor-intensive but is the most effective method for managing weeds especially in a organic farm. The choice of implementation, timing, and frequency will depend on the structure and form of the crop and the type and number of weeds. Cultivation involves killing emerging weeds or burying freshly shed weed seeds below the depth from which they germinate. It is important to remember that any ecological approach to weed management begins and ends in the soil seed bank. The soil seed bank is the reserve of weed seeds present in the soil. Observing the composition of the seedbank can help a farmer make practical weed management decisions. Burial to 1 cm depth and cutting at the soil surface are the most effective ways to control weed seedlings mechanically.Mechanical weeders include cultivating tools such as hoes, harrows, tines and brush weeders, cutting tools like mowers and stimmers, and dual-purpose implements like thistlebars. The choice of implement and the timing and frequency of its use depends on the morphology of the crop and the weeds.

Flame Cultivation: Broadcast flame cultivation prior to seeding the crop can be used effectively on most organically produced crops. It is more effective on a smooth soil surface than a rough or cloddy surface (Smilieet al., 1965). And it is more effective on broadleaf weeds than grasses, but its effectiveness decreases as weeds mature. Grasses and perennial weeds are most tolerant to flaming. Flaming burns grasses and perennial weeds to the soil surface, but sometimes these weeds are capable of regrowth. Seeding or transplanting crops after flame cultivation must be done carefully to prevent soil disturbance that can lead to weed seed germination and establishment.

Biological Weed Control

Allelopathy: Allelopathy is the direct or indirect chemical effect of one plant on the germination, growth or development of neighboring plants. It is now commonly regarded as component of biological control. Species of both crops and weeds exhibit this ability. Allelopathic crops include barley, rye, annual ryegrass, buckwheat, oats, sorghum, sudan, sorghum hybrids,alfalfa, wheat, red clover, and sunflower. Vegetables, such as horseradish, carrot and radish, release particularly powerful allelopathic chemicals from their roots. One approach of utilizing the allelopathic property of crops is to screen genotypes to examine their potential for weed suppression. The strategy for using allelopathy for weed management could be either through directly exploiting natural allelopathic interactions, especially of crop plants, or applying allelochemicals as a source of natural herbicides. However, it is unclear whether the application of natural weed killing chemicals would be acceptable to the organic standard authorities.

Beneficial organisms: Little research has been conducted on using predatory parasitic microorganisms or insects to manage weed populations. However, this may prove to be a useful management tool in the future. Natural enemies that have so far been successful include a weevil for the aquatic weed *salvinia*, a rust for skeleton weed and probably the most famous, a caterpillar (*Cactoblastis* sp.) to control prickly pear. There is also considerable research effort aimed at genetically engineering fungi (myco-herbicides) and bacteria so that they are more effective at controlling specific weeds. Myco-herbicides are a preparation containing pathogenic spores applied as a spray with standard herbicide application equipment. Some biocontrol agents and commercial mycoherbicides used for weed control are indicated below-

Parthenismhysterophorus:	*Zygrogrammabicolarata*
Lantana camara:	*Crocidosema lantana, Teleonnemiascrupulosa*
Opuntiadilleni:	*Dactylopiustomentosus, D. Indicus* (cochineal scale insect)
Eichhorneacrassipes:	*Neochetinaeichhornea, N. Bruchi* (Hyachinth weevil) *Sameodesalliguttalis* (hyancinth moth)
Salviniamolesta:	*Crytobagussingularis* (weevil) *Paulinia acuminate* (grass hopper), *Sameamuti-plicalis*
Alternantheraphiloxaroides:	*Agasideshygrophilla* (flea beetle) *Amynothripsandersoni*

Commercial mycoherbicides

Trade name	Pathogen	Target weed
Devine	*Phyophthorapalmivora*	*Morreriaodorata* (Strangler vine) in citrus
Collego	*Colletotrichumgleosporoides* f.sp. *aeschynomene*	*Aeschynomenevirginica* (northen joint vetch) in rice and soyabean
Biopolaris	*Biopolarissorghicola*	*Sorghum halepense* (Johnsongrass)
LUBAO 11	*Colletotrichumgleosporoides* f.sp. *Cuscuttae*	*Cuscutta sp.* (Dodder)
ABG 5003	*Cercosporarodmanii*	*Eichhorneacrassipes* (waterhyancinth)

Approved Herbicides

A limited number of natural substances can serve as herbicides on organic farms.

Corn Gluten Meal: The most widely used product in USA is corn gluten meal, a byproduct of cornstarch production. Corn gluten meal may be applied as a pre-emergence herbicide. Time of application is extremely important, as the gluten must be present when weed seeds germinate to inhibit root formation. Weeds affected by corn gluten meal include redroot pigweed, black nightshade (*Solanum nigrum*), common lambsquarters, curly dock, creeping bentgrass (*Agrostis palustris*), purslane, common dandelion (*Taraxacum officinale*), and smooth crabgrass (*Digitaria ischaemum*). Of weeds that have been tested, barnyard grass (*Echinochloa crus-galli*) and velvetleaf (*Abutilon theophrasti*) are the least susceptible to corn gluten meal. Broadleaf species are generally more susceptible than grasses to corn gluten meal. In field studies, weed cover has been reduced up to 84 percent when corn gluten meal was incorporated prior to planting (McDade and Christians, 2000).

Pest and Disease Management

Tillage, land configuration and crop spacing

Tillage is old age practice of pest management in agriculture. Deep summer ploughing exposes the roots of many weeds and facilitate their drying. It also helps in exposing the hibernating stages of insects for predation or killing by desiccation. The sclerotia and other resting structures of many pathogenic fungi and stages of nematodes get destroyed by summer ploughing. Intercultural operations besides proving proper aerations and growing conditions to soil, also helps in weed management. Hence summer ploughing and proper interculture should be among main strategies for weed, pest and disease management in organic farming.Planting of crops especially turmeric, ginger, pulses, vegetables, maize etc. on raised beds or bunds particularly during rainy season provides protection against some soil borne diseases caused by Pythium and Phytophthora spp.

Crop spacing should be kept at larger side to avoid the build-up of congenial environment for pests and diseases attack. Widely spaced crops have proper aeration and lower humidity and lesser attraction for insect shelter and thus avoid the heavy attack of pests and diseases. Keeping 2' space vacant at every 3-4 meters in case of basmati or non-basmati rice helps in managing brown plant hopper, sheath blight disease and other pests. Larger plant to plant distance in case of okra helps in minimizing yellow vein mosaic disease due to lesser white fly vectors.

Soil solarisation

Soil solarisation is a technique of raising the soil temperature by clear plastic sheets which allows shorter wavelength solar radiation to enter into soil and heat it up and at the same time it restricts the longer wavelength radiation into soil during night time. Thus, the soil solarization keeps soil temperature continuously above lethal range (up to 60°C) to many soil borne plant pathogens of mesophilic nature (*Fusarium* spp. *Verticillium* spp. etc.), nematodes (root knot nematode), weeds (annual grassy weeds and some broad leaved weeds also), and hibernation stages of insect-pests.The thickness of clear polyethylene sheets should be in the range of 25-30µm. The soil before solarization should be well prepared and has proper moisture for maximum conductivity of heat into the soil.

Multiple cropping and mixed cropping

Mixed cropping is also a strategy to compensate the losses caused by pests and diseases. If main crop is damaged by the disease or pests, the mixed crop can compensate for the losses in main crop. Some of the mixed crops i.e. cow pea or Dhaincha smother weeds in between the rows of wide spaced crops and also add nitrogen to the soil. Any other interested crop which is having weed smothering property and if, compatible with main crop, can be planted in rows of main crop. Intercropping of Marigold in between wide spaced crops can smoother the weeds and also controls many nematode species of the crops.

Use of resistant varieties

Since,the synthetic chemical pesticides are strictly prohibited in organic crop production and there are not many options under biological, botanical or other strategies of pest management allowed, the use of pest/disease resistant or tolerant and weed smothering varieties must be in our package of practices to manage the pests. The varieties of crops resistant or tolerant to pests vary from region to region; hence they should be selected according to locality.Induced resistance is another area which can be exploited in organic farming. Seed treatment with bioagents like *Trichoderma* and *Pseudomonas fluorescens/ Bacillus subtilis* has been reported to induce broad range resistance in many crops against various pathogens.

Seed treatment with Beejamrut

Bijamrut is a biodynamic preparation commercially exploited for seed treatment in organic farming and reported to suppress many seed borne diseases. For preparation of Bijamrut, put 5 kg fresh cow dung in a cloth bag and suspend in a container filled with water to extract the soluble ingredients of dung. Suspend 50g lime in one litre of water separately. After 12-16 hours, squeeze the bag to extract all the ingredients of cow dung and add 5 litre of cow urine, 50g of virgin forest soil, prepared lime water and 20 litre water. Again incubate the preparation for 8-12 hours. Filter the content and this filtrate is ready for seed the treatment. Apply he amount of Bijamrut on seed which can make a layer over it and dry it in shade before sowing.

Mechanical methods

Removal of affected plants and plant parts, collection and destruction of egg masses and larvae, installation of bird perches, light traps, sticky coloured traps and pheromone traps are most effective mechanical methods of pest control. In bigger plots of crop, put 'T' type of bird perches with 5-6 feet height which attracts the birds to sit over and predate the insect larvae and adults infesting the crop. The boundary trees and shrubs planted in farm also serve the purpose of bird perches.

Use of Bio-pesticides

For the management of fungal diseases and nematodes the *Trichoderma viride* or *T. harazianum* are found to be best. Four to five kg of formulation with desired number of viable spores is sufficient for one hectare. They can be applied as spray at regular intervals for desired level of disease control. *Pseudomonas fluorescence* formulations @ 4g/kg seed either alone or in combination with *Trichoderma spp.* mange most of the seed and soil borne diseases. It can also be used as spray for managing the crop diseases.For controlling the insect-pests, formulations viz. *Beauveria bassiana, Metarhizium anisopliae, Nomura earileyi, Verticillium sp.,* are available in the market and can manage their specific insect-pest.

Use of botanical pesticides

Neem has been reported to be effective in the management of approximately 200 insects, pests and nematodes. Neem is very effective against grasshoppers, leaf hoppers, plant hoppers, aphids, jassids, and moth caterpillars. It has strong repellent and anti-feedant activities. Neem extracts, are also very effective against beetle larvae, butterfly, moth and caterpillars such as Mexican bean beetle, Colorado potato beetle and diamond black moth. Neem is very effective against grasshoppers, leaf minor and leaf hoppers such as variegated grasshoppers, green rice leaf hopper and cotton jassids. Neem is fairly good in managing beetles, aphids and white flies, mealy bug, scale insects, adult bugs, fruit maggots and spider mites.

Fermented Curd water: In some parts of central India, fermented curd water (butter milk or Chhaachh or mattha) is also being used for the management of white fly, jassids, aphids etc.

Dashparni Extract: Crushed neem leaves 5 kg + *Tinospora cordifolia* (giloya) leaves 2 kg, *Annona squamosa* (custard apple) leaves 2 kg, *Nerium indicum* leaves 2 kg, *Pongamia pinnata* (Karanja) leaves 2 kg. Green chilli paste 2 kg, garlic paste 250 gm, cow dung 3 kg, *Calotropis procera* leaves 2 kg and cow urine 5 litre in 200 litre water and fermented for one month. The suspension is shaken regularly three times a day. Extract is finally obtained after crushing and filtering. The extract can be stored up to 6 months and used to control insect-pests and diseases of crops @500 litre/ha.

Mixed leaves extract: Crush 3 kg neem leaves in 10 litres of cow urine. Crush 2 kg custard apple leaf, 2 kg papaya leaf, 2 kg pomegranate leaves, 2 kg guava leaves in water. Mix both the formulas and boil 5 times at some interval till it becomes half. Incubate for 24 hrs, then filter and squeeze the extract. This formula can be stored in bottles for 6 months. Dilute 2-2.5 litre of this extract in 100 litre of water for 1 acre of crop area. This is useful against sucking pest, pod/ fruit borers.

Conclusion

Effective management of nutrient, weeds, insect-pest and disease is the major challenge for successful organic farming. Integrated management comprising cultural, mechanical and biological practices are warranted for managing nutrient, weeds, pest and diseases in an eco-friendly way in organic farms. In addition to the growing concern for protection of environment, maintain biodiversity and protection of human and animal health, integrated crop management approaches are also good ways of climate change mitigation.

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C4 Rice: An attempt towards the global food security

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Rice is the world's most important food crop and a primary source of food for more than half of the world's population. More than 90% of the world's rice is grown and consumed in Asia where 60% of the earth's people live. Rice accounts for 35-75% of the calories consumed by more than 3 billion Asians. It is planted to about 154 million hectares annually or on about 11% of the world's cultivated land. The green revolution in wheat and rice, white revolution in milk, yellow revolution in oilseed and the "blue revolution" in fisheries have augmented the food basket of the country. About 75% of India's poor people with low purchasing power live in rural areas and nearly 60% of the cultivated area is under rain fed farming. Hence, the National Agricultural Policy place high priority on raising agricultural productivity as a means to achieve more rapid agricultural growth and reduce rural poverty. Secondly, stagnating/decelerating productivity growth and declining total factor productivity in agriculture have cast doubts on the resilience of the sector to meet the challenges of a more market-driven and competitive regime. Related to the issue of stagnating productivity is the obvious limited connection between input use and productivity growth performance. Thirdly, current unsustainable land and water use practices will lead to lower agricultural productivity in the future. Fourthly, ensuring economic and ecologically sound access to food to every Indian, while conserving and improving the natural resources and traditional wisdom, in a more competitive regime, is yet another challenge. According to various estimates, we will have to produce 40% more rice by 2025 to satisfy the growing demand without affecting the resource base adversely. This increased demand will have to be met from less land, with less water, less labor and fewer chemicals. If we are not able to produce more rice from the existing land resources, the hungry farmers will destroy forests and move into more fragile lands such as hillsides and wetlands with disastrous consequences for biodiversity and watersheds. To meet the challenge of producing more rice from suitable lands, we need the rice varieties with higher yield potential and greater yield stability. Most of our conventional crops, including rice and wheat, assimilate atmospheric CO_2 by the C_3 pathway of photosynthesis, which takes place in the mesophyll cells of leaves. Photosynthetically, these plants are underachievers because on the one hand, they assimilate atmospheric CO_2 into sugars but on the other hand, part of the potential for sugar production is lost by respiration in daylight, releasing CO_2 into the atmosphere, a wasteful process termed photorespiration. This is due to the dual function of the key photosynthetic enzyme, ribulose 1, 5-bisphosphate carboxylase/oxygenase (Rubisco). High CO_2 favors the carboxylase reaction and thus net photosynthesis, whereas high O_2 promotes the oxygenase reaction leading to photorespiration. When plants first evolved, photorespiration was not a problem because the atmosphere then was high in CO_2 and low in O_2. As a byproduct of photosynthesis, O_2 accumulated in the atmosphere and reached the present level a million years ago. Current atmospheric CO_2 levels limit photosynthesis in C_3 plants. Furthermore, photorespiration reduces net carbon gain and productivity of C_3 plants by as much as 40%. This renders C_3 plants less competitive in certain environments. In contrast, with some modifications in leaf anatomy, some tropical species (e.g., maize and sorghum) have evolved a biochemical "CO_2 pump," the C_4 pathway of photosynthesis to concentrate atmospheric CO_2 in the leaf and thus overcome photorespiration. Therefore, C_4 plants exhibit many desirable agronomic traits: high rate of photosynthesis, fast growth, and high efficiency in water and mineral use.

Fig:A Rice-A C3 crop

Fig. Sorghum-a C4 crop

Increasing crop productivity to meet the burgeoning human food demand is an extremely challenging task under changing environmental conditions. Global rice production must reach 800 Tg of paddy rice to meet projected demand in 2025, which is 266 Tg more than rice production in 1995. In-depth understanding of efficient contribution of photosynthesis to maximize productivity at this juncture is a challenging task to increase the rice productivity. C_4 plants such as maize and sorghum are more productive as compared to C_3 rice and wheat, because C_4 plants are 30-35% more efficient in photosynthesis.

The C_4 pathway acts to concentrate CO_2 at the site of the reactions of the C_3 pathway, and thus inhibits photorespiration. This CO_2- concentrating mechanism, together with modifications of leaf anatomy, enables C_4 plants to achieve high photosynthetic capacity and high water and nitrogen use efficiencies and ultimately high yield. As a consequence, the transfer of C_4 traits to C_3 plants is one strategy being adopted for improving the photosynthetic performance of C_3 plants. The single cell C_4 photosynthetic system has given us the impetus that it may be experimentally feasible to genetically engineer all C_4 genes in single cell of C3 plants i.e. rice to enhance its photosynthetic activity and productivity.However at the CO_2 compensation point, net CO_2 assimilation equals CO_2 release through photorespiration and mitochondrial respiration in the light. In high CO_2 and /or low O_2 the oxygenase activity of Rubisco is virtually absent, the flux through the photorespiratory carbon cycle negligible and the CO_2 compensation point close to zero. Rice being a C_3 plant, the first product of atmospheric CO_2 fixation is the 3-carbon compound 3-phosphoglycerate (3-PGA), which is produced in the Calvin cycle by Rubisco (the only enzyme capable of net carbon assimilation) in the chloroplast stroma. However, competition of O_2 with CO_2 at the active site of Rubisco results in a loss of up to 50% of the carbon fixed in a process known as photorespiration. Oxygenetion of ribulose-1,5-biphosphate (RubP) severly diminishes the efficiency of CO_2 assimilation in rice under ambient air and results in the formation of 3-PGA as well as 2-phosphoglycollate (2-PGA). The latter is metabolized in the compartments of the leaf cell, the chloroplast, the peroxysomes and the mitochondria, involving numerous enzymatic reactions and transport processes. The overall photorespiratory cycle is also linked to amino acid metabolism in that glycine, serine, glutamate and glutamine are metabolized at high rates (Keys et al., 1978). Both CO_2 and ammonia are released at equal rates in the reaction catalyzed by the mitochondrial glycine decarboxylase complex. The loss of CO_2 during photorespiration is reflected in a CO_2 compensation point of CO_2 assimilation of between 40-60 µl l^{-1} CO_2 in the intercellular air space. At the CO_2 compensation point, net CO_2 assimilation equals CO2 release through photorespiration and mitochondrial respiration in the light. In high CO_2 and /or low O_2 the oxygenase activity of Rubisco is virtually absent, the flux through the photorespiratory carbon cycle negligible and the CO_2 compensation point close to zero. By introducing the *Escherichia coli* glycolate catabolic pathway into rice to reduce the loss of fixed carbon and nitrogen that occurs in C_3 plants when phosphoglycolate, an inevitable by-product of photosynthesis, is recycled by photorespiration. Using step-wise transformation with five chloroplast-targeted bacterial genes encoding glycolate dehydrogenase, glyoxylate carboligase and tartronic semialdehyde reductase, the plants may be generated in which chloroplastic glycolate is converted directly to glycerate. This reduces, but does not eliminate, flux of photorespiratory metabolites through peroxisomes and mitochondria. Transgenic plants thus, may grow faster, produce more shoot and root biomass, and may contain more soluble sugars, reflecting reduced potorespiration and enhanced photosynthesis that correlate with an increased chloroplastic CO_2 concentration in the vicinity of ribulose-1,5-bisphosphate carboxylase/oxygenase. These effects are evident after overexpression of the three subunits of glycolate dehydrogenase, but were enhanced by introducing the complete bacterial glycolate catabolic pathway. Diverting chloroplastic glycolate from photorespiration may improve the productivity of rice with C_3 photosynthesis. By introducing the *Escherichia coli* glycolate catabolic pathway into rice to reduce the loss of fixed carbon and nitrogen that occurs in C_3 plants. Diverting chloroplastic glycolate from photorespiration may improve the productivity of rice with C_3 photosynthesis.

Atmospheric CO_2 concentrations increased significantly in the past two centuries, rising from about 270 µmol.mol^{-1} in 1750 to current concentrations larger than 385 µmol.mol^{-1}. The primary effects of elevated CO_2 levels in most crop plants, particularly C_3 plants, include increased biomass accumulation, although initial stimulation of net photosynthesis rate is only temporal and plants fail to sustain the maximal stimulation, a phenomenon known as photosynthesis acclimation. Increase in CO_2 has double effects on C_3 (Rice) plants such as an increase in leaf photosynthesis and a decrease in stomatal conductance to water vapor. Elevated CO_2 increases net leaf photosynthetic rate primarily by (1) Competitive inhibition of the oxygenase activity of ribulose-1, 5-biphosphate carboxylase/oxygenase (Rubisco) and therefore photorespiration; and (2) Acceleration of carboxylation because the CO_2 binding site is not saturated at the current CO_2 levels. Rubisco catalyzes the competitive reactions of RuBP carboxylation and RuBP oxygenation. It has long been recognized that genetic modification of Rubisco to enhance its specificity for CO_2 relative to O_2 would decrease photorespiration and potentially increase C_3 photosynthesis and correspondingly crop productivity. Although Rubisco has been the primary focus of research to improve photosynthetic efficiency, it has been clearly demonstrate that metabolic control of CO_2 fixation rate is shared among different enzymes in the pathway.

It has been thought that a specialized leaf anatomy, is composed of two distinctive photosynthetic cell types (Kranz anatomy) is required for C_4 photosynthesis. C_4 photosynthesis can function within a single photosynthetic cell in terrestrial plants. The most dramatic variants of C_4 terrestrial plants were discovered in two species, *Bienertiacycloptera* and *Borszczowiaaralocaspica* (family Chenopodiaceae); each has novel compartmentation to accomplish C_4 photosynthesis within a single chlorenchyma cell. The amazing diversity in C_4 systems, how the essential features of C_4 are accomplished in single-cell versus Kranz-type C_4 plants and speculates on why single-cell C_4 plants evolved (Edward *et al.,* 2004). These discoveries provide new inspiration for efforts to convert C_3 crops into C_4 plants because the anatomical changes required for C_4 photosynthesis might be less stringent than previously thought.

A common feature of photosynthesis in practically all organisms is the assimilation of CO2 into organic matter via a catalyst called ribulose 1,5-bisphosphate carboxylase oxygenase (Rubisco) in the carbon assimilation cycle. One of the constraints on the process in terrestrial plants is conditions where CO_2 becomes limiting because of high temperature, drought, or soil salinity. This can occur by restricting the entry of CO_2 into leaves, by decreased stomatal conductance, by decreased cytoplasmic solubility of CO_2, and by increased photorespiration (a process resulting from O_2 competing with CO_2

in Rubisco catalysis). In response to CO_2 limitations, some terrestrial plants evolved mechanisms to concentrate CO_2 around Rubisco through a C_4 cycle that requires spatial separation of fixation of atmospheric CO_2 into C_4 acids, and the donation of CO_2 from C_4 acids via decarboxylases to Rubisco (called C_4 plants). The paradigm for C4 photosynthesis in terrestrial plants for more than 35 years was that a dual-cell system, called Kranz leaf anatomy, is required for spatial separation of these functions. Surprisingly, recent research on species in family Chenopodiaceae has shown that C_4 photosynthesis can occur within a single photosynthetic cell. Two very novel means of accomplishing this evolved in subfamily Suaedoideae. These systems function by spatial development of two cytoplasmic domains, which contain dimorphic chloroplasts. Emerging information on the biochemical and structural strategies for accomplishing C_4 has promise for improving the productivity of rice, which lacks a CO_2-concentrating mechanism, and for securing this important crop as a food supply under CO_2-limited conditions predicted with global warming.

The single cell C_4 photosynthetic system has given us the impetus that it may be experimentally feasible to genetically engineer all C_4 genes in single cell of C_3 plants i.e. rice to enhance its photosynthetic activity and productivity, water-use efficiency and limited photorespiration. The present research proposal envisages to overexpress phosphoenolpyruvate carboxylase (PEPcase) and carbonic anhydrase (CA) in cytosol, and target pyruvate orthophosphate dikinase (PPDK), NADP-Malate dehydrogenase (NADP-MDH) and NADP-Malic enzyme (NADP-ME) to chloroplasts of C3 plants using appropriate promoters and vectors. This may lead to improved CO_2 concentrating mechanism in a single cell favoring carboxylation over that of oxygenation function of Rubisco.

The compartmentation of enzymes of photorespiration and the glycolate pathway, which involves chloroplasts, mitochondria, and peroxisomes, is also important in the function of C_4 photosynthesis. In Kranz-type plants, any photorespiration that occurs as a consequence of O_2 reacting with RuBP is localized in bundle sheath cells, where it can contribute to the CO_2-concentrating mechanism (limiting the competitive reaction of O_2 with CO_2 by Rubisco) as well as allow for refixation of photorespired CO_2 by Rubisco. In the single-cell C_4 plants *B. sinuspersici*and *S. aralocaspica,* glycine decarboxylase is also localized in the mitochondria, which are associated with the Rubisco-containing chloroplasts.

Rice being a C_3 plant, the first product of atmospheric CO_2 fixation is the 3-carbon compound 3-phosphoglycerate (3-PGA), which is produced in the Calvin cycle by Rubisco (the only enzyme capable of net carbon assimilation) in the chloroplast stroma. However, competition of O_2 with CO_2 at the active site of Rubisco results in a loss of up to 50% of the carbon fixed in a process known as photorespiration. Oxygenetion of ribulose-1,5-biphosphate (RubP) severly diminishes the efficiency of CO_2 assimilation in rice under ambient air and results in the formation of 3-PGA as well as 2-phosphoglycollate (2-PGA). The latter is metabolized in the compartments of the leaf cell, the chloroplast, the peroxysomes and the mitochondria, involving numerous enzymatic reactions and transport processes. The overall photorespiratory cycle is also linked to amino acid metabolism in that glycine, serine, glutamate and glutamine are metabolized at high rates (Keys et al., 1978). Both CO_2 and ammonia are released at equal rates in the reaction catalyzed by the mitochondrial glycine decarboxylase complex. The loss of CO_2 during photorespiration is reflected in a CO_2 compensation point of CO_2 assimilation of between 40-60 $\mu l\ l^{-1}$ CO_2 in the intercellular air space. At the CO_2 compensation point, net CO_2 assimilation equals CO2 release through photorespiration and mitochondrial respiration in the light. In high CO_2 and /or low O_2 the oxygenase activity of Rubisco is virtually absent, the flux through the photorespiratory carbon cycle negligible and the CO_2 compensation point close to zero. By introducing the *Escherichia coli* glycolate catabolic pathway into rice to reduce the loss of fixed carbon and nitrogen that occurs in C3 plants when phosphoglycolate, an inevitable by-product of photosynthesis, is recycled by photorespiration. Using step-wise transformation with five chloroplast-targeted bacterial genes encoding glycolate dehydrogenase, glyoxylate carboligase and tartronic semialdehyde reductase, the plants may be generated in which chloroplastic glycolate is converted directly to glycerate. This reduces, but does not eliminate, flux of photorespiratory metabolites through peroxisomes and mitochondria. Transgenic plants thus, may grow faster, produce more shoot and root biomass, and may contain more soluble sugars, reflecting reduced potorespiration and enhanced photosynthesis that correlate with an increased chloroplastic CO_2 concentration in the vicinity of ribulose-1,5-bisphosphate carboxylase/oxygenase. These effects are evident after overexpression of the three subunits of glycolate dehydrogenase, but were enhanced by introducing the complete bacterial glycolate catabolic pathway. Diverting chloroplastic glycolate from photorespiration may improve the productivity of rice with C_3 photosynthesis.

Keeping all these in to account the following objectives can be considered for the efficient photosynthesis and yield improvement in rice

In this context our research envisages the introduction of C4 enzymes like PEPC, PPDK, NADP ME, NADP-Malate Dehydrogenase and Carbonic anhydrase isolated from diverse species of C4 plants of poaceae family and introduce in the rice for the improvement of photosynthetic efficiency and productivity of C3 crop Rice. Apart from that attempt has been made to introduce *E.coli* glycolytic pathway in rice chloroplast to minimize photorespiration in rice and ultimately improving photosynthesis.

Organic production of major plantation crops in the context of Andaman and Nicobar Islands

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Introduction

Plantation crops are the major components contributing to the economic security of various communities of Andaman and Nicobar islands. Amongst various plantation crops, coconut has a significant role in the livelihood of native tribal communities as it has been regarded as a part and parcel of their lifestyle. Coconut, arecanut, oil palm, cashew and rubber are the plantation crops grown in the Andaman and Nicobar islands. All these plantation crops being widely spaced provide an opportunity for cultivation of other important agri-horticultural crops in their interspaces. This is of utmost importance in the context of Andaman and Nicobar Islands as only about 46,000 ha area is available for crop husbandry in the islands. The concept of organic farming is highly relevant in the islands considering the vulnerability of native flora and fauna to the ill effects of *non-judicious* use of chemical inputs. According to FAO (1993), organic farming is a unique production management system that utilizes various agronomic, biological and mechanical methods for promotion of agro-ecosystem health, conservation of biodiversity/ biological cycles and soil biological activity. Present is an attempt to highlight the relevance and applicability of organic farming in important plantation crops of the islands.

Plantation crops of Andaman and Nicobar islands

Most of the area available for cultivation in the islands is under perennial horticultural crops. Coconut is the major plantation crop of the islands occupying about 21,900 ha area. It is the only plantation crop grown on large scale in the Nicobar groups of islands and is generally a community property rather than individuals'. The tribes give more importance to conservation of these natural resources rather than their exploitation for economic benefits (Velmurugan et al., 2015). Farmers of Andaman groups of islands, on the other hand, grow plantation crops mostly for commercial purpose.In recent past, due to fluctuating prices of coconut in the market, there is a tendency of replacing existing coconut plantations with arecanut especially in parts of South, Middle and North Andaman.Presently, about 4,200 ha area is under arecanut and its popularity is increasing in Andaman group of islands due to higher prices offered to the produce.Oil palm was introduced in the islands and plantation was established in the Little Andaman island. However, due to biodiversity conservation related issues, the crop was not promoted for cultivation in these islands. Cashew is cultivated mainly in the uplands and occupies about 1,200 ha in the islands. Apart from these, a number of perennial spice crops viz. black pepper, clove, cinnamon and nutmeg are also being grown in the islands, which have tremendous potential for organic cultivation in the islands.

Relevance of organic farming in plantation crops in the islands

The Andaman and Nicobar islands are geographically separated from mainland India and are known to host considerable diversity of flora and fauna of ecological and economic importance. About 81% of the total geographical area is under forests and ca. 300 plant species have been reported to be endemic to the islands. Considering this, the islands along with Lakshadweep group constitutes one of the 22 agro-biodiversity hotspots of India. A large number of crop wild relatives of horticultural crops and underutilized species have also been reported in the islands (Singh et al., 2016). In order to protect the pristine ecosystem from chemical pollutants and maintain the ecosystem health for sustainable development of the islands, reducing the use of chemical inputs and promotion of organic cultivation is a major step. Further, most of the inputs are sourced from the mainland India and use of local resources for production of organic products could help in reducing the dependence on external supplies. The islands being a popular tourist destination, marketing of organic produce would not be difficult. However, in order to reap the actual benefits of organic produce, systematic implementation of standard procedures is of utmost importance. Nutrient management, pest/ disease management and creating awareness amongst the stakeholders are the key issues to be emphasized.

Pest and disease management

Management of pests and diseases through organic inputs is rather difficult than to manage the nutrient requirement. The islands being isolated from other landmasses, are free from a number of dreadful pests such as root wilt, red palm weevil and eriophyid mite. However, diseases caused by Phytophthora group, rhinoceros beetle, rodents, slug caterpillar etc. were noticed in various parts of the islands.

Bud rot is a deadly disease affecting coconut and arecanut in the islands. The disease is generally sporadic in nature, but assumes epidemics under favourable conditions. This disease is more prevalent in low lying areas with poor phytosanitation. Talc formulations of *P. fluorescens* and *T. viride* have been reported to be effective as palm recovery within 9-15 days was observed with application rate of 200 g/ palm for mature palm (Srinivasulu, 2008).Basal stem rot was noticed in parts of Nicobar island during regular surveys (personal observation) and could be effectively controlled by incorporation of talc formulation (50 g) along with 5 kg/ palm of neem cake (Srinivasulu et al., 2004).

Trichoderma is an important bioresource having potential as a plant growth promoting rhizobacteria (PGPR) and biocontrol agent in plantation crops. Biomass obtained from the palms viz. coir pith, areca leaf sheath, dried husk etc. have been reported to be effective substrates for *Trichoderma*. As these wastes are available in plenty in the coconut and arecanut gardens, large scale production of such microbial agents could be possible without incurring any additional cost. Utilizing such resources, Trichoderma coir pith cakes have been prepared and were found to be of great potential for crown as well as soil application in the plantation based cropping system. Such cakes are light weight, eco-friendly, easy to handle, easy to apply and have shelf life of 10 months under ambient temperature (Mohanan et al., 2013).

Indigenous technical knowledge has been documented (Husain and Sundaramari, 2011) especially for the management of various pests and diseases in the plantation crops. These practices needs to be validated scientifically and promising techniques could be promoted for eco-friendly control of such pests under organic condition. For example, coiling the trunk with coconut leaves and bamboo thorns has been reported as an effective method for controlling rodents in mainland India and hence, could be promoted in the islands as well. use of *Metarhizium anisopliae*, commonly known as green muscardine fungus, has been found to be an efficient method to control rhinoceros beetles in coconut orchards. Incorporation of *Clerodendron infortunatum* in the breeding site has been reported to have synergistic effect when used with the biocontrol agent (Soman and Mohan, 2011).

Maintenance of gardens in hygienic conditions is the foremost step in preventing and spreading of pests and pathogens (Chowdappa, 2017). Regular crown cleaning, removal of wastes, following crop rotation, use of green manure crops, provision of drainage in low lying areas, soil and water conservation measures are the simple yet effective ways for successful organic cultivation. Plant based extracts have been found to be effective under *in vitro* condition for controlling bud rot pathogen (Rasmi and Iyer, 2010); however, commercializable products need to be developed for field use.

The process of organic production is not limited to the farms and equal attention needs to be paid on post-harvest handling and value addition aspects. Post-harvest contamination of copra by aflatoxins is a major concern as it may cause serious health hazards. Such contaminations can easily get into value added products prepared from the contaminated raw material. However, most of the stakeholders are unaware about this fact and hence, conducting awareness about proper drying and postharvest handling is a pre-requisite (Srinivasulu et al., 2006). Use of microbial products including *P. fluorescens* and *T. viride* have been found to be effective under laboratory conditions (Rajappan et al., 2015) and efforts for field level implementation need to be taken up.

Rodents have been known to cause economic losses to the plantation crops in nurseries, fields and storage. About 19 species of rodents including some native have been reported from the Andaman and Nicobar islands. However, only a few have been reported to damage coconut plantations (Birah et al., 2012). The rodent infestation varied between 2.5 to 74.5% in different islands, while nut damage to the tune of 5.1% was evident. High palm density was cited as one of the major reasons for rodent damage in the islands. Mechanical traps, banding with metal sheets etc. are the non-chemical means to control the menace; however, complete eradication is possible only with community participation.

In recent past, incidence of coconut slug caterpillar has been reported from mainland India as well as some parts of Andaman Islands. The pest population is noticed in hundreds in each palm and complete defoliation could be seen in the plantation. Use of light traps has been reported to be an effective method in trapping adult moths of this pest during dry period. For this purpose, placing three 200 W incandescent lamp traps per hectare at about 45 cm above ground with water pan was found to be most effective (Rao et al., 2016).

Nutrient management

Coconut is highly amenable for organic cultivation as perennial nature of the crop offers biomass production throughout the year. In Nicobar islands, coconut palms grow as natural forests and no cultivation practices are generally followed by the tribes. That means Nicobarese have resorted to zero tillage except for occasional slashing and incorporation of natural vegetation in the soil. In order to maintain the Nicobar groups of islands under organic condition, the Andaman and Nicobar Administration has banned use of any synthetic inputs here (Velmurugan et al., 2015). The farmers of Andaman group of islands, on the other hand, grow plantation crops mostly for economic benefits. Limited or no chemical fertilizers are generally applied to coconut and available wastes are recycled into the orchards at times. Some farmers have established vermicomposting units in their farms for meeting nutrient requirement of own farms. In case of arecanuts, farmers tend to use minimum fertilizers and the available wastes are incorporated in the palm basins.

It has been estimated that about 30-50% of the total produce is available as biomass for recycling in the plantation crops (Nampoothiri, 2001). Leaves, spathe, bunch waste and husk are the major biomass components amounting to 14-16 t/ha from a well-managed coconut plantation, which increases to 20-24 t/ha under high density multispecies cropping system (Rethinam and Sivaraman, 2009). Similarly, an estimated quantity of 5-6 t/ha biomass is available from arecanut gardens, which was increased to 8-11 t/ha when high density multispecies cropping system was adopted instead of monocropping (Hussain et al., 2008).

A number of farmers in various parts of the islands have started utilizing the interspaces of coconut and arecanut for production of other crops. High density multispecies cropping system has been considered as an effective way to improve the income and employment generation avenues over monocropping. Studies at ICAR-CPCRI, Kasaragod suggested that organic management practices were equally profitable, when compared with integrated crop management practices (Maheswarappa et al., 2013). Improved productivity and soil health under organic condition was attributed to the enhanced availability of recyclable biomass from multiple component crops in the system.

Constraints and way forward

Surveys in three major coconut growing states of India revealed various constraints faced by the farmers for the adoption of organic farming (Jaganathan et al., 2013). Most of these were related to the lack of awareness regarding various basic and applied aspects of organic farming. Non-availability of quality inputs in time, difficulty in management of pests/ diseases through organic methods, high cost of transportation (especially bulky manures), high labour cost, lack of knowhow about certification, lower yields in conversion period, lack of specialized markets for organic produce etc. were some of the notable constraints faced by farmers in adoption of organic farming. Record keeping, which is the most essential component of organic farming was followed by mere 12% farmers, whereas only 3% farmers had organic certification owing to its higher cost and cumbersome procedure. Interestingly, most of the farmers were following organic farming to improve the soil health and to reduce production cost through locally available inputs.

The islands being remotely situated, non-availability of organic inputs is a major concern. Inter-island transportation of bulky manure and other inputs is again a challenging task. Hence, in house production of farmyard manure, compost, vermicompost etc. could help in making the farmers self-dependent, which is a major aspect of organic farming. The authenticity and efficacy of the bio based products available in the markets needs to be monitored as failure of these products can adversely affect the production system. Promotion of small scale units for production of biofertilizers and biopesticides as cottage scale enterprises could be of great practical value. Attempts for introduction of Baculovirus for control of rhinoceros beetle in the islands were unsuccessful due to non-availability of suitable facilities for its culture. Lack of awareness amongst the farmers is a major hindrance in implementation of organic farming. Most of the farmers tend to open up compost pits in the orchard and thickly mulch the basins with coconut leaves, which serve as breeding grounds for rhinoceros beetle. Further, record keeping is generally paid least attention by the farmers and this could make the certification procedure difficult. Awareness programmes and trainings are being conducted by ICAR-CIARI, Port Blair, Krishi Vigyan Kendras and Department of Agriculture to various stakeholders. Market creation by branding 'Organic Andaman' products is envisaged. Hence, organic cultivation of planation crops could not only reduce the dependence on external inputs but would also help in maintaining the pristine nature of the islands apart from providing better income opportunities to the farmers.

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Organic fruit production

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Cultivation of fruit crops plays an important role in the prosperity of any nation. It is generally stated that the standard of living of the people can be judged by per capita production and consumption of fruits. Fruits are found to be a rich source of vitamins and minerals. For example mango, papaya and jack is the important source of beta carotene which is actually the precursor of vitamin A. Mango and papaya fruits have been estimated to be very good sources of readily available beta-carotene, 1990 ug per 100 g in mango and 880 ug per 100 g in papaya. The phytochemicals present in fruits act as powerful antioxidants which protect cells and organs from damage caused by free radicals, neutralizing their damaging effects. They are the biologically active substances in plants that give them colour, flavour, odour and protection against the non communicable diseases occurring in human beings. Some of the promising phytochemicals which act as antioxidants are bioflavanoids (Vitamin P), phenolics, lycopene, carotenoids, antioxidant vitamins (C and E) and glucosinolates. Oranges, lemons, limes and grape fruits besides being principal sources of vitamin C and folate are rich in a class of phytochemicals called limonoids. The per capita consumption of fruits is in the increasing trend in both developed and developing countries due to the growing health concern among the people. Till the last decade, high production was aimed in fruits by using hi – tech production technologies in which chemical fertilizers, pesticides, fungicides and growth regulators were used abundantly for the control of pests, diseases, weed and biennial bearing. The indiscriminate use of chemicals in fruit cultivation leads to residues in food chain which exert harmful effects in human beings and animals. But in recent years, Organic fruit farming is gaining more importance due to increased awareness of food safety issues and consumer demand. The production of organic fruit is of particular interest, as greater consumption of fresh fruit is advocated as an essential component of a healthy diet, and there are claims that organic fruit is of higher nutritional quality. This increased awareness has created a shift in consumers' taste and preference, which has led to global demand for organically produced fruits and their products. To fulfill the growing demand, organic fruit growing has become a successful enterprise in today's world. Though low yields are recorded in organic production of fruits, the increased price will compensate the lower yields. Among the different horticulture crops, fruits and plantation crops are more amenable for organic as they produce huge amount of waste biomass for recycling, which can meet major portion of nutrient requirement of the crop. The fruit crops are perennial and hence organic cultivation in these crops are highly sustainable as the soil may not require additional tillage or cultivation beyond that needed for establishment thereby minimizing soil erosion. The hill slides and other sites unsuitable for tillage agriculture may be safely adopted for organic fruit production. The organic fruit production system involves the crop rotations, crop residue management, animal manures, legumes, green manures, off farm organic wastes, mechanical cultivation, mineral bearing rock powders and biological pest control. Thus the soil health is maintained in organic fruit culture and minimizes the dependence on outside resources and be self sufficient in the long run.

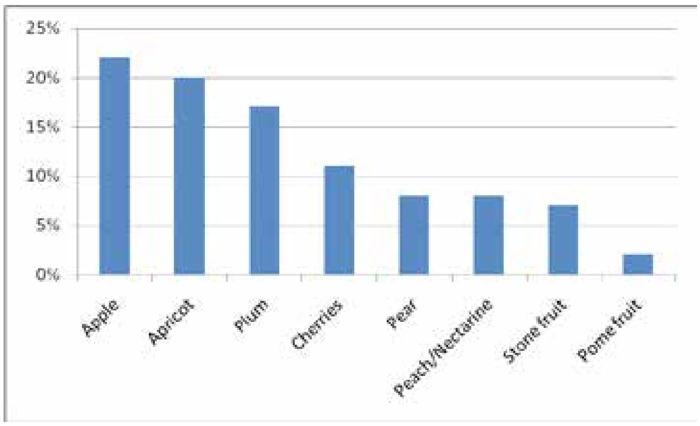
Organic Fruit Production Scenario

As per global Research Institute of Organic Agriculture (FiBL), In 2013, agricultural land under organic management represented almost 1% of all agricultural land worldwide. There were approximately 43.1 million ha of agricultural land (including permanent grazing lands, but excluding wild harvest lands) under organic management worldwide. Organic tree fruit crops comprised approximately 1.2% of all organic agricultural land or 500,000 ha. This area included both converted and in conversion land, with 44%, 61%, and 74% of area converted, respectively, for temperate, citrus, and tropical/subtropical fruits, indicating the large increase in certified organic fruit that may come to market in the next few years. Organic tree fruit production around the world continues to expand annually and Mexico have the largest areas of organic fruit production (Table 1). Among the various fruits being produced organically in the world, apple holds the leading position, followed by apricot, plum, and cherry (Fig. 1). Italy leads in acreage of organic apple production. At global level, the production area of organic fruits is a small fraction of the total area. However, the growth that the organic fruit sector has been experiencing for over a decade suggests that real opportunities remain for producers and businesses as consumer demand continues to grow. Mexico dominated organic avocado and mango production, and it was an important citrus producer. Italy has led Europe for years in organic citrus and temperate fruit production but worldwide has been supplanted by both China and Poland for temperate fruits. Poland has seen the most rapid expansion of organic apple acreage anywhere in the world. Recently China is also establishing its role as a major organic fruit producer. Asia constitutes 9% of the world's organic agriculture, with an area of 2.89 million ha and over 0.4 million producers. China, India, Indonesia, Sri Lanka, and Thailand are the major organic producers in Asia with approximately 90,000 farms on more than 3.8 million ha (FiBL-IFOAM, 2012). Production of processed organic products is growing, although a majority of production is still fresh produce with low value-added processing. Indonesia, Vietnam, Thailand, Malaysia, and Myanmar are emerging countries with organic fruit production.

Table 1. Leading producers of organic tree fruits by area (Source: Granatstein *et al*, 2016)

Rank	Country	Temperate fruits (ha)	Citrus (ha)	Tropical/sub tropical fruits(ha)	Total (ha)
1	Mexico	108	11,917	57,266	69,291
5	Italy	28,324	28,816	4882	62,022
3	China	34,975	11,531	0	46,506
4	Poland	41,990	0	0	41,990
5	USA	18,147	7,528	6716	32,391
6	Dominian Republic	0	250	29,201	29,451
7	Turkey	12,387	523	16,044	28,954
8	Philippines	0	0	25,300	25,300

Fig 1. Share of leading organically produced fruit crops in world (Source: Khan et al, 2013)

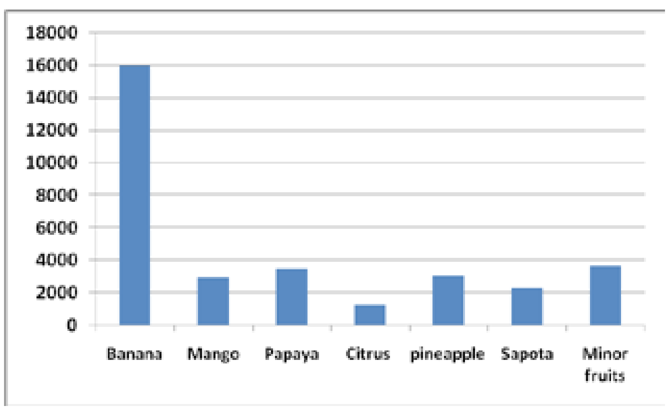


Organic fruit production in our country is picking up with the farmers. During 2015-16, 24636 tonnes of certified organic fresh fruits were produced. In addition to fresh fruits, 8613 tonnes of dry fruits were also produced. Though production of dry fruits is less than the fresh fruits, exports are more in the form of dry fruits only (2464 t in 2015-2016). Dry fruits account for 1% of total organic exports of the country. Organic fruit production in the country is confined to few states only i.e., Andhra Pradesh, Assam, Himachal Pradesh and Jammu Kashmir. The major fruits grown organically in India are Mango, banana, pineapple, passion fruit, sugarcane, orange, cashew nut, walnut (Garibay and Jyoti ,2003). Organic cultivation of fruits is gaining momentum in the North Eastern states. The basic strengths of organic horticulture in this region are (i) a vast area of cultivated land is under the shifting cultivation where chemicals and fertilizers have never been used, (ii) the undulating topography of the region restricts cultivation to small holdings, (iii) farmers from mid and high altitude areas extensively use renewable and available organic-based resources for their cultivation and (iv) production is based on available technical know-how for cultivation, which is mostly organically based. Sikkim is already declared as organic state and other North Eastern states are in process of total conversion to organic. The government of India has taken a long term vision of taking Sikkim as a healthy, sustainable and prosperous state. However, the lower yields experienced in fruit production in the transition period has to be addressed for livelihood security of the farmers. The potential fruit crops of North East region like Assam lemon, orange, pineapple and passion fruit have good demand for export as organically labeled fruits in both domestic and international markets.

Key Opportunities for Organic Fruit Cultivation in Andaman and Nicobar Islands

The fruit crops are grown in an area of 3745 ha in the Island with a production of 32,536 MT (Fig 2). The major fruits grown in the island are Banana, mango, pineapple, guava, citrus, papaya and sapota. Mango is not grown commercially by the farmers and they are of seedling origin. Some regions of the Island can be developed for specialized enterprises such as organic mango especially in the North and Middle Andaman as they are grown without any chemical inputs. The mangoes which are produced during the off season may be marketed in the organic brand in the national market. There is a wide possibility of growing the fruit crops in the Island organically as there is a very limited use of fertilizers and chemical pesticides or fungicides in the Island. The Island has great potential for growing pineapple under a pure organic system due to the climate suitability of the crop and there is a huge demand for the fruits in the Island. Since there is a deficit of land area in the Island, under vertical expansion, pineapple can be grown organically as a intercrop in plantation based cropping system. In addition to the major fruits grown in the Island, it is a home of many underutilized fruit diversity. Most of these fruits remain semi domesticated and a few became rare and endangered due to urbanization. These underutilized fruits are rich source of minerals, vitmains and phytochemicals. Some of the identified underutilized fruits in the island are Alligator apple (*Annona glabra*), Governor's plum or ramontchi (*Flacourtia indica*), Khatta phal or Burmese grapes (*Baccaurea ramiflora*), Bethphal (*Calamus andamanicus*), Khariphal (*Ardisia solanaceae*), Madhuphal (*Salacia chinensis*), Custard apple (*Annona squamosa*), Soursop (*Annona reticulata*), Carambola (*Averrhoa carambola*), Bilimbi (*Averrhoa bilimbi*), Wild passion fruit (*Passiflora foetida*), *Pandanus lerum* Var *andamanensium*, *P. tectorius*, Java plum (*Syzyium claviflorum*), Bullock's heart (*Annona reticulata*), wild mangoes like *Mangifera griffithi*, *M. andamanica* and *M. camptosperma*, Rose apple (*Syzyium jambos*), Rambutan (*Nephelium lappaceaum*), Watery rose apple (*Syzyium aqueum*), Velvet apple (*Diospyrous discolour*), Mangosteen (*Garcinia mangostana*), Chalta (*Dillenia indica*), Sapida (*Baccaurea sapida*), Pacific walnut *(Dracontomelon dao), Wild amra (Spondias pinnata),* Bread fruit (*Artocarpus sp.*), Andaman Marble Wood or Kaki (*Diospyrus Kurzii*) and Noni (*Morinda citrifolia).* These minor fruit species are integral part of the biodiversity of Andaman and Nicobar Islands. These minor fruit species are of seedling origin and the fruits are available seasonally. Minor fruit trees are grown in their backyards by the Island farmers and by default they are organic. Many minor fruits are not fully exploited for their commercial cutlivation. However, there is a wide potential for identifying some minor fruits for organic cutlivation in large scale and processing of these seasonally available fruits which may open up new avenues for marketing organic labelled products for utilization of both domestic and national market. The demand may be created in domestic market itself by targeting the national and international tourists visiting the Island. Cashew (*Anacardium occidentale* L.) is an important dollar earning crop of India with a variety of exportable potentiality and versatility embedded in it. The world demands for the organically produced cashew are growing rapidly in developed countries. Organic cashew fetches a premium price in the international market (Chattopadhyay *et al*, 2015). In the Island cashew is distributed wild in many places and it seldom receives chemical fertilizers and plant protection chemicals. Cashew is grown organically by default with utilization of naturally decomposed biomass but yield is very low. So, there is wide scope to bring a vast area under organic cashew cultivation with improved package of practices for maximization of production in the Island and for export in national and international markets. Apart from these fruits, Dragon fruit, an exotic crop which is introduced recently in the Islands. The crop comes up well under organic system and the demonstration plot established at ICAR-CIARI is grown only with organic inputs. It is a high value crop with domestic demand in the Island. Thus the Island has great potential to introduce organic pineapple, mango, banana, cashew and minor fruits as export commodity. Geographically, the Andaman and Nicobar Islands has a very important strategic location in Asia. It has access to South East Asian countries which may become high end export markets for organic products from the Island.

Fig 2. Share of different fruit crops produced (t) in the Island (Source: A & N Islands database, 2016).



Organic Fruit Production Technology

Organic production is defined by USDA's National Organic Program (NOP) as "A production system that is managed to respond to site-specific conditions by integrating cultural, biological and mechanical practices that foster cycling of resources, promote ecological balance and conserve biodiversity." The organic fruit production system is not only the exclusion of synthetic pesticides and fertilizers but it is an integrated farm management system involving nutrient recycling, productivity, minimum tillage and use of integrated preventive approach for pest and disease management to enhance the health and productivity of the orchard. To achieve maximum yield, organic growers must be prepared to develop innovative production and marketing strategies. Many commercial organic fruit growers, especially family scale farmers minimize waste and losses of potential revenue by processing (drying, preserving or juicing) fruit considered unsuitable for the fresh market.

Cultural practices in fruit production begin with selection of an appropriate site, fruit crop, rootstock and fruit variety, followed by site preparation (tillage and pre-plant soil amendments) and orchard layout (tree and row spacing). These considerations will largely determine the productivity, health and efficiency of operations in the orchard over a long term. Once the orchard is established the changes cannot be made. If the existing orchard is to be brought under organic system, orchard renewal is attempted in relation to the current market and the benefit ratios. The production system must be transformed slowly without much yield loss.

Cultural Practices for Organic Fruit Production

Site selection

Growing fruit crops offers an advantage to farmers interested in sustainable agriculture because of the minimum tillage required and soil erosion could be prevented. Fruit trees, like most crops, respond to good soil with vigour and productivity. Fruit trees can successfully produce economic yields on hillsides, rocky soils, and other sites not suitable for frequent tillage. All the factors regarding site suitability for conventional growing system apply a bit more in organic fruit growing. This is because conventional growers can use chemical fertilizers and pesticides to compensate for some poor site decisions whereas, organic growers cannot. Good drainage and air circulation are essential for disease control. The presence of certain weeds and forage species is of particular concern to the organic grower.

Crop and cultivar selection

Environmental constraints (climate, presence of certain pests and diseases, suitable soils, etc) can greatly impact the suitability of a given site or even a bioregion for organic production of a given fruit crop. The crops which are adapted to the growing region are to be selected for organic production. The crop and cultivar selected should match with the market scope and opportunities of the particular region. The appropriate production system (training system) and rootstocks resistant to biotic and abiotic stresses are to be identified which suits the growing region.

Site preparation

Important considerations in site preparation include alleviating soil compaction, enhancing fertility, adjusting soil pH, and managing weeds, pests, and diseases. If the site preparation is done effectively, it can help to reduce weed and disease problems and assure a vital planting through soil improvement. The extent of tillage depends on the previous use of the land, including crops grown, current vegetation and the presence of pests and diseases. Many growers use rip or chisel the soil to loosen layers of compaction before they plant a new orchard, since deep tillage will be disruptive once the trees are established. Before establishing an orchard, it is important to adjust the soil pH to best suit the crop selected. Traditionally, pH is adjusted through applications of lime (to raise the pH) or sulfur (to lower pH). Most fruit plants perform best around pH 6.5, although they tolerate a pH range between 5.5 and 7.2. In general, fruit crops do not require highly fertile soils for good production, though this varies with the species. Highly fertile soils, rich in nitrogen, can promote too much vegetative growth at the expense of fruiting in trees. A nutritionally balanced soil, proper soil pH and plentiful organic matter are the fundamentals of an organic fertility management plan for fruits. Pre-plant soil improvement for organic fruit plantings usually involves some combination of cover cropping and applications of compost, natural minerals, or other organic fertilizers.

Weed management prior to orchard establishment

It's easier to manage weeds before an orchard is established. Cover crops produce a thick stand that will shade or choke out weeds. Combined with a well-planned sequence of tillage, cover cropping is an effective pre-plant weed suppression strategy that also contributes to soil fertility and stable humus. The basic strategy begins with ploughing the existing vegetation, loosening the soil, planting a cover crop to suppress weed growth, mowing down and tilling around the cover crop and finally planting the desired fruit crop. Selection of specific cover crops and their management vary with the location. Depending on factors such as season, rainfall, soil type, soil erosion potential and seed cost. For example, *Crotolaria* performs less effectively than *Sesbania* at different places because it is poorly adapted to low, wet soils. Some other warm season cover crops that are suitable are aggressive maize varieties and forage soybean varieties.

Orchard layout and design

Orchard layout influences the long-term health of the trees and the ease of field operations such as pruning, irrigation, fertilization, weed and pest management. The row and plant spacing are very important which have impact of all operations from disease management to harvest. Based on the topography of the land, the terraces are to be made for planting. The planting method or system also depends on the crop selected for cultivation. The crops which are to be grown in open sun are to be planted in such a system that they receive ample amount of sunlight. For example, close in-row spacing or double rows of trees may complicate weeding in the first year or two, but thereafter shading will greatly reduce the need for weeding the inter-row. It can also be planned in such a way that the slower-growing trees are planted first using closer spacing, then every other tree are removed when they reach a certain maturity. Alternatively, annual crops can be grown between immature orchard trees.

Management of Established Fruit Orchard

Orchard floor management/Cover crops

The orchard floor—the tree rows and alleys—can be managed in a variety of ways, using tillage or mowing with cover crops, grazing, or mulching. A system that provides full ground-cover provides the best protection against erosion. Clean vegetation in the orchard has many disadvantages like soil erosion problems, gradual depletion of organic matter, increased soil compaction and reduced water infiltration. It is also difficult to move equipment through the orchard in wet weather. However the ground cover uses up the water in summer and is a disadvantage in areas where water is limited. Orchard floor management can control erosion, improve the soil and provide beneficial insect habitat. Some hardy cover crops may be selected for drought regions.

Crop rotation

In an organic orchard, crop rotation does not mean changing the economic crop itself, but diversifying the vegetation that grows around the fruit crop. The orchard floor can be planted with cover crops. The landscape garden within the orchard provides food and shelter for a variety of beneficial species. There is a proven positive effect of organic practices on beneficial insects. A diversified orchard help in sustaining beneficial insects, spiders, bats and birds within and around the orchard. The annual crops grown within the orchard may be rotated in a planned pattern such that the same species or families are not grown repeatedly without interruption on the same field. The orchard planting system involves alley cropping, intercropping and hedgerows to introduce biological diversity in lieu of crop rotation. The benefits of crop rotation in an orchard are it improves soil organic matter content, peat management in annual and perennial crops, management of deficient or excess plant nutrients and prevents erosion.

Weed management

Research indicates that without some form of weed control in the fruit planting, crop yields and plant vigour will be greatly reduced. In organic farming, weed control is only one goal of a weed management system for perennial fruit crops. A good organic weed management plan should present a minimum erosion risk with a provision of platform for the movement of farm equipments. This weed management system will not have adverse effect on pest management or soil fertility, while minimizing weed competition for water and nutrients. Apart from this, the three effective weed control measures in an orchard are cover crops, mulches and soil solarization (Selvaraj *et al*, 2007).

Orchard pest management

Organic pest management relies on preventive, cultural, biological, and physical practices. Insects, mites and microorganisms become pests when their populations grow large enough to prevent growers from reaching production goals. Integrated Pest Management (IPM) programs are useful for organic growers for effective control of pests. The different IPM practices to be followed are selection of multiple resistant cultivars, strong cultural prevention programmes such as sanitation and exclusion is required. The different management practices under IPM are as follows.

- Scouting, monitoring, trapping of insect pests.
- Employment of models to predict insect and disease outbreaks
- Treatment should be attempted prior to outbreak of a pest. Prevention is better rather than correction of problems
- Use mating disruption, trapping, predators and parasites for insect control. supplement with targeted biorational, biological and botanical insecticides
- Use cultural controls to reduce potential pest or disease
- Maintain a proactive botanical insecticide spray program in advance of anticipated pest problem

Common arthropod pests of fruits include insects (aphids, caterpillars, leaf rollers, twig borers, flies, psylla, scale insects, leafhoppers, mealy bugs, earwigs, thrips and beetles) and mites. Identification and preventative management are essential in organic production systems. Vegetation that harbor beneficial arthropods are to be planted as cover crop in the orchard. Strip management of cover crops ensures the presence of habitat for both beneficial and pests. The hedge rows and fencing with live plants may attract beneficiary insects which may have positive impact on pest management. The live fences and hedges may be made with native plants and shrubs that flower at different times of the year may provide pollen and nectar for beneficial orthropods. Thus the long-term nature of growing fruit using cover crops and other resident vegetation management can sustain populations of predators, parasites and other beneficial organisms. In peaches, some winter annual broad leaf weeds have implicated in increased populations of tarnished plant bugs in peach orchards. Dandelions and chickweed can serve as hosts for viruses that affect peaches and apples. A study conducted showed that two species of lady bird beetle were found more abundant in walnut orchard where a cover crop was maintained during the spring and summer seasons of a year. The lady bird beetles kept the walnut aphid population under check. Some legumes are also known to attract hemipterous pests like tarnished plant bugs and stink bugs, where these pests are a problem. Crops like mustards, buckwheat, dwarf sorghum and various members of the Umbelliferae (carrot, dill, fennel, anise, etc.) and Compositae (sunflower and other composites) families support substantial numbers of beneficial insects without attracting as many pests. Maintaining plant in general health and good vigour is important for effective pest management. For fruit plants, it is more applicable to indirect pests (those pests that feed on foliage, stems etc.) than to direct pests (pests that feed on the fruit). For instance, If a tree suffers significant defoliation by caterpillars early in the season, it can compensate and bounce back quickly still producing a marketable crop that year if the tree is in good vigour.

Biological control of insect pests

Biological control refers to the use of living organisms to control the population of a pest. Examples of beneficial arthropods that have been used to control pests in fruit crops include the predatory mites *Phytoseiulus persimilis* and *Metaseiulus occidentalis,* which attack spider mites; ladybird beetles and green lacewings which feed on aphids and *Trichogramma* wasps, which parasitized the eggs of several pests including codling moth. Many beneficial insects can be purchased from commercial insectaries and released in fruit orchards. However the economical way is the management of cover crops and adjacent vegetation as insect refugia to attract and sustain native populations of beneficiary insects.

For commercial orchards, only beneficial insects will not have a complete control for direct fruit pests, additional control measures using IPM are required.

Organic and biorational pesticides

Pesticides approved for certified organic production are usually derived from natural sources, that breakdown rapidly in the field and appear to have minimal impact on the environment. Examples include botanical extracts from plants, insect growth regulators, synthetic pheromone treatments that cause mating disruption, soaps, oils, minerals such as sulphur dust and biological pesticides. The term "biorational pesticide" is used to describe pesticides organically acceptable or synthetic, which have minimal impact on beneficial insects and the environment. Biorational pesticides are considered those providing the least toxic control that can be applied against a pest. Biological pesticides (biopesticides) are both originally acceptable and biorational. Biopesticides differ from biological control in part because they are formulated, labeled and applied like standard pesticides but also because the pest do not reproduce significantly in the field. Biopesticides are highly specific and do not harm humans or beneficial insects. Several biopesticides can be used in fruit pest management. To be effective, they must be used at a specific time in the pest's development cycle. The bacterium *Bacillus thuringiensis* (Bt) is an example for a commonly used biological insecticide. Bt is not as effective against lepidopterous pests that spend their larval stage feeding inside stems, crown, trunks, or fruits, etc. (e.g., peach tree borer, codling moth, grape root borer, etc.). Other microbial insecticides include *Bacillus popilliae* for Japanese beetle grubs, a granulosis virus for codling moth, and insect parasitic nematodes for grubs and wireworms. Botanical insecticides are formulated by extracting toxic compounds from plants that have pesticidal properties. They are naturally occurring, short – lived in the environment and do not leave harmful residues. However, many botanicals are broad spectrum poisons, affecting pests and beneficial organisms alike and are not always the biorational choice. Organic farmers, who are prohibited from using synthetic pesticides, frequently use botanical extracts. Some commonly used plant derived insecticides are pyrethrum, rotenone, ryania and neem.

Specially formulated soap that are high in fatty acids are effective against several soft bodied insects including aphids, whiteflies, leafhoppers and spider mites, insecticidal soap penetrates the insect's body and disrupts the normal function of cells and their membranes, causing the contents to leak out. Applying a thin layer of dormant oil to certain woody plants such as fruit trees, grapevine and bushes suppresses pests like leaf rollers, aphids, mites and scales by suffocating over wintering adults and eggs. Dormant oils should be applied prior to bud break and should never be mixed with sulphur because foliage damage may occur. Insect pheromones are chemicals produced by insects to help them communicate such things are mate availability and sexual receptivity. They are usually specific to a given insect species or genus. Scientist have learned how to synthesize many of these pheromones and these are widely used for monitoring the emergence or simple presence of crop pests. Thus information is commonly used for mating disruption of certain pests. Mating disruption pheromones are available for the oriental fruit moth, codling moth and peach tree borer and grape berry moth.

Organic disease management

Fruit rot is a common problem in fruit crops because of the relationship of soft nature and high sugar content of most mature or nearly mature fruits. The chances of fruit rots may be minimized by allowing good air circulation and sunlight penetration into the interior plant canopy. Sunlight and circulating air help to dry leaf and fruit surfaces, thereby limiting fungal and bacterial infections. In tree crops, this would mean proper pruning and training techniques. In brambles and berries, reducing plant density helps. In grapes, discouraging rank vine growth and removing leaves that shade fruit clusters in beneficial. For all fruits crops, a site that allows for good air circulation should be chosen. Another problem common to many fruit crops is root rots and intolerance of poorly drained soils. Most pear rootstocks and some apple rootstocks are adapted to poorly drained soils, but even these crops will succumb to persistently waterlogged conditions. *Prunus* species (peaches, plums, cherries, etc) are very intolerant of poorly drained soils. Other cultural aids in minimizing disease can include such things as maintaining plants in good health and vigour, removal through prunings from the planting site, roughing out of diseased plants, removal of alternate hosts or inoculums sources for the disease organisms

Copper and sulphur compounds are the principal fungicides and bactericides used by organic farmers, but they have drawbacks. These materials can cause damage to plants if applied incorrectly. Sulphur is also lethal to some beneficial insects, spiders and mites and can set the stage for further pest problems. Long term use of copper fungicides can also lead to toxic levels of copper in the soil. Furthermore, these fungicides are typically inferior to synthetic alternatives, and have to be used on a protective schedule requiring frequent applications. Biocontrol organisms are much effective in disease control. Several formulations of the fungus *Trichoderma harzianum* are now available as an effective control measure against *Botrytis* grey mold.

Post Harvest Handling

Many fruits require some type of post harvest handling. Whether done on-farm or off- farm, these processes must be documented in the organic system plan. Any off-farm post harvest handling must be done by certified organic facilities, and appropriate measures must be taken to prevent commingling or contamination of organic products with non-organic products during washing, sizing, packing, and storage. A complete documentation must be maintained from its field of origin to the point of final sale.

Conclusion

Organic tree fruit cutlivation area and the resulting production have grown dramatically in the past decade, stimulated by a steady increase in consumer demand. Organic temperate and tropical/subtropical fruits cover much more area than citrus, and citrus greening disease is leading to a loss of organic citrus area. Temperate and semi-arid regions appear to have the smallest potential yield gap with current technology. However, higher prices generally compensate for lower yields and the typically higher cost of organic production, associated with higher fertility and crop protection costs. With the growing worldwide market, and scope for organic farming in the country, India holds significant potential in the export of organic tropical and subtropical fresh fruit and processed products. Though organic fruit production is an economical venture, the viability of the enterprise is likely to hinge on site, scale, type of fruit, markets and managerial skills. Management requirements for organic production are likely to be higher in any region, and the producer must be closely attuned to local site conditions. By addressing the challenges, such as small land holdings, lower yields, widely dispersed farms, long-term investment, low in-hand capital and national policy for organic fruit growing, more farmers and entrepreneurs may be encouraged to shift from conventional to organic fruit growing. The challenge for the future is to build up a credible ("true-organic") and high quality multi-factor oriented organic fruit production that combines single factor solutions to a self-regulating, and possibly even organic pesticide-free, production system. Progress in this direction will lead to innovative organic production and marketing concepts that are clearly different from conventional ones. To achieve these goals, creative efforts along the whole chain involving producers, consumers, retailers, advisory services and researchers are essential (Weibel, 2007).

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Organic spices production in tropical island of India

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Modern day spices production largely depends on the use of chemicals based inputs such as pesticides, chemical fertilizers, herbicides and labour saving but energy intensive farm machinery while application of such high input technologies has undoubtedly increased production and labour efficiency, there is a growing concern about the adverse effects on soil productivity and environmental quality. The generally accepted organic production rules prohibit the use of synthetic fertilizers, pesticides, growth regulators, livestock feed additives and stress on long-term soil management. Use local resources for nutrient supply and control of pests and diseases restricting external inputs to the bare minimum. It is soil-building mechanisms to keep the soil alive. Keeping soil alive is the primary concern of organic farming. Organic spices farming, soil not the crop is fed. It is the conversion of soil from non-living to living. Plants can absorb nutrients only in the form of minerals irrespective of the source of manure. Organic spices farming seeks to avoid direct use of readily soluble chemicals eg-Muriate of potash is a natural rock and is not permitted because it is readily soluble. On the other hand, basic slag which is a product of iron ore is insoluble in water and hence, it is allowed

Organic spices cultivation offers great scope in sustainable natural agro-ecosystem resource management towards improving the rural livelihoods in India. Several organizations have launched programs towards promotion of organic spices practices. These are largely directed at addressing the concerns and needs of the stakeholders in the farming to market supply chain involving supply and technical services-production-post harvest handling- marketing. There is the need for empowering the farmers within formation and access to a wide range of organic crop production inputs and protection inputs It is also important to ensure that these inputs, which are produced and availed by community initiatives and also by private sectors are of dependable quality so as to safeguard the interests of the farmers.

Importance of spices in economy of India and Islands

India, considered as the-Land of Spices is one of the major spice producing and exporting country in the world, contributing about 20-25% of the world trade in spices.. Out of 109 spices recognized by the International Organization for Standardization (ISO), more than 52-60 spice crops are grown in India. There is a good export demand for Indian spices because of high quality with the maximum content of essential oil, oleoresin and active principles. Spices are grown widely in Andaman & Nicobar isands also. Tropical humid climate prevailing in these island are suitable for organic spices production. Black pepper (*Piper nigrum*), Chilli (*Capsicum annum*), Cinnamon (*Cinna*momum *verum*), Nutmeg (*Myristica fragrans*), Clove (*Euginia caryophllus*), Turmeric(*Curcuma longa*) and Ginger (*Zingiber officinale*) are major spices grown in island climate .Currently, the total area under different spices for growing in India and Andaman island 33,17,280 ha and 1675 ha with a production of 61,08,280 mT and 3220 mT respectively (NHB 2014-15). In Andaman island among the spices, the maximum area occupied by Black Pepper (600 ha) followed by Chilli 400 ha and Ginger 215 ha. However, maximum production was reported in Ginger 1910 t followed by Chilli 610 t , and Turmeric 470 t (NHB , 2014-15). Among the spices, tree spices (cinnamon, clove, nutmeg and allspice) production is very limited (5000 t) compared to the requirement of domestic demand (7000-8000 t). The world demand for organically produced foods is growing rapidly in developed countries in Europe, in the USA, Japan and Australia. The current estimated share of organic foods in these countries is approximately 1 to 1.5 per cent which is expected to increase to 10 per cent in the next couple of decade. The market size of organic spices in the US is 30,000 tonnes, Europe 21,000 and Japan 6,000. The worldwide food trends are changing with a marked health orientation. Since organic foods are free from chemical contaminants, the demand for these products should steadily increase in the new millennium.

Why Organic Spices Farming?

Pesticides pose dangers to the biodiversity; health and well-being of humans, animals and plant life; and are detrimental to soil micro-flora, microfauna and soil health. Chemical pesticides used in Black Pepper, Turmeric and Ginger etc are toxic, nonrenewable, nondegradable, lethal and stay in the environment for many years. In the long run, they become a cause for poverty, ecological imbalance, unsustained development and disharmony between man and environment. Forced production, utilizing unnatural production technologies result in poor productivity per unit area, the imbalance in the soil-water-microbes system, degradation of soil sites and irrational land use systems. A planned organic cultivation will involve site-specific and crop-specific decisions. The organic cultivation takes into consideration local resources, the status of the environment and community involvement. Products that are certified and sold as ‘organic’ fetch a premium price compared with conventional products. The poor farmer never thinks of the quality of the food he consumes, but he is interested in the profit he can make out of organic farming. Hence, for a country like India where small and marginal farmers are the majority, organic farming would be the right choice for exploiting the interests of the potential market. Organic farming also expected to offer more employment opportunities since it is more labor intensive

Spices crops currently occupy a special niche in organic agriculture in India, as there is considerable potential demand for organically grown products in the global market. This Chapter illustrates the organic production of spices which are recommended and presently available for organic crop protection of these crops in India. Policy and infrastructure support are also needed to promote the scaling up of production of organic spices as means of empowering organic farmers with appropriate technology inputs for spices crop protection.

Importance of organic spices production

- Spices produced with the use of inorganic fertilizers and chemicals are harmful to human health and environment due to presence of heavy metals, toxic chemicals and their carcinogenic effect
- The economic efficiency of chemical fertilizer is not more than 50% and the remaining is lost by leaching and volatilization.
- The growth and yield of important spices in India has been declining, for sustain the yield and quality , organic cultivation should be preferred.
- Plant also uses nutrients from organic sources through mineralization and billions of beneficial microorganisms available in soil are saved under organic cultivation.
- Excess and indiscriminate use of inorganic fertilizer has already deteriorated the soil badly with deficiency of macro and micronutrients.
- Organic spices are reported to have more vitamins, minerals, enzymes, trace elements and even cancer-fighting antioxidants.
- Various bio-pesticides like *Trichoderma viridi, Bacillus thurengiensis*, and others botanical pesticides (Neem), bio-control agents (*Trichogramma, Cryptolaemus, Chrysoperla* etc.) are capable of controlling pests and diseases. These bio-pesticide are eco-friendly and good for the environment s well as soil health
- The production and productivity of spices under organic farming may be less in the initial years, but the yields could be increased progressively 2-3 year under organic farming.

Principles of organic farming

The principle of organic farming is to allow `Mother Nature' to provide us food the way nature intended. The soil is of central importance. Organic farmers nourish the soil and its micro universe rather than force-feeding the plants to grow unnaturally fast. In organic farming, animals are treated with care and respect. There are no cages, animals move free, grazing on grass and other natural pastures. The fertility and biological activities of the soil should be maintained by the cultivation of legumes, green manures, and deep-rooting plants and by incorporation of raw or composted organic material in the soil. If these methods are not sufficient to ensure adequate nutrition of crops and to maintain the mineral balance of soil, a limited number of other organic or mineral fertilizers may be applied. For compost activation, appropriate microorganisms or plant-based preparation (biodynamic preparations) may be used.

Conversion requirements to organic spices farming

Organic farming means a process of developing a viable and sustainable agro ecosystem. The time between the start of organic management and certification of crops is known as conversion period. When traditional agricultural methods fulfill the principles of these standards, no conversion period is required. When claiming virgin land for organic agriculture, no conversion period is required. The whole farm including livestock should be converted according to the standards over a period of time. This time is defined by certification programme. If a farm is not converted all at once, it should be done on a field-by-field basis, whereby full standards are followed from the start of conversion on the relevant fields. These areas of land being managed to the full standards will therefore progressively increase.

Organic Spices Cultivation: Strategies

The following strategies are to be adopted for organic spices cultivation

1. Rotations and diversification are key principles in organic crop production system
2. Diversity of crops in both time and-space prevents insects and disease build-ups and gives a grower a hedge against poor market conditions for any one crop.
3. In an annual cropping system, legumes are cultivated to improve soil fertility. Allelopatheic crops that exude toxins from their roots can suppress weeds and insect pests
4. Pest free and weed-free fields are neither always possible nor economically and ecologically desirable. Hence, one should learn the threshold of tolerable levels of weeds, insects, birds and rodents through experience and as an on-going process.
5. In a perennial system, cover crops are used to hold the soil, improve soil fertility and provide habitat for beneficial insects.
6. Varietal selection should look beyond maximum potential yield and consider insect and disease resistance, nutritional quality, flavour and positive response to lower inputs of nutrients and water.

7. Proper timing of planting and use of trap crops can minimize pest problem.
8. Materials are used only to solve specific problems, but not as a strategy.

BLACK PEPPER

In India, black pepper is generally produced with an inorganic source of nutrition. Many farmers' particularly small and marginal, produce organically. When pepper is grown with tea, coffee, arecanut and coconut then fertilizer and pesticides applied to the main crop also used by pepper. These inputs may leave residue in the product which may be beyond the acceptable levels in some case. Besides contaminating ecosystem they also cause the major health hazard.

Black pepper is famously known as "Block gold" and king of spices. It is one of the oldest and the world's most important spices. Among all the spice crops, pepper has the highest contribution to trade and foreign exchange turn over.

Propagation and nursery preparation

Pepper can be propagated by seeds as well as by vegetative means. For the preparation of disease-free and healthy plant following procedure should be followed.

Nov- Dec	Identification of healthy high yielder, coiling, and lifting of runner
January	Preparation of nursery mixture and solarisation
March	Mixing nursery mixture with Trichoderma and VAM and filling in the polybag. Planting the 2-3 node cutting. Watering and covering the polythene hood
April	Lifting Polythene hood and spraying with 1 % Bordeaux mixture
May	*Pseudomonas fluorescence* is used for spraying and drenching
June	Spray 1 % Bordeaux mixture

Planting

Black pepper plants should be planted in 50 cm 3 pits at a distance of 30 cm away from the base. The pits are filled with a mixture of topsoil, farmyard manure @ 5 kg/pit and 150 g rock phosphate. Neem cake @ 1 kg and *Trichoderma harzianum* @ 50 g also may be mixed with the mixture at the time of planting.

Cultural practices and its advantages

Cultural practices	Advantages
Lifting of runners and coiling in January	Avoidance of rooting and soil born diseases.
Earthing up	Avoidance of water stagnation and prevention of feeder root desiccation
Light mulching- in November - December	Avoidance of root desiccation
Irrigation in March - April	Early uniform spiking and good setting
Opening drains	Avoidance of water stagnation excessive moisture and root infection
Skirting (leaving 1 or 2 runners for rejuvenation) in May/ November	Avoidance of soil born spread through splashing
Healthy vigorously growing planting material	Good establishment and avoidance of nematode and fungal pathogen
Solarization of rooting mixture	Avoidance of soil born pathogen
Removal of infected parts	Reduction of air born infection
Destruction of dead vines	Destruction of soil born infection
Avoidance of close planting	Reduction of plant to plant spread through splash and root contact
Avoidance of excess shade	Reduction of the damp condition which influences the inoculums build-up. Higher proportion of bisexual flower
Liming	Neutralize the soil pH and creating microclimate for multiplication of useful microorganism
Application of vermicompost, cow dung slurry, Gober gas slurry and cow urine	Correcting plants nutrition problem, enrichment of soil microflora and growth promotion

Nutrient management

Manuring for pepper vines is to be done in basins in a semicircular band on the northern side of the standard around the plants, 10-15 cm deep and 50-75 cm radius.

Advantages of prophylactic and bio-intensive measures

Application of neem oil cake/ pongamia cake	Suppression of nematodes
Mulching with green manures	Enrichment of soil microflora and suppression of soil nematodes
Spraying bordeaux mixture	Reduction of air-borne spread of foot rot, anthracnose pathogens
Incorporation of VAM	Promotion of root growth and suppression of soil born nematode and root pathogen
Incorporation of *Trichoderma* and *Pseudomonas* to soil	Growth promotion and suppression of soil born borne pathogen

Pest and diseases

Among the several pest recorded in black pepper ~~pollu *Beetle (Longitarsus nigripennis)*,~~ Top shoot borer (*Cydia hemidoxa*) and scale insect (muscle insect Lepidosaphes piperis) and coconut scale (*Aspidiotus destructor*) are the major pests in different part of growing area. Among the diseases, Phytopthora foot rot and anthracnose are major disease. ~~Pollu beetle and its grub cause considerable damage to leave and berries of black pepper at lower altitude.~~ Commercial formulation of neem could effectively reduce pollu beetle infestation. Pollu beetle infestation high in field from September to October in more shaded area. So regulation of shade of standard (support tree) helps in reducing the pest infestation. A few cultivars of pepper viz., Karimunda and Kulluvally least susceptible to pollu beetle. The main focus areas for managing foot rot are use of field tolerant varieties (IISR-Shakti, IISR-Thevam and Narayakodi). Avoid the close planting, apply Trichoderma and *Pseudomonas fluorescens* during pre-mansoon and post mansoon. These antagonistic suppress the soil born inoculums of *Phytopthora capsici.*

NUTMEG

Nutmeg yields two types of spice viz., Nutmeg, kernel and mace which is the hard and brown, enclosed in a thin shell and brittle. Aril (mace) is surrounding the shell which is scarlet in colour. Mace is used as a culinary spice and largely as a flavoring agent. The husk is used for pickling when the fruit is at a tender stage. The fresh husks of the ripe fruit can be used for making jelly. Nutmeg butter is used in the manufacture of scented oils, ointments, perfumes and soaps, and as a flavoring agent in cooking and confectionery.

Land conversion

Farmers convert a portion of the farm to organic cultivation, it is advisable that the entire farm is of convened to organic at a time. However, in the case of large farms, the conversion can be on phased out for which a conversion plan is made and followed. For an existing plantation, a minimum of three years is required as conversion period for organic cultivation. For a newly planted or replanted area raised through organic cultivation practices, the first yield itself can be considered as organic produce. In order to avoid contamination of organically cultivated plots from neighboring farms. a suitable buffer zone is to be maintained. An isolation distance of at least 25 m width is to be left all around the conventional plantation.

Nutrients management

Farm yard manure is applied at 10 kg per pit and gradually increased to 50 kg per plant for a 15-year-old tree. The manure may be applied in shallow trenches dug sufficiently far away from the base of the tree. Depending on the availability of moisture or rainfall, manures is applied twice a year once in May-June and then again in September-October

Pest and disease

No serious insect pests are reported in nutmeg. Occasionally scale insects infect tender leaves and shoots in the nursery. Scale insect infestations which are occasionally seen in the nursery can be managed by spraying neem oil 0.5% during early stages of infestations. Among diseases, fruit rot caused by *Phytophthora sp.* and *Diplodia natalensis*. die back caused by *Diplodia sp*. thread blight caused by *Marasmius pulcherima* and leaf rot and shot hole caused by *Cylindrocladium quinquiseptatum* are some of the major diseases affecting nutmeg. Restricted use of Bordeaux mixture 1% will be helpful in controlling these diseases.

CLOVE

The clove of commerce is the fully grown but unopened aromatic dried flower bud of an evergreen tree *Syzygium aromaticum*. It is is one of the important tree spice crop grown in India. The volatile oil obtained from the clove bud contains mainly eugenol- (80-90%) and caryophyllene (4-8%). The major use of cloves is for domestic culinary purposes, as a spice to flavour both sweet and savory dishes and in the preparation of pickles and sauces.

Raising Nursery

The beds should be made of the loose soil-sand mixture over which a layer of sand (about 5-8 cm thick) may be spread. Seeds can be sown in sand beds of 15-20 cm height, 1 m width and with convenient length in a cool and shady place. Seeds are sown at 2-3 cm spacing to a depth of about 2 cm. If only small quantities of seeds are available for sowing, they can be sown directly in biodegradable polybags or in mud pots filled with the soil-sand-cow dung mixture and should be kept in a shady cool place. The seedlings are ready for transplanting in the field when they arc 18-24 months old. Transplanting time can be reduced to one year by planting clove seedlings in a mixture consisting of soil and vermicompost in 1:1 proportion. The nurseries arc usually shaded and irrigated daily.

Field Management

For a newly planted or replanted area raised through organic cultivation practices, the first yield itself can be considered as organic produce. In the case of cultivation on virgin land and for farms where records are available that no chemicals were used previously, the conversion period can be relaxed. It is desirable that organic method of production is followed in the entire farm, but in large plantations, the transition can be phased out for which a conversion plan is to be prepared. For an existing plantation, a minimum of three years is required as conversion period for organic cultivation. In order to avoid contamination of organically cultivated plots from neighboring farms, a suitable buffer zone is to be maintained. An isolation distance of at least 25 m width is to be left all around the farm/conventional plantation.

Nutrient management

Well, rotten cattle manure or compost @ 15 kg/plant/year during May/June in the initial Years may be applied. The quantity may be increased gradually so that a well-grown tree of 15 years and above gets 40 to 50 kg of organic manure. Cattle manure or compost @ 50 kg and be meal or fish meal @ 2-5 kg per bearing tree per year can be applied. Organic manures can use applied as a single dose at the beginning of the rainy season in trenches made around the trees.

Insect-pests and diseases

Scales (*Lecanium psidii*) and mealy bugs (*Planococcus sp.Pseudococus* sp.) attack are being noticed in the nursery. Spraying neem oil (0.5%) can control scale-insects. Stem borer (*Sahvadrassus malabaricius*) is a serious pest in clove and infests the main stem of young trees at the basal region. The infected portion shall be removed and the borer manually pulled out with a long hooked wire and destroyed. Also, keep the basins free of weeds. Washing with soap solution is effective for control of mealy bugs.

Leaf rot caused by *Cylindrocladium quinquiseptatum,* leaf spot and bud shedding caused by *Colletotrichum gleosporioides* and dieback of young seedlings and grown-up trees can be controlled by restricted use of Bordeaux mixture 1%. Seedling wilt is an other serious problem in the nurseries and causes considerable damage. *Cylindrocladiwn sp, Fusarium sp.* and, *Rhizoctonia sp*. are the casual organisms associated with the diseases. The infested seedling is to be removed and destroyed. If the occurrence is severe, Bordeaux mixture 1 % may be used to spray the plants and drench the soil to arrest the spread of the disease.

CINNAMON

Cinnamon is famous for its bark and leaves which are strongly aromatic. The bark has a sweet and agreeable taste. The bark, either as small pieces or powder, is extensively used as spice or condiment. It is aromatic, astringent, stimulant and carminative. In addition, the true cinnamon of commerce cassia is obtained from various sources like C. *cassia,* (True cassia or Chinese cassia) C. *burmanni,* (Indonesian cassia) and *C. lourneirii* (Saigon cassia) and *C.* time/an (Indian cassia). The other economically important species include *C. camphora*, C. *oliven* and C. *malabaricum.*

Preparation of Land and Planting

~~Preparation of land and planting~~ It is essential that all the crops in the field where organic spices are produced are also maintained using organic methods of production. Soils which are not contaminated with heavy metals, pesticides, and other industrial chemicals should be selected. The area for planting cinnamon is cleared and 50 cm x 50 cm x 50 cm size pits are dug at a spacing of 3 m x 3 m. They are then filled with compost and top soil before planting. Cinnamon is planted during June-July to take advantage of the monsoon for the establishment of seedlings.

TURMERIC and GINGER

Turmeric is one of the most valuable ancient sacred spices of India. In turmeric curcumin the yellow colouring pigment present in the rhizome, this has high medicinal value. Turmeric powder and water are used as cosmetics. Turmeric is considered a carminative, tonic, blood-purifier, vermicide and an antiseptic. It is used in folk medicine for intestinal disorders, worms, anemia, measles, asthma, sore throat, cough and cold, diabetes, sprains, skin disorders, etc., both externally and internally. Ginger, one of the oldest known spices, is esteemed for its aroma and pungency. Ginger of commerce constitutes both fresh and dry rhizome. Ginger is used in the production of ginger beer, ginger wine, cordials and carbonated drinks in confectionery, pickles and pharmaceutical preparations. Organic turmeric and ginger production procedure is summarized the following.

Criteria	Turmeric	Ginger
Conversion	Minimum 2- 3 year	
Buffer zone	25-30 m	
Land preparation	March April 1-1.5 width and 15 cm height bed or ridge and furrow	
Seed treatment	Hot water treatment of rhizome bit at 52 ^{o}C for 10 minutes or 45^{o}C 30 minutes. Treatment with Trichoderma and VAM formulation	Store with Glycosmis leaves Treatment with trichoderma and VAM formulation. Solarize selected rhizome bit in moist 200 gauge polythene cover in morning 9-11 am Mulched with green leaf @ 12-15 t/ha or
Mulching	Mulched with green leaves @ 12-15 t ha or any other locally available material	any other locally available material Mulched with Green Leaf @ 12-15 t ha
Weeding	Manual 2-3 time and mulched with leaf and organic fertilizer	+ chop the leguminous intercrop and mulched 2-3 time or any other locally available material 25 -40-ton FYM + Cow dung slurry
Nutrition	25 -40-ton FYM + Cow dung slurry vermicompost	vermicompost, Neem cake/ Pongamia cake, poultry manure bone meal
Disease and pest		
Pest	Mechanical collection of larvae from bore hole and destruction at 15-day interval, spray 0.5% Neem formulation / bacterial bioside (Dipel) formulation at 15-day interval and mulch with *Virtex negundo* leaves and Lantana Leaves	
Root-knot Nematode	Application of Neem seed / Neem cake @ 2000kg /ha	
Soft Rot/ Soft Rot	Planting on raised ridge bed. Provide 30 cm deep drain at regular interval to check soft rot. Plant PCT-13 PCT-14 and Shilong local for field tolerant to soft rot	Planting on raised ridge bed. Provide 30 cm deep drain at regular interval to check soft rot. Make adequate drain and clean regularly
Foliar Disease	Provide 25% shade by planting sesbania, spray with 1% Bordeaux mixture, Plant short duration varieties because all short duration varieties are resistant to foliar disease	Provide 25% shade by planting sesbania, spray with 1% Bordeaux mixture
Harvesting and processing	Harvest at after 9 month	Harvest at after 7-9 month. addition of lime during drying bleaching should be avoided

Challenges and opportunities of organic spices production

India is not in a position, at present, to completely do away with the use of synthetic agrochemicals, especially the inorganic fertilizers, in view of the large demand of the increasing populations for food commodities. Systematic phasing out of the use of agrochemicals and synthetic fertilizers and increasing the use of organic manures, reduced tillage bio fertilizers etc. may prove beneficial in this direction. At present, the country lacks a systematic research and development programme in respect of sustaining agricultural systems through organic farming practices. The technological and economic feasibility of organic farming will certainly influence its large-scale adoption and promotion. Coupled with this, the need for the alternate farming system in view of emerging environmental problems and energy constraints will have a bearing on an agricultural structure in general, and adoption of organic farming practices, in particular. However, awareness about degradation of earth's natural resources at an alarming rate.

The Research institutes must have encountered problems facing in growing organic spices crops. It is the common experience that when plants were grown in isolation they will have less problem of competition for nutrients, aeration, pest, and diseases. One of the recommendation in organic spices production is to keep optimum space between plants and rows to keep watching for "Catch and kill, Pull and burn". This has given good results but there will be the reduction in yield on a hectare basis. Three to four good crops can be taken under good humus rich soil with moisture in spite of pest and disease. There has not been enough research on this line. Similarly, for other spices like black pepper, Ginger, turmeric which have major problems of pest and diseases, the appropriate approach to organic nutrient management may be the future solution. Dung and cow urine in various combination and additives have been found effective means for nutritional and pest management in several crops. For many of the difficult problems, the answers may be very simple and locally available with humble farmers. The researchers need to keep their eyes and ears open to the surroundings. Now a large number of ITK's documented by ICAR are available for guidance which may help in organic spices cultivation.

There is no scope to be too ambitious to get the highest yield and quick riches in organic farming. The aim of organic farming is the sustainability of production. Many problems arise when we attempt to cross the bearing capacity of the soil and plants. In recent years we have seen at certain places disastrous consequences in ginger and green chillies production.

In organic spices cultivation, the resistance gene sources hold promise against pest and diseases which are major constraints in productions. Effective microbial bio-control agents are being developed by several agencies including private laboratories. Similarly, a plethora of microbes (bacteria, yeast, fungi, protozoa etc.,) which are an integral part of natural fertility cycles, not only play a crucial role in mineralization of nutrients but produce such products in the soil at are not clearly understood by science but provide resistance pest and diseases. The only condition is to provide suitable organic substrate and moisture for them to multiply to the optimum level. In organic farming, no nutrient is fed to plants directly but the soil is fed to feed the microbes which inturn produce alchemy of plant nutrients. There is a great scope to work in this direction to produce the quality products. We have to re-orient our research from fertilizer and pesticides trails towards the wide range of organic amendments to build the life in the soil. The value addition to the products by way of aroma, taste and keeping quality is done by microbes.

Summary and conclusion

Organic farming does not aim at a particular crop, but it is a system for the well being of the soil, environment and all flora and fauna inhabiting the earth. Hence, this system is to be implemented in the production of spices also in a harmonious manner so as to make the natural aromas and flavors used throughout the world. Organic spice farming represents a highly suitable form of land use for areas with particularly stringent ecological requirements, in particular, catchments for drinking water. Research into the economic analysis of organic spices production system shows that productivity and operating incomes are comparable with those obtainable from conventional farming when the holdings have reached a good soil management balance and taken control of the marketing of their produces

Organic spices farming imply growing of spices crops without chemical fertilizer, herbicide, and pesticides. Agricultural practices followed in organic spices farming are governed by the principles of ecology and are within the ecological means. Organic spices cultivation is a production methodology that avoids or largely excludes the use of pesticides, growth regulators, livestock synthetically compounded fertilizers, feed addictive and genetically modified organisms. Organic farmers rely on crop rotation, green manures, compost, biological pest control, and mechanical cultivation to maintain soil productivity and control pests as far as possible and practicable. In view of declining trend in export of certain spices like black pepper, cardamom, clove and nutmeg etc. due to the emergence of new competitors like Vietnam, Guatemala, and Sri Lanka coupled with change requirements of emerging market of organic spices, the organic production technology need to be popularized to sustain the quality. There is scope in expanding of Organic spices production in the country. India with intrinsic “quality spices” grown under wide agro-ecological regions, can definitely utilize this expanding organic spices sector.

Organic Protected Cultivation Technology for Growing Horticultural Crops

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Organic Protected cultivation technology refers to growing high value horticultural crops in purely organic condition without the traditional use of chemical fertilizers, insecticide and pesticide. It is environment friendly and sustainable technology. It removes the traditional bottleneck of protected cultivation technology and facilitates to economically sustain it for longer times. This concept of growing has become popular due to traditional demand of organically grown safe vegetables, flowers, fruits and nurseries. Greenhouse technology and horticultural practices differ little between conventional and organic greenhouse production. The main variations are concerned with pest control and fertility. Due to plethora of diseases prevalent throughout the world, the health conscious citizens are demanding organically grown high value vegetables and fruits to consume. It can be achieved through growing these crops inside different types of protected structures. IPM and GAP based protocols are available for growing organic protected cultivation Technology. Drip irrigation can also be adopted for supplying good quality water to the plants but traditionally adopted fertigation practice is not suitable for organic protected cultivation. Instead of chemical based fertilizers, farm yard manure, vermicompost and bio-fertilizers are available for adoption. Similarly IPM based strategy based on organic and natural principle are available to combat various diseases. Various neem based insecticides and pesticides are possible solutions available.

The main purpose of protected cultivation is to create a favourable environment for the sustained growth of crop so as to realize its maximum potential even in adverse climatic conditions. Protected cultivation technology offers several advantages to produce vegetables, flowers, hybrid seeds of high quality with minimum risks due to uncertainty of weather and also ensuring efficient and other resources. This becomes relevant to farmers having small land holding who would be benefitted by a technology, which helps them to produce more crops each year from their land, particularly during off season when prices are higher. This kind of crop production system could be adopted as a profitable agro-enterprise, especially in peri-urban areas. At present there is a large gap between the demand and production of these crops to meet, both quantitative and qualitative needs of domestic and export markets which are difficult to be bridged with the traditional cultivation practices. Thus, protected horticulture has great potential to enhance the income especially of small farmers if appropriate technological interventions are made.

Protected cultivation offers several advantages to produce horticultural crops and their planting material of high quality and yields, through efficient land and resource utilization. Fruits, vegetable and flower crops normally accrue 4 to 8 times higher profits than other crops. This margin of profit can increase manifolds if some of these high value crops are grown under protected conditions, like greenhouses, net houses, tunnels etc. Such an agricultural production system could provide a more profitable source of income and employment in rural sector. The amount of post harvest losses in vegetables and cut flowers is very high (20-30%), which can be significantly reduced and productivity can be increased 5-10 through protected cultivation technologies by taking the crops round the year. Protected cultivation has very high entrepreneurial value and profit maximization leading to local employment, social empowerment and respectability of the growers. Environmentally safe methodologies involving IPM tactics reduce the hazards lacing the high value products. Fertigation has been found to be one of the most important production technology for hi-tech horticulture and protected cultivation. It helps in achieving higher productivity and enhancing the quality of horticultural produce.

Protected Cultivation technology is a relatively new technology for our country. The total area covered under protected cultivation in our country is approx 50,000 hectares. There has been a very good development in this area during the last five years. The leading states in the area of protected cultivation are Maharashtra, Karnataka, Himachal Pradesh, North-eastern states, Uttarakhand, Tamil Nadu and Punjab. The major crops grown in the protected cultivation are tomato, capsicum, cucumber, melons, rose, gerbera, carnation and chrysanthemum. Nursery grown in the protected cultivation is becoming very popular venture for income and employment generation.

An understanding of plant-environment interactions is essential for maximizing plant productivity under a set of operating constraints. The growth of plant could be modified by changing the parameters of its surrounding environment, that is, its microclimate. Logically, for a given plant it is possible to arrive at an optimized set of microclimatic parameters in order to maximize the plant growth. A greenhouse is, essentially, a practical means to achieve the maximization of plant productivity by maintaining the optimum microclimate.

The microclimate of a plant is specified in terms of temperature, light, air composition and the nature of the root medium. Air and soil temperatures are generally the parameters considered in studying the plant environment interactions, but some of the recent studies show that leaf and root temperatures are more appropriate. Temperatures of other objects in the surroundings affect the plant temperature and, therefore, are important. The parameters of light which influence plant growth are source of light, total energy content of the light, spectral quality, photosynthetically active radiation (PAR) and albedo of the surroundings. Crop growth has also recently been correlated with the U.V. content of light and the ratio of energies in the far-red and red portions of the light. Gaseous composition of the air surrounding the plant is important. Contents of carbon dioxide, oxygen, nitrogen, water vapour and other trace gases influence the plant metabolism immensely. Physical, chemical and microbial compositions of soil define the nature of root medium in soil culture. However, it is no more necessary to depend on soil for development of plant roots. Uses of synthetic root media, such as Rockwool, or continuous/ intermittent flowing nutrient solutions are becoming commercial realities for root development. Complete specifications of the root medium must be known in order to interpret the plant growth data and to execute accurate watering and nutrition programmes.

A number of studies have been conducted to reveal their interactions and relationships between plant growth, both vegetative and reproductive, and the microclimate. While these studies could be used to explain some of the crop productivity results, a more comprehensive utility is to develop a crop-environment model to be used as a management tool. Several such efforts have already been made and the scope is unlimited in terms of the types of models and the crops for which such models could be usefully developed. Light, temperature and relative humidity are the most important environmental parameters effecting the greenhouse.

Light

Light is the most important component of greenhouse environment because it is essential for plant growth. Sunlight is the only resource as far as the open field cultivation is concerned. Electrical light have, however been utilize in greenhouse cultivation whenever needed. Availability of sunlight at a place is time dependent due, mainly, to the season, latitude, atmospheric turbidity and cloud cover. Early greenhouse developments took place in cold and cloudy regions where greenhouse structures were designed to admit as much sunlight as possible for better crop productivity. Provisions were made for artificial lighting of greenhouse crops under cloudy or low radiation periods. Sometimes, white or reflective mulch films have also been laid in the rows to reflect the sunlight back to the plants. However, in tropical regions, high air temperatures often accompany the bright light. In these situations, shading is generally practiced to control the temperatures in the crop zone. In fact, most plants of economic value have been observed to saturate at 1/3 to 1/4 of the available sunlight on a clear day. Therefore, shading does not decrease the net photosynthesis. In recent times, artificial lights have been used for extending the day length as well as for supplementing the natural light in commercial greenhouses in the developed world. In northern Europe, seedlings are economically grown using artificial lights during winters. The use of artificial lights has also been found economically viable for timing and maturity of flower crops. In tropical situations, artificial lighting has seldom been used for supplementing the natural light.

Temperature

A plant has a temperature range in which it can be grown. The lowest temperature is the one at which ice forms within the tissue tying up water necessary for life processes. At this temperature the life stops. At the other end of the temperature scale, enzymes become inactive and again the life processes stop. In most cases the lowest possible temperature for keeping the plant alive would be a couple of degrees higher than the freezing point. However, the highest temperature at which a plant could survive depends upon the relative humidity. Plants have been noticed to survive even beyond 50 ^{0}C provided the air humidity is kept close to saturation. Generally, day temperatures are higher than the night temperatures and, thus, the photosynthetic rates exceed the respiration rates in order to achieve positive plant growth. It can be expected that if the nights are cooler, the plant growth will be higher because the loss due to respiration would be less. In addition, if the air is enriched with carbon dioxide the permissible day temperatures could be increased by 2 to 3 ^{0}C.

Greenhouse use has largely been promoted by the need to control the crop temperature so that summer crops could be grown in winters and vice-versa. Besides, if the ambient conditions are too hot or cold for a given crop, greenhouses permit the maintenance of temperatures in the favourable range. The temperature control in the cold climatic conditions has been partially achieved through 'greenhouse effect'. Heating systems based on coal, gas, liquid fuels and electricity have been developed. Greenhouses have been redesigned to improve the energy conservation properties and, thereby, reduce the energy intensiveness of the greenhouse temperature control processes. Natural ventilation systems have been devised. Uniformity of temperature control over the crop zone is essential for high quality production and, therefore, the heat distribution systems need special attention. Needless to say that greenhouse heating has been studied in greater details then greenhouse cooling.

Use of greenhouses in warmer climatic conditions has been increasing due to a number of reasons. In these regions, it is the cooling of greenhouse space that is more important than heating. Evaporative cooling is the only practical method for lowering temperature in commercial greenhouses at present. Sometimes variations of evaporative cooling, e.g., fan pad systems, fogging and misting have been devised. The theoretical limit of single stage evaporative cooling does not permit the greenhouse air temperature to go below the wet bulb temperature for that place and time. Under high humidity ambient conditions, this is a serious constraint. There have been some efforts to develop alternate cooling methods which could be commercially viable, such as heat pipes, thermal storage systems (both sensible and latent), earth-air heat exchangers, etc. These systems have, in general, not become commercially acceptable yet.

Relative humidity

Humidity of the greenhouse air is normally higher than that of ambient because of a lack of mixing of the greenhouse air with the ambient air. A complete moisture balance on the greenhouse air including evapo-transpiration, condensation, infiltration-exhilaration and moisture storage in the air determines the instantaneous humidity of the greenhouse air. However, evapo-transpiration is the major parameter influencing the greenhouse air humidity during sunshine hours. Control of humidity is generally possible through ventilation, heating and misting.

The Centre for protected cultivation technology (CPCT) at IARI New Delhi has done very good work in the area of protected cultivation technology. The centre has demonstrated and standardized many protected cultivation technologies, given training to the farmers, officials and entrepreneurs related to different state and centre government agencies, carried out active research and post graduate studies related to different aspects of protected cultivation. The centre has carried out more than 50 training programmes related to Protected Cultivation Technologies to farmers and officials of entire country.

List of important Protected cultivation technologies developed and standardized at CPCT, IARI, PUSA, New Delhi.

1. Plug Tray Nursery Raising Technology
2. Design of Protected Cultivation Structures
3. Plastic Low Tunnel Technology for off-season Vegetable Cultivation
4. Protected Cultivation Technology of High Quality Tomato and Cucumber
5. Insect Proof Net House Technology
6. Walk in Tunnel Technology for off season Vegetable Cultivation
7. Low Pressure Drip Irrigation Technology

These technologies are compatible with organic mode of cultivation. The centre has given official technical co-operation to state governments like Jharkhand, Gujarat, Madhya Pradesh, Rajasthan and to many private organizations like IFFCO, Bhart-Walmart and Harvel-Azud.

Protected structures for growing vegetables and flowers

Vegetable and flower production is significantly influenced by the seasonality and weather conditions. The extent of their production cause considerable fluctuations in the prices and quality of vegetables. Striking a balance between all-season availability of vegetables and flowers with minimum environmental impact, and still to remain competitive, is a major challenge for the implementation of modern technology of crop production.

The crop productivity is influenced by the genetic characteristics of the cultivar, growing environment and management practices. The plant's environment can be specified by five basic factors, namely, light, temperature, relative humidity, carbon dioxide and nutrients. The main purpose of protected cultivation is to create a favourable environment for the sustained growth of plant so as to realize its maximum potential even in adverse climatic conditions. Greenhouses, rain shelters, plastic tunnels, mulches, insect-proof net houses, shade nets etc. are used as protective structures and means depending on the requirements and cost-effectiveness. Besides modifying the plant's environment, these protective structures provide protection against wind, rain and insects.

Protected cultivation is relevant to growers in India who have marginal and small land holdings, which helps them to produce more crops each year from their land, particularly during off-season when prices are higher. However, growing vegetables and flowers under protected conditions requires comparatively high input cost and good management practices, which have direct bearing on the economic viability of the production system. Even if the protective structures are cost effective, proper planning, management and attention to details are needed to achieve maximum benefits.

Protective Structures / Methods

The kinds of protective structures for crop production range from simple provisions such as rain shelters, shade houses, mulches, row covers, low tunnels, cloches to greenhouse structures with passive or active climate control. Salient points of various structures are as under;

Greenhouses

A greenhouse is quasi-permanent structure, covered with a transparent or translucent material, ranging from simple homemade designs to sophisticated pre-fabricated structures, wherein the environment could be modified suitable for the propagation or growing of plants. Materials used to construct a greenhouse frame may be wood, bamboo, and steel or even aluminum. Coverings can be glass or various rigid or flexible plastic materials. Depending on the covering material, different terminology have been used in the context of greenhouse structures as mentioned below:

- Glasshouse: A greenhouse with glass as the covering material is called as glasshouse.
- Polyhouse: It is a greenhouse with polyethylene as the covering material.

Plant Environment and Greenhouse Climate

A plant grows best when exposed to an environment that is optimal for that particular plant species. The aerial environment for the plant growth can be specified by the following four factors:

- Heat or temperature
- Light
- Relative humidity
- Carbon dioxide

Materials of Greenhouses

As mentioned earlier, the purpose of a greenhouse covering is to allow sunlight to pass through it so that the energy is retained inside. Glass was the main covering material in the early greenhouses. With the introduction plastic materials, there are now several alternatives available for greenhouse coverings. A brief description of greenhouse covering materials is given below:

- **Glass:** A clean, transparent glass provides the maximum light transmittance to the extent of 90%. However, being heavier in weight, it requires elaborate structure for adequate support. It is brittle and can break with minimum shock or vibrations resulting in high maintenance costs.
- **Acrylic:** This material has long service life, good light transmittance (80%), moderate impact resistance, but prone to scratches. It has a high coefficient of expansion and contraction. Being inflammable and costly, it is not a preferred material.
- **Corrugated / Multi Wall Polycarbonate Sheet:** It is available in single or double wall sheets of different thickness. A new polycarbonate sheet has good light transmittance of about 78%, but reduces with age. It has excellent impact resistance and low inflammability. High cost limits its use on large scale.
- **Fiberglass Reinforced Plastic Panels (FRP):** These plastics consist of polyester resins, glass fibers stabilizers etc. It has a initial light transmittance of about 80% and has high impact resistance with a service life ranging from 6-12 years. Good quality FRP materials for greenhouse coverings are not quite assured.
- **Polyethylene Film:** A clear, new polyethylene sheet has about 88% light transmittance. Its higher strength and low cost have made it most popular replacement to glass. An ultra-violet (UV) stabilized plastic sheet can have a service life of 3 years. These sheets are generally available in 7 and 9 meter widths with 200 micron (0.2 mm) thickness.
- **Thermal and Shedding Net:**

Types of Greenhouses

The greenhouses design and cost range from a simple plastic walk-in tunnel costing about Rs.100/m^2 to a climate-controlled, saw-tooth greenhouse with automatic heating, ventilation and cooling, costing more than Rs. 3000/m^2. The selection of the greenhouse design should be determined by the grower's expectations, need, experience, and above all its cost-effectiveness in relation to the available market for the produce. Obviously, cost of greenhouse is very important and may outweigh all other considerations. Greenhouses are classified in different shapes, which also determine their cost, climate control and use in terms of crop production. Commonly used structural designs are briefly described below. **Gable:** This is the most basic structure similar to a hut-like construction and was perhaps the first version of a greenhouse with glass as the covering material. The roof-frame can be inclined at any angle to present an almost perpendicular face to the sun to minimize losses due to external reflection. The structure also allows large openings in the side-walls and at the ridge for high rates of natural ventilation. Modern gable-shaped greenhouses are multi-span units with bay widths of 6-12 meters.

Gambrel: These structures are similar to the gable but have high strength to withstand high wind loads during storms. This design is more suitable where wood or bamboo are to be used for the greenhouse construction.

Skillion: In this kind of structure, the roof consists of a single sloping surface. This is because the greenhouse is built as the southward extension of a building with a solid wall on the northern side. Such greenhouses have the advantage of low structural requirements. **Curved-roof – Raised High Arch / Raised Arch:** The semi-circular tunnel greenhouse structures appeared with the introduction of polyethylene film as the covering material. These structures, besides being most simple and easy to construct, have the advantage of high strength with a relatively light frame due to inherent strength of the curved arch. But these structures have the disadvantage of poor ventilation efficiency since the curved roof is not amenable to the incorporation of ridge ventilators. In an attempt to improve the ventilation efficiency of curved roof greenhouses, raised arch type of structures have been adopted. This design has vertical side-walls, which permit high head room and improved ventilation due to the wind velocity.

Saw-tooth: In these structures, the roof consists of a series of vertical surfaces separated by a series of sloping surfaces, all of which are pitched at the same angle and facing in the same direction. The vertical surfaces consist entirely of ventilating area. These types of greenhouses are most efficient from ventilation point of view. Such greenhouses are also suitable for multi-span structures. Orientation of saw-tooth greenhouses can also be used as a means of maximizing natural ventilation. By facing the open vertical ventilation areas away from the wind, airflow over the greenhouse roof creates a negative pressure, which facilitates in sucking out warm greenhouse air. However, this air dynamics relies on the premise that there are large ventilation areas in the greenhouse walls on windward side.

Plastic Low Tunnels / Row Covers: These structures are laid in open fields to cover rows of plants with transparent plastic film stretched over steel hoops of about 50 cm height spaced suitably along the rows. Polyethylene film of 30-40 micron thickness, without UV stabilization, is used which is perforated in situ as the season gets hotter. Row covers used in vegetable production have different purposes in temperate and tropical regions. In cold conditions, they are used to conserve warmth, stimulate germination and early growth, protect plants from frost injury, and improve the quality of the crops. Other beneficial effects, such as maintaining soil structure, and protecting crops from the attacks of birds and pests, can also be expected. The main advantage of these covers in northern India is to grow vegetables, especially cucurbitaceous crops, ahead of normal season in winters. Experiments on muskmelon have proved it a highly profitable proposition. The muskmelon seedlings could be transplanted under such covers in the last week of January. The crop growth was sustained during the cold period. Temperature profile inside the cover indicated a difference of about 7°C averaged over 24-hour cycle. This rise in temperature provided necessary warmth to sustain the growth of plants. In hot season, however, materials used as row covers need to have adequate permeability to air and moisture, to prevent the accumulation of excessive heat inside the covers. The covering materials used in summer are woven polyester wind-break nets, cheese-cloth, and insect-proof screens. These types of covers are generally laid over the planted rows without the support of steel hoops, and are also called as floating covers. To provide adequate space, the seedlings are planted in the furrows and the covers are laid over the ground. But such planting should only be adopted in light textured soils having high infiltration rates.

Naturally Ventilated Greenhouse

Naturally ventilated greenhouse is the most common and most popular greenhouse type for Indian farmers. It is a zero energy model greenhouse with natural ventilation from sides and top. Saw tooth type greenhouse design has the maximum ventilation and is most effective and suitable for crop production. This type of greenhouse can be used for crop production ranging from 9-12 months depending upon the location and climatic factors. CPCT has standardized the design of naturally ventilated greenhouse and the production technologies of growing various crops inside it. The design and production technologies are tested in various parts of the country in the farmers fields.

Semi- Climate and Climate Controlled Greenhouse Design

Apart from the basic specifications required for the naturally ventilated greenhouse as mentioned above, the following design specifications are required for the semi-climate and climate controlled greenhouse.

- Exhaust Fans for removal of hot air inside greenhouse
- Cellulose Pads with Pumps for evaporative cooling
- Sprinklers for cooling
- Provision for heating

Basic requirements for producing organic greenhouse crops: It include, being grown in soil that has not been treated with a prohibited substance for 3 years; use of organic seed, or if organic seed is not commercially available, untreated seed; use of approved materials including potting media, fertilizer and pest and disease management products; and must not be contaminated by prohibited substances. Not only can a greenhouse farming operation be certified as organic but, in fact, organic greenhouse vegetable, herb and flower production is a regular and popular practice by certified organic farmers and market gardeners. In many cases, the greenhouse vegetable business is considered highly competitive. The existing greenhouse structures can be converted into organic mode by following strict guidelines. The organic plants and soil material must not come into contact with any building materials that could jeopardize their organic status, such as wood treated with prohibited substances. One can also grow both organic and non-organic plants in the same greenhouse, but just like with outdoor crops, do not let the non-organic plants and growing materials contaminate the organic ones in any way. Protecting against contamination can include installing non-permeable walls that separate the two areas and a ventilation system that also prevents cross-contamination.

Various organic waste are easily available having sufficient basic nutrients available and can be easily used in organic protected cultivation.

Table 1. Organic wastes from the agri-food industry

Fertilizer	N- P-K	Shoot wt. (grams)
Crab-shell meal	8.2-1.5-0.5	18.8
Blood meal	12.5-1.1-1.0	18.5
Dried whey sludge	5.3-2.5-0.9	18.3
Feather meal	13.6-0.3-0.2	17.3
Fish meal	10.1-4.5-0.5	17.1
Meat meal	7.7-3.1-0.7	16.3
Cottonseed meal	6.5-1.1-1.6	16.2
Fish-scale meal	10.0-3.7-0.1	15.8
Distiller's dried grains	4.3-0.9-1.1	14.5
Soybean meal	7.5-0.7-2.4	14.4
Wheat bran	2.9-1.4-1.3	13.5
Alfalfa meal	2.5-0.3-1.9	10.8
Canola meal	6.0-1.1-1.3	10.8
None (control)	0-0-0	10.3

Organic strategies for major and minor nutrients deficiency symptoms suitable for protected cultivation are as follows.

Table 2. Organic Strategies for Nutrient Deficiencies*

Element	Deficiency Symptoms	Remedy
Nitrogen (N)	Old leaves turn pale green then yellow with reddish veins and midribs. Stunted growth.	Dried blood, fish meal, or guano extracted in water. Add greater amounts in your next compost batch.
Phosphorus (P)	Stunted growth, dull green leaves with purple tints. Old leaves scorch at the edges and wither early. Early, premature bolting.	Add reactive rock phosphate or extract of guano in solution. Add greater amounts of guano, bone meal, or fish meal to the next compost batch.
Potassium (K)	Small, dark, bluish-green, glossy leaves, curving slightly backwards. Old leaves with yellow patches, scorched edges cured upwards. Small root system.	Add more kelp extract to the nutrient solution. Add greater amounts of ashes to the next compost batch.
Calcium (Ca)	Young leaves cupped backwards, with white spots around the edges. These later turn brown. Forward rolling of the leaf margin.	Add lime in solution. Add greater proportions of bone meal, gypsum, or dolomite to the next compost batch.
Magnesium (Mg)	Leaves become bronzed, and later, yellow patches appear between the leaf veins.	Dolomite or serpentine in solution. Add greater amounts of dolomite and animal manures to the next compost batch.
Sulfur (S)	Purpling of old leaves, which then shrivel. Young leaves small and yellow between the veins.	Sulfur in solution. Greater proportions of gypsum and poultry manure required in the next compost batch.
Manganese (Mn)	Veins stand out clearly with yellow in between. As the plant ages, small dead spots and papery areas appear. Slow root growth.	Add extra kelp extract.
Boron (B)	Split or thin misshapen roots. Roots with torn patchy surface and dull skin.	Add extra kelp extract.
Iron (Fe)	Very pale leaves, especially the youngest early in the season. Veins stay dark.	Add more kelp extract or place some rusty nails in the bottom of the nutrient tank.

Summary

Organic greenhouse horticultural crop production has tremendous potential as a niche market for round the year and off season production for India. Certified organic production system has to be spread throughout the country among different types of protected growers. Soil-based systems are readily adaptable to certified organic production, but special care must be taken for soil-borne disease control. Soilless systems can also be adapted to organic culture, and systems like grow bag and pot culture are easily available. The need of the hour is massive adoption, demonstration and skill development oriented training programs.

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Organic Production of root and tuber crops in the Island ecosystem

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Introduction

Worldwide concerns regarding food safety, environmental degradation and threats to human health have aroused interest in alternative sustainable agricultural systems (Carter et al., 1993). "Land degradation" is considered to be one of the world's greatest environmental challenges as per the UN millennium ecosystem assessment. Globally, 40% of the arable land is seriously degraded and 11% of this is situated in Asia (Suja and Sreekumar, 2014). The major challenge faced by world agriculture is the production of food for a population of nine billion by 2050, with the anticipated climate change (Branca et al., 2013). There is an urgent need for transformations to increase the productive capacity and stability of smallholder agricultural production systems. There is considerable discussion about the inadequacy of the present system of agricultural intensification and growth, which relies on increased use of capital inputs, such as fertilizers and pesticides.

The generation of unacceptable levels of environmental damage and problems of economic feasibility are cited as key problems (Tilman et al., 2002). Increasing concerns about the negative impacts of industrial agriculture have led to a serious debate over the feasibility of transition to alternative forms of agriculture, which are capable of providing a broad suite of ecosystem services while producing stable yields for human use. Greater attention is thus being given to alternative models of intensification, and in particular, the potential of sustainable land management technologies. Such practices can provide private benefits for farmers, by improving soil fertility and structure, conserving soil and water, enhancing the activity and diversity of soil fauna, and strengthening the mechanisms of nutrient cycling. These benefits can lead to increased productivity and stability of agricultural production systems and offer a potentially important means of enhancing agricultural returns and food security as well as reducing the vulnerability of farming systems to climatic risk. Organic agriculture is one such promising alternative.

The land quality for food production ensures future peace. "Organic farming" is a viable option that enables sustainable production, maintenance of soil health, protection of human health and conservation of environment. It envisages non-use of synthetic chemicals, reduced use of purchased inputs and maximum use of on-farm-generated resources. Tropical tuber crops constitute important staple or subsidiary food for about 500 million of the global population. They have high content of carbohydrate, rich in energy, protein content and better balance of amino acids. They are food security crops grown in tropical countries, mainly West Africa, the Caribbean, Pacific Islands and South East Asia. Tropical tuber crops in general and edible aroids like Elephant Foot Yam (EFY), taro and tannia respond well to organic manures. Hence, there is great scope for organic production in these crops. There is a great demand for organically produced root and tuber crops among Asians and Africans living in Europe, USA and Middle East (Suja and Sreekumar, 2014). In India most of the coastal states including Andaman and Nicobar Islands and Lakshadweep Islands broadly cultivates the root and tuber crops (Figure 1). They all have underground organs, i.e. parts of the plant for storing energy in the form of starch, sometimes sugar. These storage organs may be swellings on the roots (cassava), whole underground stems or stem tubers (cocoyam and xanthosoma where they are called corms and cormels) or a portion of the underground stem as in the case of yams and Irish potatoes.

The edible roots and tubers contain much starch, little protein, hardly any fat, few vitamins, and much water. Cassava tubers are poor in protein, and if it is used as the main staple food, people may well suffer from lack of protein. On the other hand, cassava leaves are very rich in protein so that a diet consisting of garri and cassava leaf soup comes close to being a balanced diet, at least as far as starch and proteins are concerned. Cereals contain a little more protein than most tuber crops, but in every other aspect of food quality tuber crops are superior to cereals. Yams and Irish potatoes especially produce as much protein as some cereals (Westphal, 1978).

2. Status of Tuber crops

The economically and socially important tropical tuber crops are Cassava (*Manihot esculenta*), Sweet potato (*Ipomoea batatas*), Yams (*Dioscorea alata*, *D. esculenta* and *D. rotundata*), Aroids which include Elephant foot yam, Taro and Tannia (Amorphophallus, Colocasia or Taro, Xanthosoma or Tannia) and other minor tuber crops namely Chinese potato, Arrow root, Yam bean, Canna etc. Among the tuber crops, Cassava is cultivated in 16 m ha, spread over the continents of South America, Africa and Asia, producing 158 m t of tubers. The average productivity in the world is 10.88 t ha^{-1} and that in India is 27.42 t ha^{-1} from an area of 0.24 m ha. However in sweet potato, average productivity in India is only 8-9 t ha^{-1} as against the world average of 16 t ha^{-1} (FAO, 2016). Area under cultivation of tuber crops in India is 4 lakh ha under cassava and sweet potato besides approximately 2 lakh ha in elephant foot yam, Colocasia, Xanthosoma etc. There are five major areas of distribution of root and tuber crops in India (Table 1). (i) South-western hilly and coastal region, (ii) Southern peninsular region, (iii) Eastern coastal region, (iv) North eastern region and (v) North-western region.

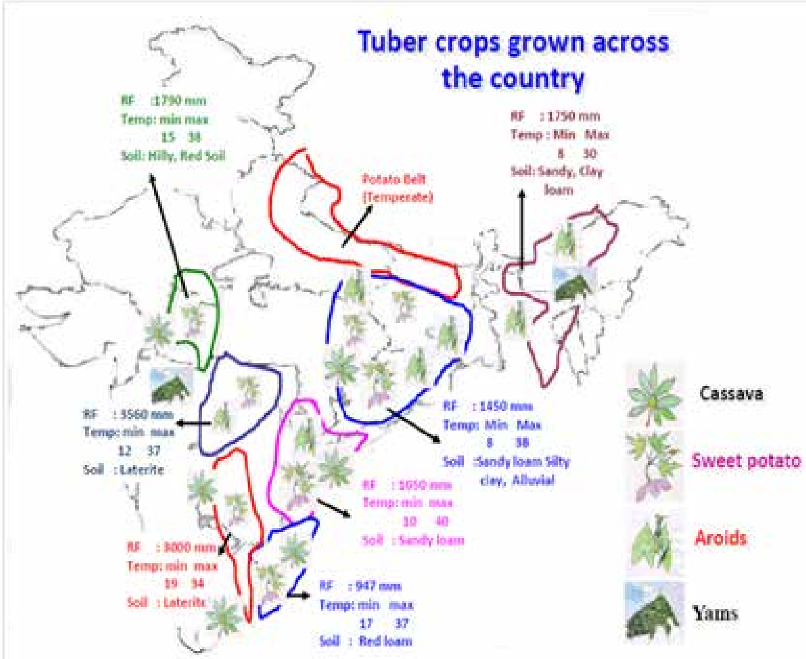

Fig. 1 Tuber crops grown area in India (source; CTCRI, 2016)

Table 1. Important tuber crops grown in India and the regions of biodiversity

Common Name	Scientific Name	Family	Places/Areas Grown
Cassava	*Manihot esculenta*	Euphorbiaceae	Southern region Occasionally in North eastern and western regions, A& N Islands
Sweet Potato	*Ipomoea batatus* (L.)	Convolvulaceae	Introduced and found all over but mostly concentrated in Eastern U.P, Bihar, West Bengal, Orissa and A& N Islands
Greater Yam	*Dioscorea alata* (L.)	Dioscoreaceae	South & North Eastern region and A& N Islands
White Yam	*Dioscorea rotundata*	Dioscoreaceae	Introduced to India and spread to South and North Eastern region
Lesser Yam	*Dioscorea esculenta* (Lour.) Burk.	Dioscoreaceae	South, N.E & Eastern region
Potato Yam	*D. bulbifera* var. sativa	Dioscoreaceae	Southern, North East and Eastern region
Taro	*Colocasia esculenta* (L.) Schott	Araceae	Throughout India with greater diversity in North east. Eastern region and South and A& N Islands
Tannia	*Xanthosoma sagittifolium*	Araceae	South and North eastern region and A& N Islands
Elephant Foot Yam	*Amorphophallus paeoniifolius* (Dennst.) Nicolson	Araceae	Southern, North East and Eastern region and A& N Islands
Chinese Potato	*Solenostemon rotundifolius* (Poir.) J.K. Morton *Plectranthus rotundifolius*	Labiatae	Southern parts of India
Yam Bean	Pachyrrhizus erosus (L.) Urban	Leguminosae	North Eastern region
Winded Bean	*Psophocarpus tetragonolobus* D.C.	Leguminosae	South 8f North East
West Indian Arrow Root	*Maranta arundinaceae* L	Marantaceae	Adapted to plain areas with high rain fall; shade loving

3. Uses of tuber crops

The tuber crops like cassava, sweet potato, yams, *colacasia* and elephant foot yam etc are rich source of carbohydrate and they are mainly used as human food. The leaves, young shoots and corms of *colacasia* are used for consumption as vegetables. The roots and leaves have a particular flavour that can give an acrid taste, which, however, on cooking and drying, reduces the acridity. In sweet potato, the tuberous roots are consumed which are sweet in taste and rich in starch content. Sweet potato and cassava tubers are consumed after boiling or baking in fire. The sweet potato vines are nutritive and palatable feed for the cattle. The cassava and sweet potato tubers are also used as a feed for cattle. Sweet potato leaves are highly nutritious and contain as much as 27% protein and can be supplemented as animal feed.

3.1. Tuber crops as animal/Fish feed

- One of the major factors for restricted use of tapioca tuber in swine diets has been the presence of hydrocyanic acid (HCN). Various processing methods like boiling, chopping/crushing followed by sun drying remove HCN.
- The process of crushing and pounding fresh roots followed by sun drying eliminated as much as 95 per cent cyanogens. The extent of toxicity which might result from cassava consumption is determined by the relative amounts of free cyanide, acetocynohydrin and linamarin in processed cassava
- Explored the possibilities of utilization of tuber crops for feeding grass carps in a grass carp based composite fish culture system. The whole plant parts are utilized for developing fish feed, periphyton development and as a cover crop to strengthen the bund.
- Tapioca flour and sweet potato flour can be effectively used up to 20% level for fish feed preparation.
- All parts of cassava can be utilized as fish feed. Leaves are rich in protein and can be directly fed to grass carp, tilapias and *Puntius* spp. It is observed that even major carps relish its leaves especially less in HCN content.

4. Organic production in tuber crops

In general for organic production of different tuber crops, use of organically produced planting material, seed treatment with cow dung, neem cake, bio-inoculant slurry, farmyard manure inoculated with bio-inocluants, green manuring, application of neem cake, bio-fertilizars and ash (Kerala Agricultural University, 2009).

4.1. Cassava

For organic cultivation of cassava, it is recommended to incorporate crop residues of the previous crop (dry biomass @ 3 t ha^{-1}), planting setts of 15-20 cm from organically produced cassava stems, application of FYM @ 12.5 t ha^{-1} (1 kg per plant) at the time of planting along with the application of *Azospirillum*, phosphobacteria and K solubilizer @ 3 kg ha^{-1} each at the time of planting and sowing of green manure cowpea (20 kg ha^{-1}) between the inter row mounds and the subsequent incorporation of green matter at 45- 60 days of after sowing. The green matter addition from the green manure crop will be about 10-15 t ha^{-1} (Suja et al., 2016)

4.2. Elephant foot yam

It has been recommended to use organically produced planting material, seed treatment of corm pieces of 500 g with slurry containing cowdung, neem cake and *Trichoderma harziannum* (5 g per kg seed) and drying under shade before planting, raising of green manure cowpea (20 kg ha^{-1}) prior to elephant foot yam and incorporation of the green matter at 45- 60 days, application of *Trichoderma harziannum* incorporated FYM @ 36 t ha^{-1} or 3 kg per pit at the time of planting (FYM: neem cake mixture (10: 1) inoculated with *Trichoderma harziannum* @ 2.5 kg per tonne of FYM neem cake mixtute. *Trichoderma* can be multiplied to form sufficient inoculam quickly within 7-8 days if neem cake is also used along with FYM. It is effective against collar rot caused by *Sclerotium rolfssi.* Apply neem cake @ 1 t ha^{-1} or 80-85 g per pit at the time of planting, sowing of green manure cowpea @ 20 kg ha^{-1} between the elephant foot yam pits and incorporation of the green matter in pits at 45-60 days. The addition of green matter from the two green manure crops should be 20-25 t ha^{-1}. In addition application of ash @ 3 t ha^{-1} or 250 g per pit at the time of incorporation of green manure in pits is recommended.

4.3. Yams

It has been recommended to plant organically produced tuber pieces of 250- 300 g for greater yam and white yam and medium size tuber of 100-150 g for lesser yam, application of FYM @ 15 t ha^{-1} (1.2 kg per plant in pits) at the time of planting, application of neem cake @ 1 t ha^{-1} or 80-85 g per pit at the time of planting, application of bio fertilizers *viz Azospirillum* @ 3 kg ha^{-1}, mycorrhiza @ 5 kg ha^{-1} and phosphobacteria @ 3 kg ha^{-1} at the time of planting. Sowing of green manure cowpea @ 20 kg ha^{-1} between yam mounds and subsequent incorporation of the green matter in pits at 45-60 days. The addition of green matter from the green manure crops should be 15-20 t ha^{-1}. In addition application of ash @ 1.5 t ha^{-1} or 120 g per pit at the time of incorporation of green manure in pits is recommended.

4.4. Taro

Use of organically produced planting materials, seed treatment of cormels (20-25 g size) with slurry containing cow dung, neem cake and *Pseudomonas* (5 g per kg seed) and dry under shade before planting, application of FYM @ 15 t ha^{-1} (400 g per plant in pits) at the time of planting, application of neem cake @ 1 t ha^{-1} or 25-30 g per pit at the time of planting, application of bio fertilizers *viz Azospirillum* @ 3 kg ha^{-1}, mycorrhiza @ 5 kg ha^{-1} and phosphobacteria @ 3 kg ha^{-1} at the time of planting, sowing of green manure cowpea @ 20 kg ha^{-1} between the pits and incorporation of the green matter in pits at 45-60 days. The addition of green matter from the green manure crops should be 15-20 t ha^{-1}, application of ash @ 2 t ha^{-1} or 60 g per pit at the time of incorporation of green manure in pits followed by spraying of akomin @ 3 ml per litre from one month after planting at fortnightly interval up to 4 months to manage taro leaf blight incidence as a prophylactic measure is recommended.

4.5. Tannia

Planting of organically produced whole cormels of size 50-80 g or mother corm pieces of 150-200 g, application of FYM @ 20 t ha^{-1} (1.6 kg per plant in pits) at the time of planting, application of neem cake @ 1 t ha^{-1} or 80-85 g per pit at the time of planting, sowing of green manure cowpea @ 20 kg ha^{-1} between the pits and incorporation of the green matter in pits at 45-60 days which will add green matter about 15-20 t ha^{-1}, application of ash @ 2 t ha^{-1} or 160-165 g per pit at the time of incorporation of green manure in pits has been recommended.

4.6. Ginger

Ginger is a tropical crop adapted for cultivation even in regions of subtropical climate such as the high ranges. This crop thrives best in well drained friable loamy soils rich in humus. Being an exhaustive crop, it may not be desirable to grow ginger in the same field year after year. Therefore, it is essential to convert the whole farm as organic with ginger as one of the crops in rotation. The crop cannot withstand water logging and hence soils with good drainage are preferred for its cultivation. In order to cultivate ginger organically an isolation distance of 25m wide is to be left on all around from the conventional farm. Ginger can be cultivated organically as an inter or mixed crop provided all the other crops are grown following organic methods. It is desirable to include a leguminous crop in rotation with ginger. Carefully preserved seed rhizomes free from pests and diseases, which are collected from organically cultivated farms can be used for planting. While preparing the land, minimum tillage operations may be adopted. Beds of 15 cm height, 1 m width and of convenient length may be prepared giving at least 50 cm spacing between beds. Solarisation of the beds is beneficial in checking the multiplication of pest and disease causing organisms. The polythene sheets used for soil solarisation should be kept away safely after the work is completed. At the time of planting, apply 25 g powdered neem cake and mix well with the soil in each pit taken at a spacing of 20-25 cm within and between rows. Seed rhizomes may be put in shallow pits and mixed with well rotten cattle manure or compost mixed with *Trichoderma* (10 g compost inoculated with *Trichoderma).* Mulching the ginger beds with green leaves is an essential operation to enhance germination of seed rhizomes and to prevent washing off soil due to heavy rain. This also helps to add organic matter to the soil and conserve moisture during the later part of the cropping season. The first mulching is to be done with green leaves @ 10 - 12 t/ha at the time of planting. It is to be repeated @ 5 t/ha at 40^{th} and 90^{th} day after planting. Cow dung slurry or liquid manure may be poured on the bed after each mulching to enhance microbial activity and nutrient availability. Weeding may be carried out depending on the intensity of weed growth. Such materials may be used for mulching. Proper drainage channels are to be provided in the inter rows to drain off stagnant water. Application of well rotten cow dung or compost @ 5-6 t/ha may be made as a basal dose while planting the rhizomes in the pits. Enriched compost giving a start to phosphorus and potassium requirements may be highly useful. In addition, application of neem cake @ 2 t/ha is also desirable.

5. Pest, disease and weed management:

Compared to cereals and vegetables, tuber crops have fewer pest and disease problems. Barring a few major ones, like cassava mosaic disease (CMD), cassava tuber rot, sweet potato weevil (SPW), *Phytophthora* leaf blight in taro, and collar rot in EFY, the others are of minor significance. In general, for the management of pests and diseases, non-chemical measures or preventive cultural techniques can be resorted to. This includes use of tolerant/resistant varieties, use of healthy and disease-free planting materials, strict field sanitation (against almost all), deep ploughing (e.g. tuber rot), roguing the field (e.g. CMD), use of pheromone traps (e.g. SPW), use of trap crops (e.g. SPW, root knot nematodes), adapted crop rotations, use of neem cake (collar rot, tuber rot), use of bio-control agents like *Trichoderma*, *Pseudomonas* (collar rot, leaf blight), etc. Normally, two hand weeding are advocated in tuber crops for efficient weed management. As most of the tuber crops (except sweet potato) take approximately 75–90 days for sufficient canopy coverage, raising a short-duration intercrop (like green manure/vegetable/grain cowpea, vegetables, groundnut, etc., in cassava, cowpea in yams and aroids) can also help to a great extent to reduce weed problem. Mulching the crop using any locally available plant materials (green leaves, dried leaves, etc.) immediately after planting (in yams and aroids) will help conserve moisture and regulate temperature, apart from weed control (Suja, 2008).

Soft rot or rhizome rot caused by *Pythium aphanidermatum*is a major disease of ginger. While selecting the area for ginger cultivation care should be taken to see that the area is well drained as water stagnation pre-disposes the plants to infection. Hence provide adequate drainage. Select seed rhizomes from disease free areas since this disease is also seed borne. Solarisation of soil done at the time of bed preparation can reduce the fungus inoculum. However, if the disease is noticed, the affected clumps are to be removed carefully along with the soil surrounding the rhizome to reduce the spread. *Trichoderma* may be applied at the time of planting and subsequently if necessary. Restricted use of Bordeaux mixture (1 %) in disease prone areas may be made to control it.

Regular field surveillance and adoption of phytosanitary measures are necessary for pest management. The shoot borer (*Conogethes* punctiferalis) is the most important pest of ginger. It appears during July-October period. Spot out the shoots infested by the borer. Cut open the shoot and pick out the caterpillar and destroy. Spray neem oil (O.5%) at fortnightly intervals if found necessary. Light traps will be useful in attracting and collecting the adult moths.

6. Major Prospects in Bay Islands

- Soil and climatic conditions are highly favourable for cultivation of tuber crops
- Tuber crops plays an important role and it already exists an integral part of food habits of the tribal communities of Bay islands
- Rich biodiversity of tuber crops in these islands
- These crops requires less care
- These crops can be grown on marginal land
- Wide scope for intercropping in plantation crops

In Andaman and Nicobar Islands tropical root and tuber crops namely cassava, greater yam, lesser yam, elephant foot yam, taro and tannia are mostly cultivated in association with plantation crops like coconut and areca nut. Intercropping the root and tubers with tree crops both at the immature and mature phases is a common practice especially in small and medium sized land holdings, in order to augment the net income and employment opportunities. In such farms, the produce from the perennials generates the cash income, while the starchy root and tubers partially meet the food requirements of the farm family and the feed needs of farm animals.

6.1. Resource use in plantation crops

Most of the plantation crops occupy the land for several decades and utilize the natural resources only to a very limited extent. Roots of coconut trees planted at the recommended spacing of 7.5 x 7.5 m effectively use only 25% of the land and the canopy intercepts about 40 to 50% of the solar radiation at mature stage. Areca nut palms spaced at 2.7 x 2.7 m exploit only 50% of the land and about 50 to 75% of the solar radiation. In other perennial crops also (rubber, banana etc.) which are planted at wider spacing, resources like land and solar radiation are not fully utilized. Hence intercropping is recommended in plantation crops. The desirable traits for crops suitable for growing in the interspaces of plantation crops must be: The crops should be shade tolerant, should not overgrow the main crop, and should not host the same pests and diseases of the main crop. The cultural operations for the intercrop should not damage the main crop or promote soil erosion, its economic life should not exceed that of the main crop, and should be adapted to the same ecological conditions. In addition, the produce should have good storability and be marketable. On critical evaluation of the characteristics of the root and tubers, it may be observed that root and tuber crops especially edible aroids and arrowroot are shade tolerant, most are shorter in stature and are comparatively tolerant to pests and diseases and do not harbour common pests and diseases. The root and tuber crops are adapted to the same ecological conditions as that of plantation crops and have shorter duration, their produce has fairly good storability and all of them have demand in local markets.

7. Organic Root and Tuber cultivation: A case example from Andaman and Nicobar

The Andaman and Nicobar Islands comes under the humid tropics with an average rainfall of about 3100 mm distributed over 8 months. The average relative humidity ranges from 68 to 86% and the maximum and minimum temperature is 32^{0} C and 22^{0} C, respectively. The soil temperature ranges from 25 to 27^{o}C at 5, 15 and 30 cm depth. The climatic conditions are highly suited for cultivation of different tuber crops and the islands are also considered as the store house for diversity in tuber crops. The area, production of tuber crops in Andaman and Nicobar Islands depicted in Table 2.

Table 2. Area and Production of tuber crops in Andaman & Nicobar Islands

Crops	Area (ha)				Production (MT)			
	2010-11	2011-12	2013-14	2014-15	2010-11	2011-12	2013-14	2014-15
Tapioca	278.0	265.0	239.22	212	2150.0	2045.0	4246.6	3265
Sweet potato	163.0	150.0	168.4	149	925.0	845.0	2693.2	2662
Others	449.0	586.0	472.98	449	5193.0	6563.00	9163.2	8202
Total	890	1001	880.6	810	8268	9453	16103.0	14129

(**Source:** Directorate of Economics & Statistics, Andaman & Nicobar Administration, 2015)

7.1. Importance of Tuber crops in island ecosystem

Root and tuber crops are the third important food crops of human kind after cereals and grain legumes, and constitute either staple or subsidiary food for about a fifth of the world population. These crops have a remarkable position in the food security of the developing world due to its high calorific value and carbohydrate content. Apart from supplying cheap source of energy, these crops provide other micro nutrients and vitamins. These crops have a higher biological efficiency as food producers and also the highest dry matter production per unit area among all the crops. Their capacity to grow under rain fed conditions as well as sustainability against the drought condition is remarkable. Thus the tuber crops are very important in the context of food and nutrition security and assume a great relevance due to the ever increasing population. Tuber crops not only enrich the diet of the people but also possess medicinal properties to cure many ailments or check their incidence. Many tropical tuber crops are used in the preparation of stimulants, tonics, carminatives and expectorants. The tuber crops are rich in dietary fibre and carotenoids viz. ß carotene and anthocyanin. These crops are adapted to the wide range of agro-climatic conditions and give good performance even under marginal growing conditions. Tuber crops such as Elephant foot yam, Greater yam and Cassava etc. are hardy crops and fit well in various cropping systems. These crops act as a supplementary food crop in the Region (low cereal production). Its tuber and foliage can be used as feed for Livestock (cattle, pigs, and goats), Poultry and Fishery. These crops are highly suitable for the integrated farming system since it is available throughout the year. Its production cost is low compared to other crops and these crops are high yielding and more storage life.

7.2. Traditional method of tuber crops cultivation by Nicobari Tribes

The Nicobari tribes clear the bushes and forest floor before planting and plant the tuber crops such as Greater yam, Colocasia, Tannia, cassava, arrow root at the same time in a field during March-April every year. They cut and fell down the small trees and shrubs in the field which provides sufficient sunlight for the cultivation of various crops. They do not cut the leguminous plants especially the *Dendrolobium umbellatum* which is a multipurpose tree (fodder & feed) fixes the atmospheric Nitrogen. A portion of the wood is being used for making the strong fence which protects crops from animals especially pigs and cattles. (Sankaran et al, 2014). The dried branches are used as standards for spreading of the greater yam vines and it also provides the partial shade for the aroids (Taro, Elephant foot,Tannia and Arrow root) and the dried leaves supplies the required nutrients to the crops. Among all crops, the Nicobari Aloo forms a major portion of Nicobari Tribes diet. ~~among all crops.~~ The tuber crops are harvested at various intervals based on their life span and the biomass is again incorporated in the soil and the harvested produce is distributed among the tuhet (Joint family).

7.3. Yield of tuber crops in traditional system vs Tuber crops based farming system

A tuber crop based farming system study was conducted in tribal area at Harminder Bay, Little Andaman during 2014-16. The model comprises of 300 m^2 of fenced area in the vicinity of the tribal settlement and integrated with piggery unit. In the traditional system, Nicobari tribes clear the forest ground cover before planting and then plant Nicobari aloo (greater yam) during March- April and allow the vines to trail over the dried branches of the trees and shrubs. They harvest the crop during December - January every year and the harvested produce is distributed among the tuhet (joint family) (Fig.2.). However in the tuber crops based farming system, among the different tuber crops, elephant foot yam recorded the highest production of 69.2 kg followed by Colocasia (60.7). This is mainly due to more area under elephant foot yam. Even though the area allocation under elephant foot yam was more (66.7%) as compared to colocasia the yield of colocasia ranged from 45 to 81 kg as the tribes were familiar with colocasia while elephant foot yam was non traditional crop for them and it has been recently introduced in the system. Highest yield was recorded from the farmer's field of Shri Leo viz., Ginger (31.5 kg), Colocasia (81 kg), and Nicobari Aloo (45 kg). However, the maximum number of pig population was maintained by Shri Fred Levi 11 no's) followed by Feastus (9 no's) respectively (Table 3). In this system, the yield of component crops was converted into equivalent yield of Nicobari aloo. The yield level ranged from 172.2 to 326.4 kg among the farmers with an average yield of 251.1 kg and production efficiency of 29.30 kg ha^{-1}day^{-1} based on the crop duration (285 days). From the study it has been concluded that the initial two years the tuber crop based farming system with integration of pigs is more remunerative and provides sustainable livelihood opportunities which also create great scope for employment generation round the year in tribal areas. Therefore, tuber crop based farming system can be adopted commercially in large scale in tribal areas (Damodaran et al., 2016).

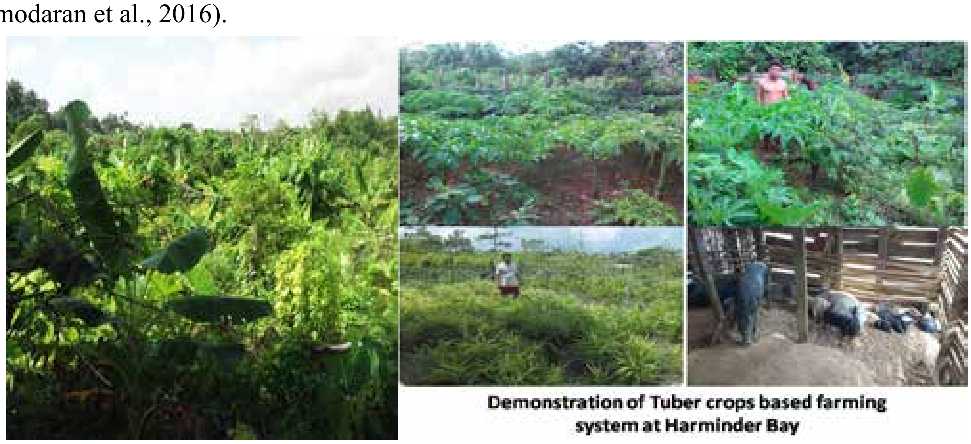

Fig 2.Traditional System (Tuhet) Vs Tuber crops based farming system

Table 3. Nicobari aloo equivalent yield (0.03 ha) (NAEY) and Production Efficiency of tuber crops in farmer's field (Mean of two years)

Farmer	Yield of tuber crops (kg)					Nicobari aloo equivalent yield (NAEY) in kg				Total NAEY (kg)	Value of crop based on NAEY (Rs.)	Production Efficiency (kgha^{-1}day^{-1})
	Nicobari Aloo	Ginger	EFY	Colocasia	Sweet potato	NAEY of ginger	NAEY of EFY	NAEY of Colocasia	NAEY of sweet potato			
Fred Levi	37.5	22.5	75.0	45.0	13.0	90.0	60.0	45.0	15.6	248.1	12405	29.0
Judith Fred	22.5	27.0	75.0	52.5	8.0	108.0	60.0	52.5	9.6	252.6	12630	29.7
Feastus	30.0	27.0	82.5	67.5	9.0	108.0	66.0	67.5	10.8	282.3	14115	33.0
Joab Levi	37.5	30.0	90.0	60.0	11.0	120.0	72.0	60.0	13.2	302.7	15135	35.3
Adaliya	45.0	24.0	67.5	60.0	8.0	96.0	54.0	60.0	9.6	264.6	13230	31.0
Sylvamus	22.5	25.5	82.5	45.0	7.0	102.0	66.0	45.0	8.4	243.9	12195	28.7
Henry	30.0	15.0	67.5	60.0	14.0	60.0	54.0	60.0	16.8	220.8	11040	25.7
Niconar	22.5	10.5	60.0	52.5	6.0	42.0	48.0	52.5	7.2	172.2	8610	20.0
Mabel	37.5	21.0	52.5	60.0	7.0	84.0	42.0	60.0	8.4	231.9	11595	27.0
Jaob Titus	31.5	24.0	45.0	75.0	9.0	96.0	36.0	75.0	10.8	249.3	12465	29.0
Lambson Victor	24.0	18.0	52.5	54.0	8.0	72.0	42.0	54.0	9.6	201.6	10080	23.7
Apolus	22.5	24.0	63.0	61.5	6.0	96.0	50.4	61.5	7.2	237.6	11880	27.7
Patrick	27.0	28.5	82.5	76.5	10.0	114.0	66.0	76.5	12.0	295.5	14775	34.7
Leo	45.0	31.5	75.0	81.0	12.0	126.0	60.0	81.0	14.4	326.4	16320	38.3
Timothy	22.5	22.5	67.5	60.0	9.0	90.0	54.0	60.0	10.8	237.3	11865	27.7
Mean	**30.5**	**23.4**	**69.2**	**60.7**	**9.1**	**93.6**	**55.4**	**60.7**	**10.9**	**251.1**	**12554**	**29.3**

Ginger- RS.200/kg; EFY- RS.40/kg; Colocasia and Nicobar Aloo – RS.50/kg; sweet potato= RS.60/kg Pig- RS.250/kg

7.4. Standardization of spacing and size of corm in Elephant foot yam for organic cultivation under Coconut Plantations in Bay Islands

Studies on impact of spacing (S) and sizes of corms (T) of organically grown Elephant foot yam under coconut plantations were made in Island ecosystem. The results (Table 4) shows higher corm weight/plant (1.5 - 2.3 kg) was recorded with spacing of 1 x 1m and 90 x 90 cm with the size of 400-500g. Irrespective of the spacing and size of corm, the highest corm weight/plant (2.3 kg) was recorded with the combination of 90 x 90 cm spacing and 300 g size of corm ~~(Table 4)~~. The present study revealed that organic cultivation of elephant foot yam can be done under coconut plantations with the spacing of 90 x 90 cm and 300 g of corm size instead of 1 x 1m and 500 g corm/setts (CIARI, 2012-13).

Table 4. Effect of spacing and corm size on Yield (t/ha) of elephant foot yam

S X T	T_1 (500g)	T_2 (400g)	T_3 (300g)	T_4 (200g)	T_5 (100g)	Mean
S1- 1 x 1 m	31.0	31.4	35.2	23.2	17.4	27.6
S2-90 x 90 cm	33.2	30.5	37.8	33.9	17.7	30.6
S3-90 x 75 cm	25.9	36.6	37.4	33.9	20.3	30.8
S4-75 x 75 cm	27.6	26.5	28.8	13.6	8.9	21.1
Mean	29.4	31.3	34.8	26.2	16.1	
	SEd	CD(P=0.05)				
S	1.2	2.4				
T	1.3	2.7				
S XT	2.7	5.5				

7.5 Effect of size of ginger rhizome on growth and yield under coconut plantation

An experiment was conducted at Sippighat farm to standardize size of rhizome (10 g, 20 g, 30 g,40 g, 50 g and >50 g) for organic cultivation of ginger under coconut plantations in Island ecosystem. The result revealed that, planting of ginger mother rhizome (>50g) size recorded the highest yield (35.6 t/ha) (CIARI, 2013-14).

7.6 Intercropping of root and tuber crops

Intercropping is the best alternative to boost the income of the coconut growers from a unit holding by using horizontal and vertical space more efficiently. Elephant foot yam and Ginger are ideally suitable for growing as an intercrop in coconut plantation and also fetches high returns. Five farmers from South Andaman district were adopted for demonstration of organic production of ginger and elephant foot yam under coconut based cropping system. They were provided with the planting materials viz. Ginger (50 kg) and elephant foot yam (100 kg) each and imparted training on scientific cultivation practices. Farmers adopted basal application of FYM, Seed treatment before sowing, Glyricidia green leaf mulching after sowing and after 45 days and Weeding after 45 days and earthing up.

At the end the farmers realized a total yield of 145 to 150 kg of ginger and 800 to 1000 kg elephant foot yam from 0.02 ha area plot. They have taken care to maintain the farm records to ascertain the cost of cultivation. Considering the prevailing market rate of Rs100- 150 per kg of ginger and Rs 30- 40 per kg of elephant foot yam they were able to earn about Rs 15000 from ginger and Rs 24000- 30000 from elephant foot yam as additional income. Encouraged by this learning experience, they have expanded the area under ginger and elephant foot yam cultivation and at present they are one of the major sources for supply of seed rhizomes of ginger and elephant foot yam for the needy farmers of their respective villages. (CIARI, 2013).

7.7. On farm trials on Organic tuber crop cultivation

During the period 2012-17, a total of 26 FLD on organic production of elephant foot yam (var. Gajendra) and 33 FLD on organic production of ginger (var.Jorhat) and turmeric were conducted at farmers field under coconut plantation and observed the yield of 15- 21.5 t/ha in elephant foot yam, ginger (8-10 t/ha) and turmeric (12-16 t/ha).

7.8. Conclusion

Organic farming is an alternative for sustainable and safe food production. Tropical tuber crops, cassava, yams and aroids are ethnic starchy vegetables with good taste and nutritive value. In general the organic management enhanced yield by 10-20%, net profit by 28%, improved the tuber quality with higher dry matter, starch, crude protein, K, Ca and Mg contents and lower anti-nutritional factors and promoted the physico-chemical properties, dehydrogenase enzyme activity and microbial count. The higher yield in these crops may be due to the overall improvement in soil physico-chemical and biological properties under the influence of organic manures. Higher soil organic matter status of organic plots, available N, P and K under organic management was due to the direct result of inputs and constituents of various manures, especially green manure. The studies on organic cultivation of root and tuber crops has shown encouraging results in Island condition and already one of the island namely Havelock Island has been already declared as organic Island and in near future the efforts are on the way to promote organic agriculture in entire A& N Islands. Hence, organic cultivation of root and tuber crops are very much suitable for Island condition due to its fragile ecosystem which enables not only the restricted use of chemicals but also preserves the soil health and environment in the tropical Islands, besides the quality root and tubers.

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Floral diversity in Andaman and Nicobar Islands and their exploitation in organic farming

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Introduction

Andaman and Nicobar Islands represent one of the hotspots of rich biodiversity regions in India and are usually acknowledged as 'botanical paradise'. Andaman and Nicobar group of islands with about 572 islands, islets and rocks and are elements of scientific curiosity in terms of species diversity. The general climatic condition of these islands is that of warm and humid tropics. The land area of these islands is 8249 km^2 of which 48,675 hectare of land is under agriculture More than 86% of the area is under luxuriant forest cover with 2654 angiosperm species, out of which 353 species are reported to be endemic (Pandey and Diwakar, 2008). The forests of Andaman are dominated by forest types such as Andaman tropical evergreen, Andaman moist deciduous, littoral mangrove, mangrove scrub and wet bamboo brakes.

The indigenous people are the first inhabitants of these islands. Six groups of native aboriginals are present in the islands and their number is about 5000 who include Great Andamanese, Onges, Jarawas, Sentinels are Negrito Origin. The most primitive tribes are Onges who have been relegated to the reserved pockets at Dugong Creek and South Bay of Little Andaman Island and have been rapidly dwindling in numbers. Nicobarese and Shompens are Mongoloid stock. Nicobarese tribes living throughout many of the islands, Shompens live only in Great Nicobar having port town called Campbell bay. In addition to tribal people different types of settlers also inhabited these islands who are mostly from Bihar, Jharkhand, Madhya Pradesh, Orissa and other parts of the country who are also tribes of that part of the country.

During domestication, a small number of gene combinations accumulated in crop species resulting in narrow genetic diversity. The search for genetic diversity in economic plants is a constant goal for the breeders. This diversity can be broadened by the utilization of wild relatives of crop plants. Adaptation to biotic and abiotic stresses has made the local land races and wild relatives extremely useful in various breeding programmes. Plant genetic resources (PGR), one of the crucial components of agro-biodiversity are extremely valuable for present and future generations of human race. The spectrum of PGR comprises diversity from the gene pool and centres of origin one geographical variation and from island ecosystem with special abiotic and biotic stress resistance are targeted in the present study which are also useful for organic farming.

Wild species especially the wild relatives of crop plants (WRCPs) are invaluable sources of resistance to several biotic and abiotic stresses, yield, nutritional quality, adaptation and genetic diversity. However, their utilization in the crop improvement programmes depends largely on their availability as well as their cross ability relationship with the cultivated types. Destruction of habitat land use pattern have led to their genetic erosion. Hence, their collection and conservation require immediate attention for sustainable utilization.

Realizing the importance of wild relative and related taxa in crop improvement programmes, it became imperative to compile the available information on their collection and conservation for effective utilization.

The Andaman & Nicobar Islands which are land lock up between mainland India, (North East India) Myanmar, Indonesia, Thailand, Sri Lanka and Australian continents. Natural calamities like Tsunami, Cyclones, Urban developments, Forest clearance for different urbanization and Agricultural programmes are disturbing the plant biodiversity of these unique Islands.

Many underutilized plants are wild species, ecotypes and landraces, adapted to narrow agro-ecological niches and marginal areas and may be highly nutritious, having medicinal properties and offer multiple uses like resistant to Insect pests, pathogens and for salinity and other abiotic stresses and also to develop suitable varieties for organic farming.

At present there are 2428 species of angiosperms which include 12.69% (308) indigenous angiosperm species to these islands. The flora of the Andaman group of Islands shows striking dissimilarities with the flora of Nicobar Islands. The Andaman Islands have more species common to north east India, Myanmar and Thailand; the Nicobar group has more species common with Indonesia in the South and Malaysia in the east.

The biotechnological tools that can be used in gene transfer from wild to cultivated have developed and standardized, most important in them are Tissue culture and regeneration, Allen gen transfer techniques, Embryo Rescue techniques, Double haploid breeding, Molecular markers and Bioinformatics approaches which are hand to be utilize in district by hybridization programme for producing cultivars that can be suitable for organic farming.

The Andaman and Nicobar Islands stretching from Arakkan-Yoma in Burma to Sumatra in Indonesia are characterized by rare and distinct flora although exhibiting phyto-geographical affinity with the neighbouring bio-geographical zones of south-east Asian countries and north-east, Western Ghats and Deccan peninsular bio-geographical zones of mainland India by virtue of which the Islands constitute a transition zone photographically which creates more interest to collect plant genic resources with special reference to wild relatives of crop plants useful to humankind.

Plant genetic resources of Andaman and Nicobar Islands have been collected and conserved by NBPGR in site collections (Abraham et al., 2008). In this paper an attempt has been made to highlight the importance of wild relatives of Horticulture breeders is drawn to the biological paradise of India, the Andaman and Nicobar Islands.

Visit of the authors were made to different locations of the Islands where wild relatives are present and got first-hand information. With the help of GPS important locations were recorded.

Table 1. Families and species distribution in A & N Islands which can be taken into consideration for suitable for Organic farming programme

S.No.	Family	Total species present in A&N	Closest species to cultivated	Endemic and Rare	Cultivated sp. In the family & Common name
1	Anacardiaceae	26	5	6	Mango
2	Annonaceae	60	5	14	custard apple
3	Araceae	32	2	7	Aroids
4	Arecaceae	49		23	Areca nut
5	Culusiaceae	28	2	8	Garcinasp
6	Cucurbitaceae	22	1	0	Bottle gaurds& other gaurds
7	Dioscareaceae	9	2	2	Tuber medicinal use/ veg
8	Fabaceae	110		4	Legumes &
9	Moraceae	64		1	Jack fruit, bread fruit etc
10	Musaceae	7		3	Banana
11	Myristicaceae	11		2	Nut meg
12	Myrtaceae	31		1	Tamarind, guava, rose apple
13	Orchidaceae	153	3	28	many flowering & vanila producing
14	Piperaceae	9	1	1	Black pepper, beetel leaves
15	Rosaceae	6			Many floriculture plants
16	Rutaceae	29		6	Citrus related
17	Sapindaceae	21		3	Litchi flowering for floriculture
18	Theaceae	3			Tea family, Camellia sinenis
19	Tiliaceae	16		2	Jute and related
20	Zingiberaceae	22		9	ginger, turmeric etc
21	Vitaceae	16		2	Grape etc.

Material and Methods

The literature that is available in different journals has been thoroughly screened for horticultural important families, genera and species. All the literatures has been pooled and digitalized for further utilization. During this course of work many important wild relatives of horticultural plants have been notices. Even though all horticulturally relevant literature has been collected, in this paper discussion has been restricted to few important species. Some of them can be readily domesticated under organic farming (Piper sp., *Hematocarpus validus* and for root stock Myristica sp., etc.) and many of them can be used in breeding programs, upon locating useful gens which are given in the Table 1 with their possible horticultural uses.

Results and Discussion

The crop plants that are most suitable for organic farm should possess good healthy root system, resistant to common diseases and insect pests, able to withstand drought and low input strategies, producing maximum returns. Most of these characters are present in wild relatives of Horticultural crops which have to be utilized in breeding programmes. They should also produce more vegetation so that this can be useful in recycling in producing organic manure. Twenty one families were scrutinized for their possibility as parentage for hybridization with cultivated species for developing cultivars for organic farming. Their total number of species present in these islands, closest species to cultivated, endemic and rare and their close relatives of horticultural crops were given in Table 1. Endemic, rare and important species with their habitat are given in Table 2. Global position of some of the wild species is presented in Table 3. Most of the species developed under a stress environment may be possessing some important genes to be transferred to cultivated species. To do such work well organized breeding/ screening programmers have to be undertaken for developing suitable varieties for organic farming. Some of the most important species are that can be used for such breeding programmes are species of *Mangifera, colocasia, Garcinia, Momordica, Dioscoria, Musa, Vanilla, Piper, Amomum, Myristicaceae* and *Zingiber*.

Table 2. Endemic and Rare species present in Andaman & Nicobar Islands that can be used in distant hybridization programme

S.No.	Family	*Botanical name*	Habitat			
			A	N	M	O
1	Anacardiaceae	*Boueaoppositifolia*	√		√	√
2		*BuchanaialanzanSpreng.*				
3		*Buchanaiasplendens*				
4		*Dracontomelondao (Blanco) Merr& Rolfe*				
5		*Lanneacoromandelica*				
6		*Mangiferaandamanica king*	√(E)			
7		*Mangiferacamptosperuma*	√	√		√
8		*Mangiferagriffthi*	√			√
9		*MangiferaNicobaricaKosterm, in Kosterm. &Bomard.,Monogr. Mangoes.1933.*		√(E)		
10		*Mangiferasylvatica*	√	√		√
11		*Semecarpuskurzii*				
12		*Spondiascytherea*				
13		*Spondiaspinnata*				
14	Annonaceae	*AnnonaGlabra.*	√		√	√
15		*I .grandifoliaZoll. et Mor. Var. kurzeana (Teysm. et Binn) Hook. F.*				
16		*I.grandifoliaZoll. et Mor. Var. rosella (kurz) Hook.f.*				
17		*I.hymenophyllaBremek.*				
18		*I.multibracteata Pearson ex King et Gamble.*				
19		*Oropheakatschallica*kurz	√	√(E)		
20		*V. marina (Burm .f) Meer.*				
21	Araceae	*A.CarnosusEngler*	√(E)			
22		*A.hirsutusTeysm. Et Binn.*		√(E)		
23		*A.longistylusKurz ex Hook. f.*	√(E)			
24		*A.OncophyllusPrain*	√(E)			
25		*A.paeoniifolius(Dennst.) Nicolson var. campanulatus (Decne) Sivadasan.*	√		√	√
26		*Amorphophallusblumei Schott*	√(E)			
27		*C. virosa (Roxb.) Kunth*		√	√	

28	Arecaceae	*Areca triandra*Roxb.	√	√	√	
29		*Arengapinnata Merrill*	√		√	√
30		*Calamusandamanicus*	√	√(E)		
31		*Calamusviminalisvar*	√	√(E)		
32		*Caryotamitis Lour*	√(E)			
33		*Cocosnucifera L.*	√(wild)	√	√	√
34		*Coryphaumbraculifera*	√		√	√
35		*NypafruticansWurmb*	√	√	√	√
36		*Phoenix paludosaroxb*	√	√	√	
37		*Rhopaloblasteangustata*(Kurz)		√(E)		
38	Cluslaceae	*Garciniaandamanica King*	√			√
39		*GarciniacowaRoxb. Ex DC.*	√	√	√	√
40		*GarciniadhanikharensisSirvastav. & Rao*	√(E)			
41		*Garciniahombroniana Pierre*	√	√		√
42		*GarciniamicrostigmaKurz*	√	√(E)		
43		*GarciniaxanthocymusHook.f& T. And.*	√		√	√
44		*Mesuaferrea L.*	√	√	√	√
45	Cucurbitaceae	*Momordicacochinchinersis*	√	√	√	√
46		*Trichosanthestricuspidata Lour.*	√		√	√
47	Dioscoreaceae	*Dioscoreaalata L.*	√	√		√
48		*Dioscoreabulbifera L.*	√		√	√
49		*Dioscoreaesculenta (Lour.) Burkill*	√	√	√	
50		*DioscoreaglabraRoxb.*	√	√	√	
51		*Dioscoreaoppositifolia L.*				
52		*Dioscoreapentaphylla L.*	√		√	√
53		*Dioscoreavexansprain et Burkill*	√	√(E)		
54	Fabaceae	*Abrusprecatorius L.*	√	√	√	√
55		*Atylosiascarabaeoides*				
56		*Canavaliaensiformis DC.*				
57		*Erythrina variegate L.*	√		√	√
58		*Flemingiamacrophyalla (Willd.) Kuntze.*	√		√	√
59		*Mucuna gigantean (Willd.) DC.*				
60		*Mucunamonosperma DC.*				
61		*Pongamiapinnata (L.) Pierre*	√	√	√	√
62		*Puerariaphaseoloides (Roxb.) Benth.*	√	√		
63		*Tephrosiapurpurea*				
64		*Vigna marina (Burm.f.) Merr.*	√	√	√	√

65	Moraceae	*Artocarpusalitilis.*				
66		*ArtocarpuschamaBuch. - Ham.*	√	√	√	√
67		*ArtocarpuschaplashaRoxb.*	√		√	√
68		*Artocarpusgomezianus Wall ex Trec.*	√	√	√	√
69		*ArtocarpuslacuchaBuch.-Ham*	√		√	√
70		*Ficuscarica L.*	√	√	√	√
71		*FicusgeniculataKurz*				
72		*Ficushispida L. f.*	√	√	√	√
73		*FicuslaevisBlume*	√	√	√	√
74		*FicusmangoleaefoliaBlume*		√		√
75		*Ficus nervosa Heyne ex Roth.*	√	√		√
76		*Ficusracemosa L.*	√		√	√
77		*MorusmacrouraMiq.*	√		√	√
78		*Streblusasper Lour.*	√	√	√	√
79	Musaceae	*Musa acuminate Colla*	√	√		
80		*Musa balbisianaCollacvar. Andamanica Singh et.al.*	√(E)			
81	Myristicaceae	*Horsefilediaglabra (Blume.) Warb.*	√	√	√	√
82		*Knemaandamanica*(Warb.)		√		√
83		*Myristicaandamanica Hook. F.*	√	√(E)		
84	Myrtaceae	*Pisoniagrandis R.Br.*	√	√	√	√
85		*Pisoniaumbellifera (J. Forst. & G. Forst.) Seem.*				
86		*Syzgiumclaviflora.*	√	√		√
87		*Syzygiumaqueum (Burm. F) Alston*		√	√	√
88		*syzygiumcumini (L.) skeels.*	√		√	√
89		*Syzygiumsamarangrnts (Blume.) Merr. & Perry*	√	√		√
90		*Syzygiumzeylanium (L.) DC.*	√	√		√
91	Orchidaceae	*V. andamanica Rolfe.*	√(E)			
92		V. *sanjappaeRasingam, Rasingam Pandey, wood & Srivastava*	√(E)			
93	Pandanaceae	*PandanusandamanensisKurz*	√	√(E)		
94		*Pandanusleram jones*	√	√(E)		
95		*PandanusodoritissimusL.f.*	√	√	√	√
96		*PandanustectoriusSoland.*	√		√	√
97	Piperaceae	*P.longum L.*		√	√	√
98		*P.miniatumBlume*		√		√
99		*P.ribesioides Wall.*	√			√
100		*Piper betle L.*	√	√	√	√
101		*Piper clypeatum Wall. ex Hook. f.*		√(E)		
102	Rosaceae	*Rubusmoluccanus L.*				

103	Rubiaceae	*J. andamanicumBalakr. et N.G. Nair.*				
104		*J. multiflorum (Burm. F.) Andrewa*				
105		*J.Syringifolium Wall. ex G. Don*				
106		*JasminumacuminatissimumBlume*				
107		*Morindacitrifolia L. var. bracteata (Roxb.) Hook. F.*	√	√	√	√
108		*Morindaumbellata L.*	√		√	√
109	Rutaceae	*Acronychiapedunculata (L.) Miq.*	√	√	√	√
110		*Aeglemarmelos (L.) Correa*	√	√	√	√
111		*Atalantiamonophylla (L.) DC.*	√	√	√	√
112		*Atalantiaspinosa (Willd.) Tanaka.*	√	√	√	√
113		*Citrus medica L.*	√	√	√	√
114		*Glycosmispentaphylla (Kerz.) A.DC*	√	√(E)		
115		*Triphasiatrifolia (Burm. f.) F. Wilson.*	√	√	√	√
116		*Zanthoxylumrhestsa (Roxb.) DC.*	√		√	√
117	Sapindaceae	*Allophylluscobbe (L.) Raeusch*	√	√	√	√
118		*DodonaeaViscosa L.*	√	√	√	√
119		*Eurphorialongansteud.*				
120		*Lepisanthesrubiginosa (Roxb.) Leenh.*	√	√	√	√
121		*Lepisanthestetraphylla (Vahl) Radik.*	√	√	√	√
122		*Nepheliumlongana*				
123		*Pometiapinnata J.*	√	√		√
124		*Schlechieraoleosa (Lour) O. Ken*				
125	Theaceae	*Camellia drupifera*				
126	Tiliaceae	*Corchorusaestuans L.*	√		√	√
127		*Corchoruscapsularis L.*	√		√	√
128		*GrewiacalophllaKurz.*		√		√
129		*Triumfettaannua L.*	√		√	√
130	Vitaceae	*CissusrepensLamk.*				
131		*CissusrepensVahl.*	√	√	√	√
132		*Tetrastigmaandamanicum*(King)	√	√(E)		
133	Zingiberaceae	*Alpiniamanii King ex Baker.*	√	√(E)		
134		*AmomumaculeatumRoxb.*	√(R)			
135		*Amomumfezlii*				
136		*Etlingerafenzlii (kurz) skornick& M. Sabu*				
137		*Zingiberodoriferum*	√		√	√
138		*Zingiberspectabile*	√	√	√	
139		*Zingibersquarrosum*	√(E)			
140		*Zingibersquarrosum*Roxb.	√(E)			
141		*Zingiberzerumbet*	√	√	√	√

Present in Andaman group of Islands (√), Nicobar group of Islands (√), mainland India (√) and Outside India (√).

Musa species in Andaman and Nicobar islands

This species is cultivated throughout the islands. The Nicobar tribes, Jarawa tribes and others love it. There are many described wild species in these Islands (Singh et al., 1998; Abrahim et al., 2008; Lalji Singh, 2014, Sharma, 2013). There may be more undescribed. It is well know that *Musa acuminata* is the source for resistance to fusarium wilt fungus. This species is also found in Andaman Islands. Now scientists are searching for resistant to black sigotaka as the previous developed resistances have been broken down. There is a possibility for resistant genes available in the wild species present in these Islands. My personal observation (may be species) in Great Nicobar Islands, at least two different types of wild banana. Most of the fruits produce lot of seeds. No disease or pest found. Very large leaves with strong pseudo stem and less suckers. Great Nicobar is a cyclonic storm effected area the wild banana seems to with stand winds and heavy rain fall which is a character required for the cultivated once. It is also observed white powdery coating on the leaves which keeps the leaves away from cattle damage these characters have to be studies further. The GPS location of banana in the islands are, Jerkatang to Kandamtala south and middle Andaman. In great Nicobar they are present in many isolated spots. (Conservation of wild bananas can be done through seeds (Dayarani et al., 2011) and therefore they should be conserved.

Zingiberaceae

In Andaman and Nicobar Islands there are 26 species reported with nine species endemic to these Islands. *Amomum andamanicum* a new species have been reported recently. The diseases like Fusarium, rhizome rot, white fungus, bacterial soft rot are effecting the cultivation and yield of Zinger. Among these insect pests, cutworm, helminthic and root rot nematodes are major problem. Therefore search for resistant gene from the wild relations will be a great help for developing resistant limits by utilization district breeding programme. One of these species called as Giant Zinger can be such candidate for resistance screening. This can also be utilized in ornamental gardening. Finding out a resistant source in A&N Islands will be more use full as these islands are also hot spot for diseases&Pests of agricultural crops.

Like these many wild relatives from these Islands can be used for breeding programmes. Lesser yam female clones are available in Andaman and Nicobar Islands which can be used in breeding programmers. The geographical isolation of many species caused variability which has to be studied. Studies on agronomic characters, reaction to pests, and usefulness in organic farming have to under taken on the species which are in wild to be considered as candidate for crossing programme to transfer the useful genes to the cultivated.

Piperaceae

It also be thought of utilizing Piper species present in these Islands as lot of variability is present, in different breeding programmes. Most important of these can be crossed with the cultivated black pepper with *Piper ribesioides* which is a perennial, flowers in Andaman and Nicobar Islands, may be having some resistant genes required for improving the black pepper. *Piper ribesioides* stem is used in food preparation for its flavour and softens the non-veg dishes. This can also be cultivated under organic farming. There is a lot of variability in *piper betel* species with small to large leaves, Green to brown stem. There are some clones of *Piper betle* which are flowering and fruiting.

Wild species that can be domesticated under organic farming

Piper betle L.: Selected clones can be brought under organic cultivation for leaves.

Piper ribesioides Wall.: Selected clones can be brought under organic cultivation for matured stem harvest to be used in non-vegetarian preparation for flavour and softing. This will also help in conservation of this species as it has to be harvested destructively.

Mangifera andamanica King.: Can be used as root stock for *M. indica* for cultivation in organic farming as the root system of *M. andamanica* King may be very strong as it competes with forest flora.

Myristica andamanica Hook F.: Can be used as root stock for *M. frangrence* to be cultivated in organic farming.

Recommendations

- A mega project of studying the wild relative of crop plants in A & N Islands should be planned.
- Evaluation of these plant species for biotic and abiotic stress tolerance/ resistance and suitability for organic farming has to taken up.
- Useful plant species that can be domesticated have to be studied and recommended for cultivation.
- *In-situ* and *ex- situ* conservation should be encouraged by different organizations. (C.I.A.R.I., B.S.I., I.C.M.R. and NGO's).
- Studies on variability among the species should be taken up as there will be useful changes due to geographical isolation and tolerance to climatic changes (Inter species variability).
- A tropical gene bank should be planned in-situ with the guidance of NBPGR and other ICAR organisations and BSI should be planned in these Islands.

- A network on the database of economically useful Plant species of Andaman and Nicobar Islands should be developed for updating/reviewing the existing literature.
- Micro-propagation of useful plants by Cryo-preservation Unit, Field Gene Bank etc. should be set up preferably in CIARI/BSI/ICMR/any NGO.

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THEME V:
ORGANIC FARMING IMPACTS ON FARM ECOSYSTEM

Organic farming: Impacts on energy use efficiency and energy dynamics

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Organic agriculture represents a broad set of practices that emphasize farming based on ecosystem management, integrated cropping and livestock systems, diversity of products, and reliance on natural pest and disease control without the use of synthetic inputs. The objectives of organic agriculture are to produce sustainable and healthy food through harnessing natural biological and ecological processes. The Codex Alimentarius Commission (2001) defines organic agriculture as “a holistic production management system which promotes and enhances agro-ecosystems health including biodiversity, biological cycles, and soil biological activity. It emphasizes the use of management practices in preference to the use of off-farm inputs, taking into account that regional conditions require locally adapted systems. This is accomplished by using, where possible, cultural, biological, and mechanical methods, as opposed to using synthetic materials, to fulfil any specific function within the system”. An organic agricultural system is therefore designed to rely on renewable energy sourced as much as possible from on-farm or natural local systems. Although organic agriculture adheres to certifiable standards, farmers have the flexibility to enhance the ecological and sustainable practices of their farms beyond what the standards require. Conventional agriculture is in reference to any non-organic farming system and encompasses a wide range of agricultural methods including high external input agriculture, integrated production management, traditional pastoral systems, precision agriculture, and conservation agriculture, among others.

Energy can be broadly defined as the capacity to do work. As it can neither be created nor destroyed, energy is conserved and transferred within a closed system. The various forms of energy (kinetic, potential, electrical, thermal, etc.) can be converted, at least partially, from one to another and ‘used’ to perform work. In an agricultural context, energy in the form of fossil fuel, electricity, natural gas and human labour is used to operate machinery, manufacture inputs, cultivate soils, control plants, pests, and animal disease, dry and cool crops, heat and ventilate glasshouses, and heat and light livestock housing. Energy in agriculture is typically evaluated under two overlapping and complementary measures: energy consumption for both direct and indirect energy expenditures and energy efficiency. Energy consumption is used to refer to the basic data on farm and farm input energy expenditure which is measured as the total energy used per unit of land over unit of time. Typically, researchers convert all fossil fuel and sometimes also human labour, to a standard unit of energy, either joules or calories, measured per hectare for one year (Mendoza, 2002, Williams *et al.* 2006, Bos *et al.* 2007, MAFF, 2000). The total commercial energy input to Indian agriculture has increased from 425.4 × 109 Mega Joules (MJ) in 1980-81 to 2592.8 × 109 MJ in 2006-07. The consumption of energy per hectare of net sown area has increased from 3000 MJ to 18500 MJ during this period. The consumption of energy per hectare of gross cropped area has also increased from 2500 MJ to 13400 MJ during this period. This clearly indicates that energy intensity per unit of area for various crops has increased manifold during 1981 to 2007 (Jha *et al.,* 2012). Increase in cropping intensity and shift of area towards energy-intensive crops were mainly responsible for this shift.

Energy efficiency is the ratio of energy use per unit of crop or per calorie produced, usually joules per tonne or joules per calories. Energy efficiency is used to standardize comparisons between a variety of crops and to normalize higher or lower yields for a given production method (Refsgaard *et al.,* 1998). This is the measure used in this report to compare the energy use of organic and non-organic systems. Examining efficiency in terms of non-renewable energy consumption does not fully capture the total energy use on a farm. Importantly, organic agriculture additionally harnesses the energy of natural ecological and biological processes to carry out or assist with a range of key agricultural functions, including soil structure, nutrition, water supply, plant pest control, animal parasite and disease control.

Use of energy intensive inputs is increasing in a modern intensive agricultural production system. The effect of energy intensive inputs are directly associated with the cost of crop production and environmental issues. These necessities the need of energy input – output analysis. A study on the energy input-output analysis of rice (*Oryza sativa* L.) – wheat (*Triticum aestivum* L.) cropping system studied at Indian Institute of farming system research, Modipuram (Paramesh *et al.,* 2017) reveal the variations in energy consumption from rice (25819.4 MJ/ha) and wheat (17714.9MJ/ha). Nitrogenous fertilizer (25-33%), fuel (6.8-18.2%) and irrigation water (8.6 - 23.7%) consumed the bulk of the input energy in rice and wheat. Rice crop with the higher energy output produced higher energy use efficiency (7.6), energy use efficiency for grain (4.1) net energy (171399.2 MJ/ha) and energy profitability (6.6 MJ/ha), while the human energy profitability (162.9) was higher in wheat indicating that it was more labour energy efficient than rice (Table.1). The consumption of direct (6522.7 MJ/ha) and indirect energy (19296.8 MJ/ha) was found higher in rice crop. Econometric model estimation emphasized that direct energy was found more positive on increasing rice and wheat yield. Thus sensitivity analysis also indicated marginal physical productivity of 0.96. Both rice and wheat were found energy intensive; in order to reduce the energy consumption crop diversification and farm mechanization would be the possible solution.
(MJ/ha)

Table.1 Energy indices for the rice – wheat system

Indices	Rice	Wheat
Energy Use Efficiency	7.6	7.5
Energy Use Efficiency M*	4.1	3.9
Net Energy(MJ/ha)	171399.2	114622.0
Net Energy M*(MJ/ha)	79711.9	51522.1
Energy Profitability(MJ/ha)	6.6	6.5
Human Energy Profitability	125.4	162.9
Energy Productivity (kg/MJ)	0.28	0.27
Direct Energy (MJ/ha)	6522.7	4832.1
Indirect Energy (MJ/ha)	19296.8	12882.8
Renewable Energy (MJ/ha)	5097.8	3162.6
Non-renewable Energy (MJ/ha)	14601.7	13022.3

M* - Main Product

Source: Paramesh *et al.* 2017 (ICAR- IIFSR, Modipuram)

Factors limiting the analysis of energy use in agricultural systems

Many factors can be considered when comparing organic and conventional agricultural systems; however, a significant challenge to conducting a practical and replicable comparison of organic and conventional farming is that neither system is homogenous. Although conventional can be defined as the negative of organic, conventional farming encompasses a wide range of production methods. Farms will vary depending on the crop produced, location and size of the farm, climate, and the individual choices of the farmer. Likewise, organic agriculture, although adhering to basic standards, differs in its implementation from highly organized ecological systems to large-scale monocropping or concentrated livestock operations similar in many ways to conventional agriculture, save for the absence of synthetic pesticides and fertilisers. Comparing any complex system to another is a challenge. It should be noted that while energy use is an important criterion for evaluating farming systems sustainability, it is only one difference in the impacts of the two systems.

Since farming systems are multi-functional, analyses of just one impact are of limited value without a broader consideration of the other costs and benefits of the system. Therefore, the quantitative analysis of energy expenditures and efficiencies is often coupled with a qualitative analysis that measures individual and societal benefits of farming practices. Organic has additional intangible benefits that are impossible to directly compare to a conventional system such as improved ecosystems which result from balanced nutrient and energy flows, as well as maintenance of living countryside, opportunities for skilled agricultural labour, stewardship of the land and natural resources, animal welfare, and strengthening rural communities. For the purposes of simplicity and for comparison, energy output of crop yield is measured in total calories or mega-joules; this one-dimensional quantification of energy output ignores the varied nutritional contents of agricultural products. Obviously, producing a variety of foods with different vitamin and mineral content is vital to nutritional well-being despite the relative energy inefficiencies of certain foods when compared to others. Because of this limitation, this analysis focuses more on comparing energy efficiency of different production methods for any given crop rather than comparing the energy efficiencies between crops themselves.

Energy consumption in production

Agricultural systems utilize both, direct energy from on farm activities such as operating machinery and maintaining infrastructure, and indirect energy, from the manufacture and transport of inputs. Different production methods drastically alter the amount of energy needed to grow a particular crop or raise livestock.

Soil organic matter

Maintaining high levels of soil organic matter is beneficial for all agriculture, but is especially critical on organic farms. On average, the amount of soil organic matter is significantly higher in organic production than in conventional farming. Typical conventional farming systems with satisfactory soil generally have 3% to 4% soil organic matter, whereas organic systems soil averages from 5.2% to 5.5% soil organic matter. The high level of soil organic matter in the organic systems is directly related to the high energy efficiencies observed in the organic farming systems; organic matter improves water infiltration and thus reduces soil erosion from surface runoff and conserves water resources, and it also diversifies soil-food webs and helps cycle more nitrogen from biological sources within the soil.

Nitrogen fertiliser

Nitrogen fertiliser is cited as the biggest energy sink in non-organic production. Not only is nitrogen fertiliser produced from the raw materials of fossil fuel but the conversion process to usable fertiliser is energy intensive (Soil Association, 2006, 2007). The production of one tonne of nitrogen fertiliser utilises one to one and half tonnes of equivalent petrol. In productions, like grains, in which high amounts of synthetic nitrogen fertilizers are applied, about half of the total energy (direct and indirect) needed is the energy used for the manufacture of the nitrogen fertilizers. Compared to such conventional production systems, the energy use in organic agriculture is therefore about half. According to the Soil Association (2006), the largest portion of energy utilized in conventional agriculture i.e. 37% of the total energy is synthetic pesticides and mineral fertilisers, particularly nitrogen, and to a lesser extent, phosphorous, and potassium. Refsgaard *et al.* (1998) found that energy consumption through the use of fertilisers accounted for anywhere from 25-68 percent of total energy use depending on the type of crop and growing conditions.

According to a research project from the British Ministry of Agriculture, Fisheries and Food, the energy input per hectare in organic farming is 40% of the energy input in conventional farming for wheat production, 54% for potatoes, 50% for carrots, 65% for onions, 27% for broccoli (MAFF, 2000). A comparative study conducted in Canada of two crop rotations (wheat-pea-wheat-flax and wheat-alfalfa-alfalfa-flax) cultivated organically and conventionally concluded that the energy use was 50% lower with organic than with conventional management. Even though the energy output was 30% lower under organic, the energy efficiency (energy produced /energy used) remains better in organic agriculture. (Hoeppner, 2006).

Pesticides and chemicals

Conventional agriculture's energy inefficiency is directly tied to the high energy consumption of producing and transporting synthetic pesticides and fertilisers used to grow these crops. Organic agriculture utilizes manure, legumes, and other natural sources of nitrogen, which replace the fossil fuels to manufacture synthetic nitrogen fertiliser with a natural biological processes. Legumes fix atmospheric nitrogen naturally in their root-nodules by the activity of micro-organisms. Water and other plant nutrients are supplied via the active soil biology of organic systems; soil microbes break down and cycle minerals from soil rock particles, decaying plant matter, manure, and compost to the plant roots. This natural symbiosis of soil microfauna and crops is suppressed in many non-organic systems with less biologically active soils. On either conventional or organic farms, when animals produce some or all of the fertiliser needed for crop production, the energy expenditures are greatly reduced. Because of its reliance on natural fertilisers, organic agriculture often performs relatively better in terms of energy efficiency (measured as the ratio of energy input per unit of crop output) despite lower yields. In an analysis of conventional rice farming in the Philippines, one expert concluded that increases in rice yield come with a 6 to 25 fold increase in energy consumption predominately because of fertiliser used to achieve incremental gains in crop yield (Pretty, 1995).

Mechanisation

Farming practices and the use of machinery greatly influence energy use on individual farms. Mechanical weeding, pesticide application, and greenhousing are all high energy use practices that can significantly affect a farm's energy consumption and efficiency. Organic carrot and potato production are both cited in various studies as having high energy inputs per unit of output because of mechanical weeding (Stolze *et al.,* 2000; Williams *et al.,* 2006; Bos *et al.,* 2007). Precision agriculture and zero (or minimal) tillage farming are methods of conventional agriculture that are often presented as environmental alternatives to standard conventional agriculture. Precision agriculture focuses on the careful allocation of fertilisers based on testing of soil nutrients; no tillage practices emphasize cultivation of crops without disturbing the soil through ploughing. Environmentally, these methods have been shown to reduce soil erosion and minimize nutrient runoff; however, from an energy conservation perspective their benefits are less clear. Low or no till systems decrease direct energy inputs but can increase indirect energy by requiring more herbicides, pesticides, and other chemicals (Smolik *et al.*,1995).

Irrigation

Pump irrigation is another energy-intensive agricultural practice, one that is utilized by both organic and non-organic farms. While some methods of irrigation are more energy efficient that others, overall energy use for irrigation is largely determined by depth from which water is pumped, climate, and crop type. Organic agriculture has been shown to decrease irrigation need because the higher soil organic matter generated by organic practices retains water better than the soil from conventional systems (Fan *et al.,* 2005).

Concentrated Feed

When calculating energy consumption from livestock products, energy efficiency of feed must be considered. As noted above, crop production uses a substantial amount of energy; therefore, feeding livestock grain (especially conventionally grown grain) reduces their energy efficiency considerably. Cattle that are fed a mixture of grain and grass forage throughout their lives (which is typical of conventional systems) use twice as much energy per kilocalorie of protein produced than grass-fed (Pimentel, 2006) because of the efficiency in their conversion of feed. For this reason, broiler hens have been shown to be less energy efficient on organic farms than conventional farms. Conventional systems typically rely on an off-farm supply of concentrated feed, while organic systems more often source their livestock forage locally or produce it directly on the farm. Conventional livestock feed is often produced in the most intensive form of agricultural production, which relies heavily on synthetic chemical and fertiliser input (Willeke-Wetstein, 1998) and because livestock consumes large amounts of silage, grain, and grass, the energy inefficiency of conventional crop production is magnified. An FAO report estimates that almost two thirds of energy consumption in conventional livestock is attributed to production, processing, and transport of feed (De Haan *et al.,* 1997). Several comparative studies confirm the energy efficiency of organic livestock systems. Research in the UK concluded that organic dairy cow production utilised only 22 per cent of the energy from conventional production because in the organic systems cows mainly ate grass whereas the conventional cows were fed predominately with corn silage, grain and soybean cake (MAFF, 2000).

Greenhouses

High value crops are grown in green houses to extend their growing seasons and to meet the off season demand. Tomato farming, which is often done in heated greenhouses for off-season production, is very energy demanding in comparison to field crops. Because energy consumption is dominated by heating and electricity costs for the greenhouse and establishment of the infrastructure, organic and non-organic systems performed very similarly, with small differences arising based on variety of tomatoes cultivated. Additionally, in the controlled environment of the greenhouse, organic and non-organic systems both utilize biological pest control, which decreases the amount of synthetic pesticides applied in the non-organic systems. The energy used in this specialized production of tomatoes is comparatively less efficient than other forms of agriculture, whether organic or conventional; therefore, any energy savings in switching production methods would be marginal at best (Williams *et al.,* 2006).

Human labour

In most organic systems, the energy saved from reduced inputs is compensated for by an increase in human labour. Although energy is not simply transferred from synthetic inputs to human labour, low-inputs systems such as organic agricultural on average require additional manpower when compared to high-input conventional systems. Estimates vary and depend on climate, crops, and size of the operation. In addition to weeding, cultivating, and plant and animal maintenance activities (which are largely performed by machinery and chemicals in conventional systems), organic farmers plant cover crops, spread manure, and produce compost. Developing and maintaining an integrated agro-ecosystem requires additional labour from the farmer, who has the knowledge and skills to perform this work and cannot be easily replaced by mechanization.

Conclusions

Despite the complexities, uncertainties, and gaps in knowledge regarding energy consumption in both conventional and organic agriculture, a few general conclusions can be drawn. Typically, organic agriculture uses 30 to 50 percent less energy in production than comparable non-organic agriculture. Though organic agriculture on average uses energy more efficiently, it often requires an indirect trade-off of energy intensive inputs with additional hours of human labour—approximately one third more than conventional agriculture. Organic agriculture holds a great potential for pioneering energy reducing practices through the framework of organic standards. Organic principles, which emphasize environmental stewardship, farm-level self-sufficiency, and incorporation of externalities can be leveraged to develop strategies for limiting use of fossil fuel-based energy in organic agriculture.

Conventional agriculture does not have a similar set of regulations and standards from which to launch an energy-saving initiative. Market pressures, rising fuel costs, and government policies will affect how conventional agriculture uses and limits energy in the future. Developments in technology will continue to reduce fertilizer and chemical usage as application methods become more precise. Organic agriculture, in the meantime, can pave the way in identifying energy inefficiencies and developing alternative practices to reduce energy consumption in the food system. With non-renewable energy sources waning and a global, mounting concern over greenhouse gas emissions, reducing the food system's energy burden is imperative. Organic agriculture already uses less fossil fuel based inputs and has a better carbon footprint than standard agricultural practices. Organic operations provide promising possibilities for further energy reductions throughout the food system. Organic production can point the way to wisely balancing energy efficiency with economic and environment factors in all stages from production to consumption, which will ultimately determine both the social and financial viability of adopting energy saving practices.

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Soil microbial enzymes and their role in assessing soil health under conservation agriculture practices

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Soil enzymes are considered as important bioindicators of biological processes or properties within the soil component of an ecosystem that indicate some state of the ecosystem. Enzyme activities in soil are primarily expression of bacteria, fungi and plant roots, and are responsible for the flux of carbon, nitrogen and other essential elements in the biogeochemical cycles. Enzyme activities when combined with other soil properties may provide enough information to allow the rational manipulation of soil processes for commercial and environmental benefits. Many long-term studies have shown that soil enzyme activities are sensitive in discriminating among soil management practices, such as organic fertilization by animal manures or green manures/crop residues, municipal refuse amendments, as well as tillage regime and herbicide additions. The response of soil enzyme activities to specific soil practices has been used to compare agricultural systems such as organic versus conventional farming.

Sources of soil enzymes

Sources of soil enzymes include living and dead microbes, plant roots and residues, and soil animals. Enzymes stabilized in the soil matrix accumulate or form complexes with organic matter (humus), clay, and humus-clay complexes, but are no longer associated with viable cells. It is thought that 40 to 60% of enzyme activity can come from stabilized enzymes, so activity does not necessarily correlate highly with microbial biomass or respiration. Therefore, enzyme activity is the cumulative effect of long term microbial activity and activity of the viable population at sampling. However, an example of an enzyme that only reflects activity of viable cells is dehydrogenase, which in theory can only occur in viable cells and not in stabilized soil complexes.

Why it is important: Enzymes respond to soil management changes long before other soil quality indicator changes are detectable. Soil enzymes play an important role in organic matter decomposition and nutrient cycling (Table 1). Some enzymes only facilitate the breakdown of organic matter (e.g., hydrolase, glucosidase), while others are involved in nutrient mineralization (e.g., amidase, urease, phosphatase, sulfates). With the exception of phosphatase activity, there is no strong evidence that directly relates enzyme activity to nutrient availability or crop production. The relationship may be indirect considering nutrient mineralization to plant available forms is accomplished with the contribution of enzyme activity. Some other advantages of soil enzymes as bio-indicators are as follows

1. Most assays are straightforward and do not require any sophisticated equipments
2. Large number of samples can be analysed in a short time
3. Air dried samples can be used which eases storage problem

Major classes of soil enzymes

1. *Exclusively intracellular enzymes*: These enzymes describe overall microbial activity in the soil but do not yield much information regarding the rate of specific catalytic steps such as nutrient acquisition and biogeochemical cycling, processes which define soil health. eg dehydrogenase
2. *Intracellular and extracellular enzymes*: In these enzyme assays, the products of the reaction are a result of the activites of many different enzymes. For example fluorescein diacetate (FDA) can be hydrolysed by the action of lipases, proteases and esterases. So FDA sometimes is suggested as measure of the global hydrolytic capacity of soils and a broad spectrum indicator of soil biological activity.
3. *Extracellular enzymes*: These assays estimate the activity of hydrolytic enzymes involved in specific stages in C,N, P and S acquisition

Limitations

1. *Extraction*: Most important difficulty in studying soil enzymes is that only small amounts of the total enzymes found in the soil can be extracted from soils. Harsh extraction procedures with good recovery rates generally denature enzymes which results in loss of enzymatic activity.
2. *Enzyme assay*: Enzyme assays measure the potential activity under optimal conditions and not the in situ activity because assay conditions are quite different from those in the original soil, particularly substrate concentration which saturates the system. Secondly, enzymatic activity of the abiontic or extracellular enzymes cannot be separated from living cells.

Thirdly, assay procedures require costly chemicals.

Measuring soil enzymes: Enzymes are measured indirectly by determining their activity in the laboratory using biochemical assays. Enzyme assays reflect potential activity and do not represent true in situ activity levels and must be viewed as an index. In lab, generally we estimate β glucosidase (enzyme involved in C cycling), phosphatase (P cycling),

Table 1. Role of soil enzymes

Enzyme	Organic Matter Substances Acted On	End Product	Significance	Predictor of Soil Function
Beta glucosidase	Carbon compounds	Glucose (sugar)	Energy for microorganisms	Organic matter decomposition
FDA hydrolysis	Organic matter	Carbon and various nutrients	Energy and nutrients for microorganisms, measure microbial biomass	Organic matter decomposition nutrient cycling
Amidase	Carbon and nitrogen compounds	Ammonium (NH_4)	Plant available NH_4	Nutrient cycling
Urease	Nitrogen (urea)	Ammonia (NH_3) and carbon dioxide (CO_2)	Plant available NH_4	Nutrient cycling
Phosphatase	Phosphorus	Phosphate (PO_4)	Plant available P	Nutrient cycling
Sulfatase	Sulfur	Sulfate (SO_4)	Plant available S	Nutrient cycling

dehydrogenase(oxidation reduction reactions),arylsulphatase (S cycling) and FDA hydrolase (extracellular enzymes). The protocols of all these enzymes are as follows:

When possible, compare the site of interest to samples taken from an adjacent, undisturbed site on the same soil type. Alternatively, for a newly implemented land management system, track changes from time zero to five or more years with annual sampling to detect temporal changes in activity of soil enzymes.

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http://www.soilquality.org/indicators/soil_enzymes.html

Estimation of major soil enzymes

β-glucosidase

Reagents

1. Toluene, Fisher certified reagent (Fisher Scientific Co., Chicago).
2. Modified universal buffer (MUB) stock solution: Dissolve 12.1 g of tris (hydroxymethyl) aminomethane (THAM), 11.6 g of maleic acid, 14.0 g of citric acid, and 6.3 g of boric acid (H_3BO_3) in 200 ml of IN sodium hydroxide (NaOH) and dilute the solution to 1 liter with water. Store it in a refrigerator.
3. Working Modified universal buffer (MUB) solution, pH 6: Place 200 ml of MUB. Stock solution in a 1000 ml beaker containing a magnetic stirring bar, and place the beaker on a magnetic stirrer. Titrate the solution to pH 6 with 0.1 N HCl and the volume to 1 liter with water.
4. p-Nitrophenyl β D glucoside solution (PNG) (0.025M): Store at 4^0C.
5. Calcium chloride ($CaCl_2$),O.5M
6. Sodium hydroxide (NaOH),O.5M
7. Standard p-nitrophenol solution (1000 mg ml^{-1}) : Store the solution in a refrigerator.
8. THAM (Tris hydroxymethyl amino methane) buffers (.1M)

Procedure

1. Place 1 g of soil in a 100 ml Erlenmeyer flask, add 0.2ml of toluene, 4 ml of MUB, 1 ml of p-nitrophenyl β D glucoside solution made in the same buffer, and swirl the flask for a few seconds to mix the, contents.

2. Stopper the flask, and place it in an incubator at 37^0C.
3. After 1hour, remove the stopper, add 1 ml of O.5M$CaCI_2$ and 4 ml of 0.1 M THAM, swirl the flask for a few seconds, and filter the soil suspension, through Whatman no. 42 filter paper.
4. Measure the yellow colours intensity of the filtrate with spectrophotometer at 490 nm. Calculate the p-nitrophenol content, by reference to a calibration graph plotted from the result obtained with standards containing 0, 10, 20, 30, 40, and 50 ug of p-nitrophenol.

Calculation: µg of p-nitrophenol released/g soil/hr observed at 490 nm by applying standard readings.

Reference: Eivazi F, Tabatabai MA (1988) Glucosidases and galactosidases in soils. *Soil Biol Biochem* **20:**601–606**.**

Aryl Sulfatase

Reagents

1. Toluene, Fisher certified reagent (Fisher Scientific Co., Chicago).
2. Acetate buffer (0.5M) pH 5.8
3. p-Nitrophenyl sulfate solution (0.025M): Store at 4^0C.
4. Calcium chloride ($CaCl_2$) O.5M
5. Sodium hydroxide (NaOH) O.5M
6. Standard p-nitrophenol solution (1000 µm): Store the solution in a refrigerator.

Procedure

1. Place 1 g of soil in a 100 ml Erlenmeyer flask, add 0.2ml of toluene, 4 ml of acetate buffer, 1 ml of p-nitrophenyl sulfate solution, made in the same buffer, and swirl the flask for a few seconds to mix the, contents.
2. Stopper the flask, and place it in an incubator at 37^0 C.
3. After 1hour, remove the stopper, add 1 ml of O.5M$CaCI_2$ and 4 ml of 0.1 M NaOH, swirl the flask for a few seconds, and filter the soil suspension, through Whatman no. 42 filter paper.
4. Measure the yellow colours intensity of the filtrate with spectrophotometer at 490 nm. Calculate the p-nitrophenol content, by reference to a calibration graph plotted from the result obtained with standards containing 0, 10, 20, 30, 40, and 50 ug of p-nitrophenol.

Calculation: µg of p-nitrophenol released/g soil/hr observed at 490 nm by applying standard readings.

Reference: Tabatabai, M.A. and Bremner, J.M. (1970). Arylsulfatase activity of soils. *Soil Sci. Soc. Am. Proc***. 34**: 225-229.

Dehydrogenase Enzyme

Principle:Biological oxidation of organic compounds is generally a dehydrogenation process and is represented as follows:

$$XH_2 + A \xrightarrow{\text{dehydrogenase}} X + AH_2$$

Triphenyl tetrazoliumchloride (TTC) used as a substrate in this assay, possesses the property of being easily transformed into intensely colored water insoluble but methanol soluble, triphenylformazan. This method is based on the extraction of triphenylformazan (formed by reduction of TTC in soil) with methanol and its colorimetric determination. The transformation occurs through the rupture of the ring and the reaction is as under

$$TTC + 2e^- + 2H^+ \xrightarrow{\text{dehydrogenase}} TPF + HCl.$$

Reagents

1. 2**,** 3, 5**-** Triphenyltetrazolium chloride (TTC), 3%:Store in dark.
2. Methanol, analytical reagent grade.
3. Triphenyl formazan (TPF) standard solution

Procedure

- Place 6 g field moist soil in a screw capped tube.
- Add 1ml of 3% aqueous solution of TTC and 2.5 ml of distilled water.
- Mix the contents of each tube and stopper it.
- Incubate for 24 hrs at 27^oC in dark.

- Remove the stopper and add 10ml methanol, stopper it and shake for1min.
- Unstopper the tube and filter the suspension through a glass funnel.
- Wash the tube with 10ml methanol and quantitatively transfer the soil to funnel until the reddish color has disappeared.
- Measure the intensity of reddish color at 485 nm using methanol as blank.
- Calculate the amount of TPF produced by reference to a calibration graph prepared from TPF standard.
- Represent the results as µg TPFg^{-1} soil h^{-1}

Reference

Casida, L.E.,Jr., D.A.,Klein and T. Santoro (1964) Soil dehydrogenase activity. Soil Sci. 98: **371-376.**

Alkaline Phosphatase activity (Tabatabai and Bremner 1969)

Principle

The procedures described for assay of phosphomonoesterase activities are based on colorimetric estimation of the p-nitrophenol released by phosphatase activity when soil is incubated with buffered (pH 6.5 for acid phosphatase activity and pH 11 for alkaline phosphatase activity) sodium p-nitrophenyl phosphate solution and toluene. The colorimetric procedure used for estimation of p-nitrophenol is based on the fact that alkaline solutions of this phenol have a yellow color (acid solutions of p-nitrophenol and acid and alkaline solution of p-nitro phenyl phosphate are colorless).

The $CaCl_2$-NaOH treatment describe for extraction of p-nitro phenol after incubation for assay of acid and alkaline phosphatases serves (i) to stop phosphatase activity, (ii) to develop the yellow color used to estimate this phenol, and (iii) to give quantitative recovery of p-nitrophenol from soils.

Reagents

1. Toluene, Fisher certified reagent (Fisher Scientific Co., Chicago).
2. Modified universal buffer (MUB) stock solution: Dissolve 12.1 g of tris (hydroxymethyl) aminomethane (THAM), 11.6 g of maleic acid, 14.0 g of citric acid, and 6.3 g of boric acid (H_3BO_3) in 488 ml of IN sodium hydroxide (NaOH) and dilute the solution to 1 liter with water. Store it in a refrigerator.
3. Working Modified universal buffer (MUB) solution, pH 11: Place 200 ml of MUB. stock solution in a 1000 ml beaker containing a magnetic stirring bar, and place the beaker on a magnetic stirrer. Titrate the solution to pH 11 with 0.1 N HCl and the volume to 1 liter with water.
4. p-Nitrophenyl phosphate solution (0.025M) : Store the solution in a refrigerator.
5. Calcium chloride ($CaCl_2$),O.5M
6. Sodium hydroxide (NaOH),O.5M
7. Standard p-nitrophenol solution (1000 mg ml^{-1}): Store the solution in a refrigerator.

Procedure

1. Place 1 g of soil in a 100 ml Erlenmeyer flask, add 0.2ml of toluene, 4 ml of MUB, (pH11 for assay of alkaline phosphatase), 1 ml of p- nitrophenyl phosphatase solution made in the same buffer, and swirl the flask for a few seconds to mix the, contents.
2. Stopper the flask, and place it in an incubator at 37^0 C.
3. After 1hour, remove the stopper, add 1 ml of O.5M$CaCI_2$ and 4 ml of 0.5 M NaOH, swirl, the flask for a few seconds, and filter the soil suspension, through Whatman no. 1 filter paper.
4. Measure the yellow colors intensity of the filtrate with spectrophotometer at 490 nm. Calculate the p-nitrophenol content, by reference to a calibration graph plotted from the result obtained with standards containing 0, 10, 20, 30, 40, and 50 ug of p-nitrophenol.

Preparation of standard curve

To prepare the graph, dilute 1ml of the standards p-nitrophenol to100 ml in a volumetric flask, and mix the solution thoroughly. Then pipette 0-, 1-, 2-, 3-, 4-, and 5 ml aliquots of this diluted standard solution into 50-ml Erlenmeyer. flasks, adjust the volume to 5 ml by addition of water, and proceed as described for p- nitrophenol analysis of the incubated soil samples If, the color intensity of the filtrate exceeds' that of the 50 ug of the p-nitro.phenol standard, an aliquot of the filtrate should be diluted with water until the colorimeter reading falls within the limits of the calibration graph. Controls should be performed with each soil analyzed to allow for, color not derived from p-nitrophenol released by phosphatase activity. To perform controls, follow the procedure described for assay of phosphatase activity, but make the addition of 1ml of PNP solution after the additions of *O.5M* $CaCl_2$, and 4 ml of *O.5M* NaOH (immediately before filtration. of the soil suspension).'

Calculation

μg of p-nitrophenol released/g soil/hr observed at 490 nm by applying standard readings.

Reference

Tabatabai, M. A.and Bremner, J. M., (1969). Use of p-nitrophenyl phosphate for assay of soil phosphatase activity. *Soil Biol. Biochem*. **1**:301-307.

Microbial activity by FDA Hydrolysis in soil

Principle: Fluorescein diacetate (FDA) hydrolysis is a simple, sensitive and rapid method to measure microbial activity in the rhizosphere soil as well as in the plant litter. FDA is hydrolysed by a number of enzymes including protease, lipase and esterase. These enzymes convert fluorescein diacetate to fluorescein which can be visualized and quantified spectrophotometerically.

Reagents

1. Acetone
2. FDA stock solution :Dissolve10mg FDA (Hi- Media) in 5ml reagent grade acetone (store in fridge)
3. 60 mM of potassium phosphate buffer (pH7.6)

Procedure

- Take 1 g soil and add 5mlof 60mM of potassium phosphate buffer and 10 μl FDA solution.
- Incubate at 37^{o}C for 2 hrs.
- Add 0.2 ml of acetone (5%v/v) to stop the reaction
- Filter through Whatman no 2 filter paper.
- Take O.D at 490 nm.

Express the results as μg of fluoresce in released g^{-1} soil h^{-1}

Note: Run blank for each soil sample by adding only 0.1ml acetone (no FDA sol)

Run blank with no soil sample (only reagent), take O.D after 2 hrs at 37^{0}C and subtract from all the readings, or set auto zero with this.

Perform the experiment in stopper tubes.

Reference

Green,V.S., Stott, D.E. and Diack,M (2006) Assay of fluorescein diacetate hydrolytic activity-optimization of soil samples. Soil Biol. Biochem. 38: 693-701.

Dick RP. 1994. Soil Enzyme Activity as an Indicator of Soil Quality. In: Doran JW et al., editors. Defining soil quality for a sustainable environment. Madison, WI. 107-124.

Does Organic Farming Benefit Biodiversity Conservation or vice versa?

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Most of the countries in the world have undergone major agricultural intensification to cope up with the increased human demand for food and the post-war technical advancement. Due to this, old farming traditions using more extensive farming methods have been abandoned in favour of specialised farms with large input of synthetic fertilisers and pesticides. Though, agricultural intensification was resulted with an unprecedented increase in agricultural productivity, which has also been criticized for being the foremost cause behind a worldwide biodiversity decline (Kleijn *et al.*, 2009). Pesticide use and other factors (related to landscape homogenisation and fragmentation through the conversion of native and semi-natural ecosystems to agriculture) contribute the most consistent negative effects on biodiversity. Agro-biodiversity is an important aspect of biodiversity that is directly influenced by different production methods, especially at field level. It can also supply several ecosystem services to agriculture, thus reducing environmental externalities and the need for off-farm inputs. Organic farming aims at ecosystem management and it excludes inorganic fertilisers and synthetic pesticides. It can be an alternative to conventional farming, where negative consequences on biodiversity occurred in agricultural landscapes due to the replacement of several key ecosystem processes by use of mechanical and chemical practices (Stoate *et al*., 2001).

What does organic agriculture means?

Organic agriculture is a production system that sustains the health of soils, ecosystems and people. It relies on ecological processes, biodiversity and cycles adapted to local conditions, rather than the use of inputs with adverse effects. Organic agriculture combines tradition, innovation and science to benefit the shared environment and promote fair relationships and a good quality of life for all involved. The principles of organic agriculture are: 1) Principle of Health: It should sustain and enhance the health of soil, plant, animal, human and planet as one and indivisible, 2) Principle of Ecology: It should be based on living ecological systems and cycles, work with them, emulate them and help sustain them, 3) Principle of Fairness: It should build on relationships that ensure fairness with regard to the common environment and life opportunities and 4) Principle of Care: It should be managed in a precautionary and responsible manner to protect the health and well-being of current and future generations and the environment.

Impact of Organic farming on Biodiversity

The studies on effects of organic farming on biodiversity mainly based on assessment of species richness ~~[review article (e.g.~~ (Hole *et al*., 2005) and meta-analyses (~~e.g.~~ Bengtsson *et al*., 2005); Tuck *et al.* (2014)] concluded that organic farming increases the local biodiversity with on average about 30%, but that there is large variation between studies and organism groups (Table 1). This kind of variation attributed by differential responses of organisms to changes in farming practice, modifying effect of the heterogeneity of the surrounding landscape, variation in the time since conversion to organic farming and the scale at which organic farming is applies: field, farm or whole landscape. Spatial distribution of organic farming could also contribute to the variation; organic farming is often more common in extensively managed agricultural areas with a larger proportion of permanent habitats such as grasslands. Comparing biodiversity between organically and conventionally managed farmland, without considering this, would make it difficult to separate the influence of the farming practice from that of for example soil conditions or landscape structure.

Table 1. Effects of organic farming on the species richness of different organism and functional groups relative to conventional farming, with examples for case studies and additional reviews [source: from Rundlöf et al. (2016)].

	Effect*	Case studies and additional reviews
Organism group (n)		
Microbes (6)	=	Kong *et al.* (2011); Birkhofer *et al.* (2012)
Plants (62)	+	Roschewitz *et al.* (2005); Winqvist *et al.* (2011)
Arthropods (89)	+	Feber *et al.* (1997); Weibull *et al.* (2000); Birkhofer *et al.* (2015); Inclán *et al.* (2015)
Birds (17)	=	Batary *et al.* (2010); Winqvist *et al.* (2011)
Functional group (n)		
Decomposers (19)	=	Birkhofer *et al.* (2012)
Producers (plants) (62)	+	Roschewitz *et al.* (2005); Winqvist *et al.* (2011)
Herbivores (6)	=	Birkhofer *et al.* (2015)
Pollinators (21)	+	Andersson *et al.* (2013)
Predators (49)	+	Birkhofer *et al.* (2012, 2014a, 2015); Winqvist *et al.* (2011); Inclán *et al.* (2015)

*Effect direction and sample size are based on results in Tuck *et al.* (2014): +, higher species richness on organic farmland; =, no significant difference in species richness between organic and conventional farmland (i.e. when the 95% credible interval overlap 0); *n*, number of studies included in the meta-analysis.

Effect of organic farming practices

According to Hole *et al*. (2005), the impact of organic farming practices on biodiversity might be directly and/ or indirectly (Table 2). The direct effects include reduced exposure to pesticides and inorganic fertilisers (increased use of pesticides reduced the diversity of plants, carabids and birds in Europe) and indirect effects include effects of changed farming practices (the restrictions on agrochemical use, such as the use of organic manure and changed crop choice, which can result in increased local habitat diversity on organic farms).

Table 2. Farming practices characteristic of organic systems and their likely impacts on biodiversity [Source: Appendix A from Hole et al., (2005)]

Farming practice	Probable effects on biodiversity
Prohibition/ reduced use of chemical pesticides	• Organic systems rely on a variety of practices (e.g. biological control; crop rotation; mechanical weed control) to manage plant and invertebrate pests ⇨ avoids direct and indirect effects of pesticides on target and non-target organisms • *Direct effects*: herbicides ⇨ significant factor in the declines of many once common arable flowers in the UK and Europe, e.g. corn buttercup *Ranunculus arvensis*, night-flowering catchfly *Silene noctiflora* and prickly poppy *Papaver argemone*; insecticides ⇨ major negative influence on invertebrate communities, including anecic earthworms, butterflies and epigaeic arthropods • *Indirect effects*: removal of plant food resources and alteration of microclimate ⇨ negative impacts on invertebrate populations; reduction in both plant seed food resources and invertebrate abundance significant factor in the declines of a range of farmland bird species; e.g. grey partridge *Perdix perdix*, yellowhammer *Emberiza citrinella* and likely to have had a negative impact on mammals such as common shrew *Sorex araneus*, woodmouse *Apodemus sylvaticus* and badger *Meles meles*
Prohibition of mineral-based Fertilisers	• Organic systems rely on a variety of practices (e.g. animal and green manuring; traditional crop rotations including a grass-clover ley or legume crop) to enhance soil fertility ⇨ avoids detrimental impacts on biodiversity resulting from high levels of inorganic fertiliser application and consequent high stocking rates • *Effects predominantly indirect*: elevated crop growth rates ⇨ crop out-competes slower-growing arable weeds; e.g. cornflower *Centaurea cyanus*; increase in crop structural density ⇨ alters microclimate at soil level with potentially negative consequences for invertebrate fauna; limits foraging and nesting opportunities for bird species; e.g. lapwing *Vanellus vanellus*, skylark *Alauda arvensis* and yellow wagtail *Motacilla flava*
Mechanical weeding	• Involves the dragging of tines or hoes across the soil surface to remove young weeds • Often less efficient than using herbicides ⇨ contributes to a greater abundance of non-crop flora in arable fields, indirectly supporting higher densities of arthropods • Can be highly effective under certain conditions ⇨ extensive use may lead to the decline of long-lived winter annuals and support of short-lived summer annuals, potentially leading to a more impoverished weed flora • May cause high mortality amongst eggs and chicks of ground-nesting bird species, unless carefully timed
Farmyard and green manuring	• Animal waste and green manures (i.e. the ploughing in of specific unharvested crops) ⇨ used to replace nitrogen and other elements and to build up soil organic matter content • Generally supports a greater abundance of invertebrates that rely on un-degraded plant matter as a food source, e.g. earthworms, carabids, and more diverse microbial communities • Can result in insufficient input of nitrogen into organic systems ⇨ leads to poor crop and weed growth, the development of an unfavourable microclimate and a depauperate invertebrate community
Minimum tillage	• Involves the use of discs or tines to disturb the soil surface without physical turning of the soil • Avoids detrimental effects of inversion ploughing (physical destruction, dessication, depletion of food and increased exposure to predators) on invertebrate populations; e.g. earthworms; spiders; collembola and other macrofauna • May negatively impact carabids ⇨ often found in greater abundance on ploughed fields • May modify floral community ⇨ minimum tillage tends to favour annual weeds, whilst perennial broad-leaved weeds are more common under ploughed regimes, as a result of variations in seed longevity and species-specific germination patterns • Effects on vertebrates are largely unknown ⇨ some evidence that minimum tillage may benefit bird communities

Intercropping and undersowing	• Both can be used in a rotation to suppress weeds and increase crop yields • Undersowing increases vegetation structure and heterogeneity ⇨ enhances invertebrate populations; e.g. sawflies (Hymenoptera: Symphyta), carabids and spiders; provides a greater abundance of invertebrate food resources for birds and mammals, e.g. grey partridge and corn bunting • Subsequent over-winter crop stubbles may provide only limited seed accessibility to granivorous birds as a result of a reduction in the area of exposed soil • Effects of intercropping on biodiversity are largely unknown ⇨ increase in heterogeneity may favour increased invertebrate diversity; e.g. polyphagous predators
Sensitive field margin/ hedgerow management/ creation of non-crop habitats	• Actively encouraged by organic standards to bolster natural predator populations • Establishment of field margins and beetle banks ⇨ develops and supports larger, more diverse invertebrate communities; e.g. predatory beetles; provides overwintering sites and refuges following harvest; supports a more diverse arable flora; provides important nesting and feeding habitat for birds; e.g. yellowhammer, grey partridge, whitethroat *Sylvia communis* and a variety of small mammals • Positive hedgerow management ⇨ reduced herbicide spray drift (prohibited in organic systems) prevents impoverishment of hedge bottom; results in greater floral diversity and increased invertebrate populations; greater width and structural diversity is positively associated with abundance and species richness of breeding birds; provides sheltering habitat for mammals; e.g. brown hare *Lepus europaeus* • Hedgerows and other non-crop habitats provide dispersal corridors and islands in otherwise fragmented landscapes ⇨ facilitate dispersal of; e.g. many bird species, mammals and beetles • Some bird species favour shorter hedgerows; e.g. whitethroat and linnet; skylark and lapwing avoid tall boundary structures
Small field size	• Requirement for stock-proof boundaries in conventional mixed and organic systems is likely to result in smaller average field size than on specialist arable farms • Evidence suggests small fields support greater biodiversity per unit area (principally as a result of a higher percentage of non-crop habitat separating individual fields) ⇨ abundance and diversity of carabids, spiders and arable flora decreases with distance from field margins; large fields support less diverse spider communities; density of brown hares is higher on farms with smaller fields
Spring sown cereals	• Delayed development of spring-sown cereals (in comparison to autumn-sown) produces shorter, less dense crops in early and mid-season ⇨ preferred breeding and foraging habitat for a number of bird species; e.g. skylark, lapwing and corn bunting • Spring sowing frequently results in stubble fields being left over part or all of the winter ⇨ allows spring germinating annual weeds to set seed and germinate; e.g. cornflower, red hemp-nettle *Galeopsis angustifolia* and corn marigold *Chrysanthemum segetum*; provides a crucial winter food source (i.e. weed seed and spilt grain) for seed-eating birds; e.g. corn bunting, cirl bunting
Crop rotation	• Involves the planting of a sequence of crops, including a grass ley (often undersown into the previous crop) – used primarily to control weeds and other pests/diseases; also to enhance soil fertility via the inclusion of a legume (e.g. clover in the grass mix) • Presence of a grass-clover ley ⇨ significantly enhances populations of non-pest butterfly species; undersowing encourages invertebrate populations (see above) • Increased crop diversity ⇨ may benefit a variety of species that require a structurally diverse crop/ habitat mosaic; e.g. skylark (in order to make multiple breeding attempts), lapwing (require adjacent cereal and pasture), brown hare (graze a variety of crops at different times of the year)
Mixed farming	• The occurrence of arable fields in close juxtaposition with pastoral elements is likely to have significant benefits for biodiversity across a range of taxa ⇨ increases habitat heterogeneity at multiple spatial and temporal scales

(Note: these practices are not exclusive to organic farming and may be utilised within some conventional systems).

Effect of different organism groups

The different organism groups’ viz., plants, herbivores, pollinating arthropods, predaceous arthropods, birds, mammals, reptiles, amphibians and protozoa can be positively, negatively or not at all affected by organic farming (Bengtsson *et al*., 2005; Birkhofer *et al*., 2014a; Tuck *et al*., 2014). These differences are due to: difficulties in detection of effects on biodiversity by mobile organisms moving over large areas, if only a small area is organically managed; how strong organisms respond to the changes that conversion to organic farming entails (the reduction in pesticide use and crop choice); local factors (agrochemical input are probably more important for sedentary organisms such as plants); landscape factors (the amount of permanent habitat, are more important for mobile organisms). The effect of organic farming on biodiversity can also depend on which aspects of biodiversity that are considered, such as taxonomic relatedness or community or trait composition. For some organism groups viz., mammals, reptiles, amphibians and protozoa, there are very few studies about the effects of organic farming.

1. **Microbes and decomposers**: The biomass of soil bacteria and fungi can be negatively affected by conventional compared to organic farming (Kong *et al*., 2011) with explicit effects of the farming system on community composition (Birkhofer *et al*., 2012). In soil animals, it is noticeable that effects of organic farming on species richness are weak to absent compared to other functional groups (Tuck *et al*., 2014). On the basis of several studies, pot worms (Enchytraeidae) and earthworms (Lumbricidae) show less consistent responses to differences in farming practices compared to some trophic groups of nematodes. Soil arthropods (meso- and macrofauna) are also not consistently affected by organic farming, with effects that range from higher abundance and species richness to no difference or even opposite patterns under conventional farming.
2. **Plants:** Plants are the organism group that usually shows the most consistent results when comparing organic and conventional farming (Bengtsson *et al*., 2005; Hole *et al*., 2005; Tuck *et al*., 2014). The relatively strong effect of organic farming on plant diversity is primarily due to the direct negative effects of herbicides in conventional farming reducing non-crop plant diversity in fields and adjacent habitats. Organic cereal fields generally have higher plant diversity compared to conventional fields. The difference can be particularly pronounced in landscapes devoid of semi-natural habitats, while approaching similar levels between farming systems in more complex and heterogeneous landscapes. The management of fields can also influence plant diversity in adjacent habitats. Plant diversity was higher in uncultivated field borders and hedges adjacent to organically managed fields compared to adjacent to conventional fields.
3. **Herbivores:** The effect of organic farming on the diversity of herbivores is not well known (Tuck *et al*., 2014), partly because many applied studies rather focus on effects of organic farming on abundances of single pest species instead of community level analyses (Birkhofer *et al*., 2016). The few available studies suggest that local farming practices have a very variable effect on herbivore species richness and that landscape-scale intensification may be a stronger driver of herbivore diversity compared to organic farming practices. True bug communities (mainly consisting of herbivorous species) have higher species richness on organic farmland and in addition have a lower functional and taxonomic distinctness under conventional farming. The later effect suggests that reduced species numbers due to intense, conventional farming may simultaneously result in a loss of phylo-genetically and trait-wise unique species from local herbivore communities. Interestingly, even if positive effects of organic farming on herbivore diversity in crop fields are observed compared to conventional farming, the number of species will still be much lower than in adjacent semi-natural habitats.
4. **Pollinating arthropods:** Pollinators, such as bees and hoverflies, and other flower visitors, such as butterflies, have been the focus of many studies comparing diversity on organic and conventional farmland (Tuck *et al*., 2014). These organism groups generally have higher species richness on organic compared to conventional farmland. As they are all dependent on nectar and/or pollen from flowering plants, their diversity probably benefits from the higher abundance of flowering plants in and around organically managed fields. High pollinator diversity on organically managed farmland could contribute to support insect pollinated plants, both wild and cultivated. The use of insecticides to control pest insects in conventional farming can have negative effects also on non-target organisms, so the limited use of such agrochemicals in organic farming may contribute to the often-found higher pollinator diversity.
5. **Predaceous arthropods:** The main groups of arthropod generalist predators (predaceous beetles and spiders) seem to benefit from organic farming in terms of abundance (Bengtsson *et al*., 2005; Hole *et al*., 2005). Effects on the diversity of these taxonomic groups are less predictable, as predaceous species groups within this functional groups can be negatively affected by organic farming. Organic farming also alters the composition of ecological traits in generalist predator communities compared to that in the conventionally managed fields. These diversity changes in the functional composition of predator communities together with effects of organic farming on predator abundance can affect the functional role of predator communities in organically compared to conventionally managed fields. Studies on the effect of organic farming on parasitoid communities traditionally focus on parasitism rates and not on taxonomic richness or other measures of diversity. Inclán *et al.* (2015) recently documented positive effects of organic farming on tachinid parasitoid species richness across local to landscape scales.
6. **Birds:** Bird are generally positively affected by organic farming, but effects vary between studies and species, and species richness may even be higher on conventional farms. The latter results may be because organic farms were associated with habitats favouring corvids, which are important nest predators. Although attempts to determine what causes organic farming to benefit birds are few, there are indications that it is related to lower use of pesticides and higher availability of semi-natural habitat, both which may benefit food availability. Positive effects of organic farming on bird species richness are found on both arable fields and in meadows. In addition, organic farming has been found to have larger effects on bird species richness in landscape with low amounts of semi-natural habitat. Organic farming may benefit birds also in winter, at least in simplified agricultural landscapes. In general, landscape structure may be a more important determinant of bird species richness than farm management.

Effects of different landscape and/ or scale

Several studies have shown that effects of organic farming on plants and more mobile biodiversity can be landscape dependent (Roschewitz *et al*., 2005; Rundlöf and Smith, 2006). In heterogeneous landscapes, with a high proportion of uncultivated habitats such as field borders and semi-natural grasslands, similar levels of diversity can be expected on organic and conventional farmland because the complexity of the landscape and high habitat availability promote biodiversity and the local management becomes less important. In contrast, simple and homogeneous landscapes dominated by arable farming are suggested to have an intermediate species pool that responds to improved local habitat quality by management, such as organic farming. Another factor that can influence the effect of organic farming on biodiversity is how large portions of the landscape are that are managed organically. This could be because effects on mobile organisms become more detectable when organically managed habitat is more agglomerated or because of non-additive effects on populations. As a result, there can be additive biodiversity benefits of managing farmland organically beyond the single farm. However, other studies found no landscape-dependent effect of organic farming. In the meta-analysis by Tuck *et al.* (2014), the difference in diversity between organic and conventional farming increased with increasing proportion of arable land and a multi-country study concludes that the species richness benefits of organic farming increased with increasing regional nitrogen input. There is however considerable variation in the results, which is partly attributed to different responses between organism groups to local farming practices and varying land-use intensity in different landscapes.

Organic Farming and Biodiversity Conservation

The difference in local biodiversity between organic and conventional farmland is most pronounced in simple and intensively farmed landscapes, the biodiversity gain would be largest if farms in such areas would convert to organic farming. However, as this landscape dependency cannot be generalised over organism groups and the knowledge of how organic farming influence rare and threatened species (are predominantly occurring in heterogeneous landscapes) is insufficient. So, the optimal location of organic farming to support biodiversity needs further investigation. Although the overall effect of organic farming on biodiversity appears to be positive (Tuck *et al*., 2014), there is some uncertainty if this positive influence on local biodiversity can contribute to higher regional diversity. This pattern could be expected if organic farming had a stronger influence on common species compared to more rare species. However, there are studies that indicate organic farming can contribute to larger diversity also at regional scales. Biodiversity conservation is not always an candid goal of organic farming and the design and implementation of this farming practice is not optimised for such purpose. Using the ecological requirement of the organisms in focus as starting points when designing the rules governing organic farming, its effect on biodiversity would most likely be enhanced. There is an ongoing debate on the optimal way to conserve biodiversity and at the same time increase agricultural production (Fischer *et al*., 2014).

Although organic farming has an overall positive effect on biodiversity (Tuck *et al*., 2014), the increased land area needed to compensate for the lower yields in organic farming (Ponisio *et al*., 2015) leaves less land that could be used for biodiversity conservation. Because of the lower yields and a suggested higher diversity per unit production under conventional farming, it has been argued that there may be no overall benefit of organic farming (Hodgson *et al*., 2010). This approach to standardise biodiversity by yield that is for example commonly used in comparing emissions of greenhouse gases between organic and conventional farming however suffers from major logical flaws for diversity. In contrast to CO_2 levels, species richness is not measured on a simple additive scale where all units are easily exchangeable because each species is a unique entity. In Europe, there are for example many rare species that depend on extensively managed farmland and thus are directly supported by low-intensity agriculture such as organic farming.

Areas of Future Research

Though evidences available for overall positive effect of organic farming on biodiversity over conventional farming (Tuck *et al*., 2014), there are several knowledge gaps also exist for future studies. They are:

- Quantification of the total biodiversity benefits including in-field and field boundary benefits
- Assessment of biodiversity benefits in different parts of the country [using before-after control impact (BACI) design] rather than conventional farming region [using paired farms design]
- Assessment of biodiversity benefits in soil and uplands
- Impact organic farming on aquatic ecosystems
- The evolution of biodiversity levels on organic farms over time
- Organic farming and management requirements of designated conservation areas
- The state and importance of agricultural genetic diversity
- The impact organic farming on genetic and ecosystem variation part of biodiversity
- The clear understanding on how organic farming influences ecosystem services for higher biodiversity on organic farmland through pollinators etc.
- The effect of different factors related to the surrounding landscape (heterogeneity and land-use intensity) on organic farmland

Indian perspectives

India is one among the 16 mega-diversity and one of the eight centres of origin of crop plants having 2.4% of the world's land with 7-8% of the world's plant and animal wealth. India is having 165 food crop species and 320 wild relatives of crops originated from here. India consists of 18,000 species of higher plants; 1,500 wild edible plant species; nearly 9,500 ethno-botanical species and 3,900 multipurpose/ edible species.

Only 20-30% nutrient needs of Indian agriculture can be met by utilizing various organic sources available in the country. To meet out food security and also to sustain the soil quality and higher productivity, India should rationalize the utilization of inorganic fertilizers along with organic ones. So, it should not be confined to age old practice of use of cattle dung and other organic inputs, but also concentrate on use of soil and crop management practices that enhance population and efficiency of below ground soil biodiversity to improve nutrient availability. Further, cultural weed control, use of bio-pesticides, bio-control agents and other sources to be utilized to conserve the biodiversity existing in and around of agricultural field in India.

Andaman and Nicobar Islands

Andaman and Nicobar Islands are having high level of endemism, which include 10% and 9% of total flora and fauna of islands. The plant diversity of Andaman and Nicobar Islands comprises 3219 species under 1251 genera and 299 families belonging to angiosperms, gymnosperms, pteridophytes, bryophytes, lichens and algae as (2428; 980; 178), (8; 4; 3), (142; 62; 38), (76; 37; 18), (383; 84; 30) and (182; 84; 32), respectively. About 10% of total flora of islands belongs to endemism, which comprises of 315 species under 187 genera and 74 families including four endemic genera. As per recent red list (IUCN, 2011), around 112 species under 74 genera and 38 families categorised under threatened species, which include dicot (78; 47; 28) and monocot (32; 25; 8). In case of fauna, endemic taxa include birds (40%), mammals (60%) and butterfly (50%). In terms of protection and maintenance, endemics are considered as a hallmark of local biodiversity.

Indiscriminate uses of pesticides under modern agriculture pose severe threat to existing biodiversity, especially endemism. Moreover, endemism is commonly regarded as an important criterion for the conservation priority of the particular area, one considered as more useful than species richness. Since organic agriculture is advocated for the islands owing to sensitivity of terrestrial and marine biodiversity to harmful pesticides, there is still a greater role of harnessing agriculturally important indigenous bioresources for achieving sustainable food and nutritional security (Roy et al., 2015).

Conclusions

Different studies and meta-analyses on effect of organic farming on biodiversity suggested the overall positive effect of organic farming over conventional farming on basis of species richness over all organism groups. The effect of organic farming differs between organism groups, with positive influence on plants and pollinators and possibly also predators and birds, but less influence on microbes, herbivores and decomposers and insufficient knowledge about for example mammals and amphibians. In fact, most organism groups apart from plants, arthropods and birds appear to be understudied in relation to effects of organic farming and conclusions apply to common rather than rare species. Most of the studies are predominantly conducted as 'paired farm' design rather than BACI design. These formal experiments of BACI design could help to disentangle some of the inconclusive results in the literature. It is, however, logistically and financially very challenging to conduct experiments at a landscape scale, which is often needed for mobile organisms. The most of the studies on organic farming and biodiversity conducted on Western and Northern Europe and North America, hence, the outcomes drawn here are applicable to these regions only. So, the knowledge about the effects of organic farming on biodiversity elsewhere in the world is limited due to only few studies were available.

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Organic farming for sustainable agricultural development

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Introduction

Currently, 43.7 m ha area (0.99% of total agricultural land) is under organic agricultural management worldwide (FiBL and IFOAM, 2016) and India's rank is no. 1 in terms of no. of organic producers *i.e.*, 585,000 (FIBL and IFOAM, 2017). The total area under organic certification in India is 5.71 million hectare during 2015-16. This includes 26% cultivable area with 1.49 million hectare and rest 74% (4.22 million hectare) forest and wild area for collection of minor forest produces. India produced around 1.35 million MT (2015-16) of certified organic products which includes all varieties of food products namely sugarcane, oil seeds, cereals and millets, cotton, pulses, medicinal plants, tea, fruits, spices, dry fruits, vegetables, coffee *etc*. The production is not limited to the edible sector but also produces organic cotton fiber, functional food products *etc*. Among all the states, Madhya Pradesh has covered largest area under organic certification followed by Himachal Pradesh and Rajasthan. The total volume of export during 2015-16 was 263687 MT. The organic food export realization was around 298 million USD. Organic products are exported to European Union, US, Canada, Switzerland, Korea, Australia, New Zealand, South East Asian countries, Middle East, South Africa *etc*. Oil seeds (50%) lead among the products exported followed by processed food products (25%), cereals and millets (17%), tea (2%), pulses (2%), Spices (1%), dry fruits (1%), and others (*Source*: www.apeda.gov.in). Globally organic produce market is increasing which is around €75 billion (FIBL and IFOAM, 2017). However, Organic farming can be sustainable only if the developed organic production technologies are accessible to all the farmers and have a long-term economic viability. All the agriculture, horticulture and livestock components are inter-linked and work as integral components of integrated organic farming system to address the livelihood concerns. Organic farming system that aims to optimize the income and employment potential of the small farmers through concurrent attention to crop and animal husbandry and post-harvest technologies, needs to be fostered more widely. Organic farming benefits the society substantially by reducing pollution and conserving energy, soil nutrients, fish, wildlife and insuring the supply of food for the future generations.

Sustainable agriculture

Sustainability is concerning ecosystem integrity, social well-being, economic resilience, and good governance. According to the current level of knowledge and development, what is the contribution of organic agriculture to each of these sustainability dimensions?. Sustainability has first been equated with environmental soundness in order to ensure the continued provision of goods and services to present and future generations. Organic agriculture, as defined by the Codex Alimentarius Commission, "is a holistic production management system that avoids use of synthetic fertilizers, pesticides and genetically-modified organisms, minimizes pollution of air, soil and water, and optimizes the health and productivity of interdependent communities of plants, animals and people."

Sustainable agriculture refers to an agricultural production and distribution system that:

- Achieves the integration of natural biological cycles and controls
- Protects and renews soil fertility and the natural resource base
- Reduces the use of nonrenewable resources and external or off-farm production inputs
- Optimizes the management and use of on- farm inputs
- Provides on adequate and dependable farm income
- Promotes opportunity in family farming and farm communities,
- Minimizes adverse impacts on health, safety, wildlife, water quality and the environment.

Goals of sustainable agriculture

A sustainable agriculture, therefore, is any system of food or fiber production that systematically pursues the following goals:

- A more thorough incorporation of natural processes such as nutrient cycling nitrogen fixation and pest-predator relationships into agricultural production processes.
- A reduction in the use of those off-farm, external and nonrenewable inputs with the greatest potential to damage the environment or harm the health of farmers and consumers, and more targeted use of the remaining inputs used with a view tominimizing variable costs.
- The full participation of farmers and rural people in all processes of problem analysis and technology development, adoption and extension.
- A more equitable access to predictive resources and opportunities, and progress towards more socially just forms of Agriculture.

- A greater productive use of the biological and genetic potential of plant and animal species.
- A greater productive use of local knowledge and practices, including innovation in approaches not yet fully understood by scientists or widely adopted by farmers.
- An increase in self-reliance among farmers and rural people.
- An improvement in the match between cropping patterns and the productive potential and environmental constraints of climate and landscape to ensure long-term sustainability of current production levels.
- Profitable and efficient production with an emphasis on integrated form management: and the conservation of soil, water, energy and biological resources.

Organic farming and sustainability

Organic management is associated with several positive impacts on land and water, including: increased soil fertility and thus, enhanced productivity; better soil structure that increases stability to environmental stress; better soil moisture retention and drainage, which result in 20 to 60% less irrigation requirements; less water pollution and nitrate leaching in groundwater; reduced erosion by wind, water, and overgrazing (currently, 10 million hectares of land is lost annually by unsustainable agricultural practices); and better soil carbon sequestration rates. A new meta-analysis indicates that soil organic carbon stocks were 3.5 metric tons per hectare higher in organic than in non-organic farming systems and that organic farming systems sequestered up to 450 kg more atmospheric carbon per hectare and year through CO bound into soil organic matter. Organic farming appears to generate 30% more employment in rural areas and labor achieves higher returns per unit of labor input. By using local resources better, organic agriculture offers dual benefits: it facilitates small holder's access to markets and thus income generation; and relocalizes food production in market-marginalized areas, especially where the hungry and the poor reside. The economic performance of organic systems depends on previous intensity of conventional management; organic farmers' managerial background and skills; and the suitability of used varieties and breeds to lowinput systems. Generally, organic yields are 20% less as compared to high-input systems in developed countries but could be up to 180% higher as compared to low-input systems in arid/semi-arid areas. In humid areas, rice paddy yields are equal, while the productivity of the main crop is reduced for perennials, though agroforestry provides additional goods. Farm profitability depends on: market opportunities and input/output prices; governmental support to agricultural policy; and mostly, farmer's management abilities. Variable organic production costs are significantly lower than conventional production, ranging from 50-60% for cereals and legumes, to 20-25% for dairy cows and 10-20% for horticulture products; this is due to lower input costs on synthetic inputs, lower irrigation costs, and labor cash costs that include both family labor and hired workers. Total costs are, however, only slightly lower than conventional, as fixed costs increase due to new investments during conversion (*e.g.*, new orchards, animal houses) and certification.

Technologies for sustainable organic farming cover the whole spectrum of farming systems. All farming systems, from natural farming to organic farming, have the potential to be locally sustainable. Whether they are in practice depends on farmers adopting the appropriate technology and management practices in the specific ago-ecological environment within the right policy framework. There is no unique system that can be identified as sustainable and no single path to sustainability. However, organic farming and agroforestry is holistic production management system which promotes and enhances agro-ecosystem health, including biodiversity, biological cycles, and soil biological activity. Agroforestry has the potential to improve livelihood as it offers multiple alternatives and opportunities to farmers to improve farm production and incomes and also provide productive and protective forest functions to the ecosystems while protecting the natural environment across the globe. The multi-purpose trees in agroforestry systems play a major role in organic agriculture production by supporting food production through increasing the soil's ability to support organic agriculture. A large number of forest and fruit producing trees are integral parts of traditional homestead and other agroforestry farming systems. In hills for sustainable development of agroforestry systems, the maintenance of traditional agroforestry systems and creation of new systems is required by designing context-specific silvicultural and farming systems to optimize food production, carbon sequestration and biodiversity conservation. Agroforestry systems are believed to have a higher potential for carbon sequestration than pastures or field crops. In addition to sequestering C in biomass and soil, these systems can contribute to both carbon conservation and carbon substitution. The multi-purpose trees in agroforestry systems play a major role in organic agriculture production in two ways: directly by providing edible products such as fruits, nuts, rhizomes, leaves, and tubers; and indirectly by supporting food production through increasing the soil's ability to support agriculture. A large number of fruit-producing trees are integral parts of traditional homestead and other agroforestry farming systems. Some underexploited species in agroforestry systems are of immense cultural and economic values *viz*., medicinal plants. Some well-known agroforestry tree species grown on farms for uses such as fodder, food, fiber or fuelwood, are also used for their medicinal values. The total area under agroforestry in the world is estimated as 1023 million ha (Nair *et al.,* 2009). Currently, Forest Survey of India reported 1,11,554 km^2 (3.39 per cent of country geographical area) area under agroforestry (FSI, 2014). Agroforestry is promoted widely as a sustainability-enhancing practice that combines the best attributes of forestry and agriculture.

The nutrient and pest management system in organic production is most important factor for sustainability and livelihood security; therefore, the available pest management techniques should be followed on community basis for its proper effectiveness. Livestock is an integral part of agriculture and has profound influence on its sustainability. Apart from providing additional income, livestock generates employment in the rural area itself. Livestock contributes directly to agriculture by producing manure and influencing the availability of organic carbon to soil. It contributes indirectly through its influence on income of the households. Integration of livestock and crop production, or mixed farming, allows the use of animal manure to increase soil fertility. Agricultural productivity can be improved by better integrated crop and livestock systems, recycling crop residues, and the careful use of other available nutrients. The intensified cropping systems alongwith livestock components shall make better and more secure use of available land, water, labor, and other resources, thus reducing the risk of low returns from agriculture. In addition diversification can provide, through high-value agri-horti crops with livestock, opportunities to diversify and strengthen diets as well as improve livelihood security. Therefore, integrated development of organic agriculture is essential for food security and socio-economic development of the country.

The domestic market for organics is undeveloped in India. Lack of domestic marketing channels adds to the difficulties faced by the farmers converting to organic farming system. Market access for small producers depends on (a) understanding the markets, (b) organization of the firm or operations, (c) communication and transport links, and (d) an appropriate policy, environment. In this changing scenario, small farmers mainly need better access to capital and education. Further, collective action to deal with scale requirements needs to be designed in order to satisfy organic product demand and processing standards. Collective action through cooperatives or associations is important to be able to buy and sell at a better price and also to help small farmers in adapting new patterns and facing much greater levels of competition. Small farmers require professional training in marketing as well as in the technical aspects of production. There is also a need to strengthen small farmer organizations and provide them with technical assistance to increase productivity for the cost-competitive market and to provide help in improving the quality of produce in order to capture value addition in the supply chain. Efforts will also be needed to strengthen existing farmers' groups and form specialized groups of organic growers. These groups and co-operatives could function as the major player in the market place. Support will also be needed to strengthen links between farmers' groups and processing units. To strengthen market linkages, assistance is needed to organize organic growers into groups/co-operatives so that they can assure a bulk supply of the required grade of organic produce to exporters.

Growth in organic food sales is highly dependent on the ability of the consistent supply of diverse food products in the market. The steps needed for promoting organic farming include cost support or premium (but not in cash), certification or conversion support or subsidy for continuing with organic production. Promotion of market mechanisms and adoption of market oriented programs which are more sustainable. Targeting institutional market *i.e.* hotels, hospitals, airlines and railways, to begin with, is an important strategy for promotion of market for the organic produce in the domestic market. NGOs can also be roped in for market creation.

There is need to establish incentives/penalties system for better/poor quality of organic produce meant for, export in particular, and domestic market in general. Adoption of HACCP and better quality monitoring systems is another much needed step in this effort. Incentives for quality at producer/society/group level for meeting organic standards need to be created. Better vertical co-ordination mechanisms like contract farming, co-operative-corporate alignment is the need of the hour to achieve competitiveness in organic produce markets. In the times of competitive international trade, the processing and marketing links in the supply chain, especially super markets, can play an important role as they will increasingly convey and fashion the changes needed in the supply chains due to their own selfish interest in organics in terms of ethical trade image, differentiation from competitors, new market segments, and attracting consumer loyalty. The farmers should look at organic farming and trade as an opportunity which is in accordance with the larger developmental goal of sustainability.

Carbon farming for organic sustainability

India is a vast country covering 3.28 million km^2, occupying only 2.4 per cent of the world's geographical area but supporting 16.2 per cent of the global human population. It is endowed with varied climate supporting rich biodiversity and highly diverse ecology. More than sixty percent of its population is dependent on climate sensitive activities such as agriculture. Agricultural impacts due to climate change have received considerable attention in India as they are closely linked to the food security and poverty status of a vast majority of population. Carbon farming is a very new concept which describes a collection of eco-friendly farming techniques that has ability to increase soil organic carbon in agricultural land. Carbon farming that leads to reduction in greenhouse gas emissions is referred to as *abatement* activities. It is simply a way of farming that holds carbon in vegetation and soils, and reduces greenhouse gas emissions or captures. It ranges from a single change in land management, such as introducing zero tillage cultivation or management of grazing, agroforestry, methane-reducing feed supplements or stubble retention to integrated plan in farm which maximizes capture of carbon and reduction of emissions. If soil tillage practices releases CO_2 into the atmosphere, zero tillage in soil stops CO_2 emission into atmosphere. In fact, zero tillage starts to build up soil carbon content and this is called carbon farming. In carbon farming, the amounts of CO_2, CH_4, and N_2O will be reduced with an increasing the C sinks in soil as because of increased soil aeration from organic carbon addition into soil which reduces denitrification and increases sink capacity for CH_4. Carbon farming induces microbial immobilization of available N_2 in soil, which decrease N_2O source capacity of soil. Soil organic carbon increases cation exchange capacity; improves water retention capacity; stimulates soil microbial activity; reduces N_2O emissions significantly.

In carbon farming, there are some promising options that reduces greenhouse gas emissions in agriculture like; storage of carbon in soils and degraded rangelands, through carbon sequestration in forests tree plantings and regrowth, carbon storage through production and incorporation of biochar, substitution of biofuels for fossil fuels, decrease in CH_4 emissions from livestock. Carbon farming not only reduce the levels of CO_2 being released into the atmosphere, but also results in an improvement in farm efficiencies and profitability. Farms can be transformed from sources of carbon to carbon sinks by using right eco-friendly management practices. Improvement in cropping system, tillage, adding organic materials and pasture management are proven practices that can be incorporated into existing farming systems to increase soil organic carbon. Practices that enhance productivity and returns plant residues, such as shoots and roots to the soil, increases soil organic carbon. Its benefit includes greenhouse gas reduction, carbon sequestration, increased soil fertility, healthier soils, vegetation and animals, increased biodiversity, buffering against drought and greater water efficiency.

Sustainable nutrient management in organic production system

Sustainable input management in organic production system refers to the maintenance of soil fertility and plant nutrient supply at an optimum level for sustaining the desired productivity through optimization of the benefits from all possible sources of organic and biological components except inorganic in an integrated manner. It involves proper combination of chemical fertilizers, organic manure, crop residues, N_2~fixing crops (like pulses such as rice bean, Black gram, other pulses and oilseeds such as soybean and biofertilizers suitable to the system of land use and ecological, social and economic conditions. Organic rice production involves recycling of crops residues, crop rotation, inclusion of legumes in system both in sequence or as an intercrop, green manuring, off-farm waste recycling, use of mineral rocks like rock phosphate, mechanical cultivation, biological pest control and avoid use of synthetic agrochemicals with overall objective of sustainable production, maintaining resources and environmental quality. Weed control, soil fertility and management of pest and diseases are the principal challenges associated with organic production. Relevant/appropriate measures should be taken to ameliorate acid soil. Clearing of primary forest not permitted and burning of organic matters to clear land to the minimum level. Across the slope cultivation should be practiced. The major challenge in Organic Agriculture is the availability of huge quantities of organic inputs for satisfying the farm demand. At present, most optimistic estimates show that about 25–30 percent of nutrient needs of Indian agriculture can be met by various organic sources. Use of animal excreta based manure alone is not sufficient for meeting the nutrient needs of the crops. It is therefore, necessary to utilize all the sources available on and off farm effectively. The resource components available for nutrient management in organic farming are: farmyard manure, crop residue, weed biomass, green manures, biofertilizers, composts / phospho-compost, vermicomposting, oil cakes, mulching / cover crop, liquid manures, biodynamic preparation, botanicals, legumes in cropping sequence, crop rotation / intercropping / sequential cropping, hedge row / alley cropping, indigenous nutrient solution, conservation tillage, by-product from integrated farming systems, industrial / agricultural / household waste and certified commercial products. These organic sources besides supplying N, P, and K also make unavailable sources of elemental nitrogen, bound phosphates, micronutrients, and decomposed plant residues into an available form to facilitate the plants to absorb the nutrients. The farmers can in turn, get good remuneration from organically produced crops and if included in high value crop rotations, that is, aromatic rice due to their heavy demands in domestic, national, and international markets.

Major nutrient content of different organic input (Avasthe *et al*., 2015)

Sources	Nitrogen (%)	Phosphorus (%)	Potassium (%)
FYM	0.93	0.36	0.92
Vermicompost	2.0	1.0	2.0
Pig manure	1.19	0.38	0.98
Poultry manure	1.82	0.51	2.10
Cattle urine	1.2	-	1.2
Crotolaria juncea	3.5	0.33	2.38
Tephrosia purpurea	3.11	0.23	1.24
Eupatorium odoratum	2.38	0.07	2.84
Ambrossia artimisifolia	3.19	0.22	4.38
Rape seed cake	4.8	2.0	1.3
Neem cake	5.2	1.1	1.5

Positive impact of organic management

Organic management is associated with various positive impacts on land and water, including: higher soil fertility and thus, increased productivity; improved soil structure that increases stability to environmental stress; higher soil moisture retention and better drainage, which result in 20 to 60% reduced irrigation requirements; lower water pollution and nitrate leaching in groundwater; reduced erosion by wind, water, and overgrazing (currently, 10 million hectares of land is lost annually by unsustainable agricultural practices); and enhanced soil carbon sequestration rates. New meta-analysis indicates that soil organic carbon stocks are 3.5 metric tons per hectare higher in organic than in non-organic farming systems and that organic farming systems sequesters up to 450 kg more atmospheric carbon per hectare and year through CO_2 bound into soil organic matter.

Diversification through organic farming

In organic agriculture, limiting external inputs entails adaptation to local conditions towards harnessing ecosystem services and augment production efficiency. In order to achieve this, the main organic strategies include: rotations, diversification and integration of crop, livestock, tree, and fish to the extent possible in order to enhance nutrient cycling; use of local varieties and breeds to increase the system resilience to stress; use of biological pest control to boost predators; and promote symbiotic nitrogen fixation and biomass recycling.

With respect to climate change adaptation, organic management includes preventive and precautionary approach through diversification, generally adopted as a risk splitting strategy. In fact, diversified farms undergo natural stages of succession that best adjust the agro-ecosystem to change. Rotational grazing and organic pasture management have massive prospects in mitigating climate change. Spatial and temporal integration on organic farms (*e.g*., agroforesty, hedges, rotations, corralling) represent eco-functional features favorable to climate-proofing of agroecosystems.

Higher returns from organic farming

Farm profitability builds on: market opportunities and input/output prices; governmental support to agricultural policy; and principally, farmer's management abilities. Variable organic production costs are significantly lower than conventional production, ranging from 50-60% for cereals and legumes, to 20-25% for dairy cows and 10-20% for horticulture products; this can be related to lesser input costs on synthetic inputs, reduced irrigation costs, and labor cash costs that include both family labor and hired workers. Total costs are, however, only slightly less than conventional, as fixed costs increase due to new investments during conversion (*e.g*., new orchards, animal houses) and certification.

Reduction in production costs on organic farms in alliance with price premiums usually reimburse for reduced yields and net returns are comparable with or higher than conventional systems in both developed and developing countries. Even in the absence of premiums, organic systems are likely to be more economically profitable and, with economy of scale, premiums are less needed since post-harvest and certification costs may decrease with greater quantities of production and productivity.

Community participation for organic sustainability

Engaging in organic production means experimenting new techniques, introducing different management of labour time, investing efforts in different management of space, adapting and refining solutions to change, comparing different options with farmers that have similar conditions, and making appropriate choices. This can only be achieved through farmers' participation in research and its application. This on-farm research component can support rural communities, and generate new knowledge that will benefit all farmers. Consistent labour needs, combined with the enhanced capacity of the land and protection of water associated with organic agriculture, may encourage people to permanently locate and thus reinvigorate rural communities. Establishment of cooperation between farmers is instrumental in helping farmers to become stronger and more independent partner in the agro-business environment. In addition, providing a critical mass for renewed rural community structures sets an end to the isolation of farmers, thus increasing the viability of rural life. Most importantly, various forms of cooperation within food chain are necessary to overcome the gap between farmers and consumers.

Issues in organic farming

- Maintain organic production potential in a long-run equilibrium with nutrient and carbon budgeting.
- Sustain organic crop production under the changing climatic conditions and increased competition for land, labour, water and energy for other economic uses.
- Develop efficient and cost effective organic seed and planting material supply chain to augment productivity.
- Develop the cost effective organic crop production technologies.
- Lack of suitable cultivars for organic crops in high rainfall areas with low sunshine hours.
- Ignorance of right stage of harvesting and value addition, which results in low price for the organic produce. Lack of maturity indices for organic production.
- Lack of irrigation water during winter months and modern scientific irrigation methods.
- Inadequate attention towards value chain management to prevent losses and to ensure supply during odd periods.
- Poor knowledge / infrastructure and linkage for packaging, grading, storage, transportation and marketing *etc*.
- Creation of value chain infrastructure like pre-cooling units, cold stores, refrigerated transportation system, packinghouses, modernized market places.
- Establish market information system for intelligent marketing of truthfully labeled produce to fetch better price.

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Greenhouse Gases (GHGs) Emissions in Organic Farming *vis-a-vis* Inorganic Farming

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Carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) are important greenhouse gases (GHGs) associated to agriculture contributing 60, 15 and 5%, respectively, towards the enhanced global warming (IPCC, 2014). Methane is 28 times and nitrous oxide is 265 times more effective than CO_2 as a heat-trapping gas (Table 1). Wetlands, organic decay, termites, natural gas and oil extraction, biomass burning, rice cultivation, cattle and landfills are the main sources of methane, whereas, removal in the stratosphere and soil are the main sinks. Primary sources of methane from agriculture include animal digestive processes, rice cultivation, and manure storage and handling. Forests, grasslands, oceans, soils, nitrogenous fertilizers, burning of biomass and fossil fuels are the sources of nitrous oxide while it is removed by oxidation in the stratosphere. Soil contributes about 65% of the total nitrous oxide emission. The major sources are soil cultivation, fertilizer and manure application, and burning organic material and fossil fuels. The main sources of carbon dioxide are decay of organic matter, forest fire, volcanoes, burning of fossil fuel, deforestation and land-use change whereas plants, oceans and atmospheric reactions are the major sinks. Though agricultural soil is a small contributor, factors such as soil texture, temperature, moisture, pH, available C and N contents influence CO_2 emission from soil.

Table 1 Lifetime, global warming potential (GWP) and Global Temperature change Potential (GTP) compares components based on radiative forcing, integrated up to a chosen time horizon.

		GWP		GTP	
	Lifetime (yr)	Cumulative forcing over 20 years	Cumulative forcing over 100 years	Temperature change after 20 years	Temperature change after 100 years
CO_2	-	1	1	1	1
CH_4	12.4	84	28	67	4
N_2O	121.0	264	265	277	234
CF_4	50,000.0	4880	6630	5270	8040
HFC-152a	1.5	506	138	174	19

Source: IPCC (2014)

GHGs emission and climate change scenario

Agriculture, Forestry and Other Land Uses

In recent IPCC assessment report (AR5), the GHGs emissions from agriculture, forestry and other land use (AFOLU) sector are represented cumulatively. As a whole, this sector contributes 10-12 Gt CO_2 eq yr^{-1} of GHGs emission mainly due to deforestation and agricultural emission from livestock, soil and nutrient management. It accounts for approximately one fourth of total anthropogenic GHGs emission in world. Specifically, annual GHGs emissions from agriculture in 2000-2010 were around 5.0-5.8 Gt CO_2 eq yr^{-1}. On the other hand land use and land-use change activities accounted for around 4.3-4.5 Gt CO_2 eq yr^{-1} at the same time scale. Global trends in total GHGs emission in this sector in last decades showed (Figure 1), maximum contribution from forestry and land-use charges followed by draining of peat soils. In agriculture, enteric fermentation of animals contributed as much as 18-27%. In contrast, rice cultivation and synthetic fertilizer contributed only 4-6 and 3-4%, respectively. Overall scenario reveals that average GHGs emissions reduced considerably during 2000-2009 as compared to 1990-1999. In part, this is driven by technological intervention as well as declining rates of agricultural area expansion, which in turn is related to the slowing down the population growth (IPCC, 2014).

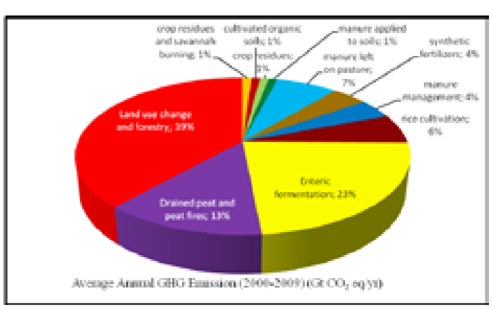

Figure 1. Average annual GHG emission

Agriculture

According to IPCC (2014), agriculture is included in broad sector of "Agriculture, Forest and Other Land Uses (AFOLU)". In 2010, world agricultural land occupied 4889 million ha, an increase of 7 % (311 million ha) since 1970 (FAOSTAT, 2013). Agricultural land area has decreased by 53 million ha since 2000 due to a decline of the cropland area and a decrease in permanent meadows and pastures. The average amount of cropland and pasture land per capita in 1970 was 0.4 and 0.8 ha and by 2010 this had decreased to 0.2 and 0.5 ha per capita, respectively (FAOSTAT, 2013). The three greenhouse gases (GHGs) associated with agriculture are CO_2, CH_4 and N_2O. Other important GHGs include water vapour and many halocarbon compounds, but their emissions are not considered to be influenced by agriculture. Being the largest anthropogenic impact on the earth in terms of the land area occupied, agriculture also contributes maximally to the greenhouse gas (GHG) emissions (Foley et al., 2011; Massé et al, 2011). The agricultural sector collectively contributes approximately 20% of the GHG emissions, e.g., CO_2 through decomposition in soil organic carbon (SOC), CH_4 from flooded rice paddy fields and cattle enteric fermentation, and N_2O through fertilizer application (IPCC, 2001). Global budgeting of the GHG exchanges between different ecosystems and the atmosphere is considered as one of the key issues of climate change research. There is a need to monitor and quantify GHG exchanges in the various ecosystems prevalent in the world and its effect of agriculture and livelihood security. There has been a drastic increase in the atmospheric concentration of GHGs, viz. CO_2, CH_4, N_2O, etc. since the industrial revolution because of fossil-fuel combustion, land-use change, deforestation and intensification of agriculture. Global emissions of GHGs from agriculture increased annually by 1.6% yr^{-1} from 1961 to 2010. The sector emits about 3.3 Gt of CH_4, 2.8 Gt of N_2O and 0.04 Gt of CO_2 in terms of CO_2 equivalent annually (in 2010; IPCC, 2014). Over half of the global N_2O and CH_4 emissions come from agriculture (Figure 2).

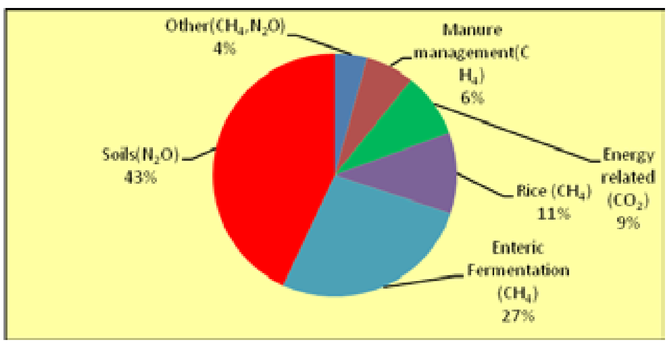

Figure 2. GHGs emissions from different components of Agriculture

Techniques of Greenhouse Gases Measurement

(i) **Manual Closed chamber method**

In this method, gas emissions (fluxes) from soil and or soil-plant systems are determined by collecting them in sealed enclosure placed over the soil surface. The gas collection chambers could be open or closed. This restricts the volume of air exchange across the covered surface. Any net emission or fluxes from soils or soil-plant systems can be measured as a change in concentration of the gas through gas chromatography.

(ii) **Infra-red gas analyzer method**

Infra-red gas analyzer (IRGA)-based field measurement is the most widely used technique for assessing soil respiration rates. The method estimates the increase of CO_2 concentration in enclosed chamber over a specified time. Different IRGA-based measurements of soil respiration or soil CO_2 efflux depends on differences in IRGA, chamber design, measurement parameters and CO_2-flux algorithms. These effects are also dependent on soil type and vegetation in which the measurements are being undertaken.

(iii) **Photo acoustic spectroscopy**

Photo acoustic spectroscopy is the measurement of the effect of absorbed electromagnetic energy (particularly of light) on matter by means of acoustic detection. Photo acoustic spectroscopy has been consolidated as an effective option for trace gases analysis (detection limits in the range of sub-ppbv and ppbv). It has good selectivity and possibility of *in situ* measurements as continuous flow systems helps in non-destructive analysis which makes photo acoustic to be a powerful analytical tool for gases monitoring.

(iii) **Micrometeorology**

This method measures GHGs fluxes in agriculture by employing eddies correlation. It is useful for real time precise estimation of gases and could be effectively used in evaluating regional model simulations (scaling from site to region). However, it requires relatively expensive equipments.

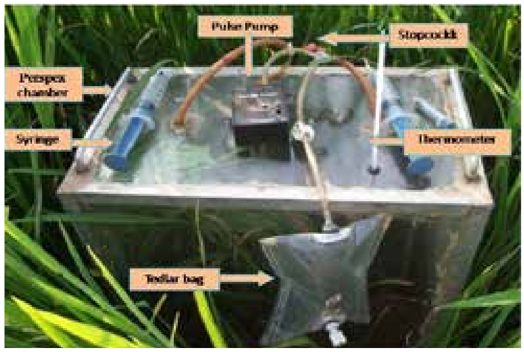

Figure 3 Schematic diagram of closse chamber fitted with pump for air circulation

The GHGs sampling from the field by closed chamber methods is presented in Figure 3. The analysis of collected gases from the chambers subjected to analysis by gas chromatography (GC). Analysis procedures are described in subsequent sections.

Analysis of GHGs

Methane

Concentration of methane in the gas samples is analyzed by Gas Chromatograph (GC) fitted with a flame ionization detector (FID). The FID is used for detection of substances, which produce ions when heated in an H_2-air flame. Gas samples containing methane are introduced into the gas chromatograph by a syringe fitted with a three-way nylon stopcock through a gas sampling valve in the injection port. A gas sample loop of 1 or 2 cm^3 is fitted to the sample valve to inject same volume of gas from each sample. Methane analysis can be accomplished by various modifications of GC settings and column materials. The various parameters of GC have to be optimized empirically in order to achieve a satisfactory separation and detection. Methane can be separated from other gaseous components on a Porapak N or Porapak Q column (3-m-long stainless steel or nickel with 3.175-mm outside diameter) with column temperature maintained at 70°C and carrier gas flow (helium, nitrogen or argon) of 20-30 $cm^3 \, min^{-1}$. Methane is detected using a FID maintained at 250°C. Hydrogen (H_2) with a flow rate of 30-40 ml min^{-1} is used for FID. The sampling valve can be accentuated manually, pneumatically or electronically using computer software or GC- microprocessor. A GC-software is used to plot and measure the peak area. The pure CH_4 gas of concentrations 1, 2, 5 and 10 ppm could be used as a primary standard.

Calculation of methane flux

$$CH_4\ flux = \frac{(\Delta X \times EBV_{(STP)} \times 16 \times 10^3 \times 60)}{(10^6 \times 22400 \times T \times A)}$$ ------- *Eq. no. 1*

Where, ΔX = Difference in flux value between 30/15 min and 0 min (converted to ppm based on the standard CH_4), $EBV_{(STP)}$ = Effective box volume at standard temperature and pressure, T = Flux time in min (15 or 30), A = Crop (e.g rice) area occupied by the box in m^2 (length × breadth).

The $EBV_{(STP)}$ was calculated using the following equation:

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$ ------- *Eq. no. .2*

Where, P_1 = Barometric pressure at the time of sampling in mm Hg, V_1 = EBV (Effective box volume), T_1 = 273^0K + temperature inside the box at the time of sampling in ^{0}C, P_2 = Standard barometric pressure (760) in mm Hg, V_2 = $EBV_{(STP)}$, T_2 = 273^0K

The Effective box volume (EBV) is calculated using the following equation:

$$EBV = Box\ [(H - h) \times L \times B] - V$$ ------- *Eq. no. .3*

Where, H = Box height (cm), h = Height of the water level in the groove of aluminium channel (cm), L = Box length (cm), B = Box breadth (cm), V = Crop (e.g. rice) biomass volume (mL) inside the box (above ground biomass only).

Nitrous oxide

Concentration of nitrous oxide in the gas samples could be analyzed by Gas Chromatograph fitted with an electron capture detector (ECD) and a Porapak Q column (6 feet long, 1/8 inch outer diameter, 80/100 mesh, stainless steel column). The ECD is used for the detection of electrophilic substances. The detector consists of two electrodes, one of which is treated with radioactive ^{63}Ni (or titanium or scandium), which emits beta rays. These high-energy electrons bombard the carrier gas (N_2 or argon mixture) to produce large numbers of low energy (or thermal) secondary electrons. These electrons are collected by the other positively polarized electrode. This steady state current is reduced when an electrophilic sample component passing through the space between the two electrodes captures some of these electrons and provides an electrical reproduction of the chromatogram peak. The temperature in injector, column and detector may be maintained at 200, 60 and 340°C, respectively, and the carrier gas (N) flow is maintained around 15 ml min^{-1}. The gas chromatograph should be calibrated before and after each set of measurements by using 110 parts per billion (ppb) N_2O in N_2 as the primary standard and 310 and 398 ppb N_2O in N_2 as the secondary standard (Bhattacharyya et al., 2012 a, b; Bhattacharyya et al., 2013). A GC-software is used to plot and measure the peak area.

Calculation of N_2O flux

$$N_2O\ flux = \frac{(\Delta X \times EBV_{(STP)} \times 44 \times 10^8 \times 60)}{(10^6 \times 22400 \times T \times A)} \qquad \text{---------------}Eq.\ no.\ .4$$

Where, ΔX = Difference in flux value between 30/15 min and 0 min (converted to ppm based on the standard N_2O values), $EBV_{(STP)}$ = Effective box volume at standard temperature and pressure, T = Flux time in min (15 or 30), A = Crop area occupied by the box in m^{-2} (length × breadth).

Rest of calculation of $EBV_{(STP)}$ and subsequent portion was same as mention in previous section in methane flux calculation.

Carbon dioxide

The CO_2 flux measurement from soil using closed-chambers is done by collecting gas samples at periodic interval and measuring the changes in concentrations with time during the period of linear concentration change similar to methane and nitrous oxide. The analysis can be done in gas chromatograph fitted with FID (discussed above) along with a methanizer. The methanizer consists of a 6” x 1/8” stainless steel tube which is mounted alongside the edge of the heated valve oven, and thermo stated to 380ºC. The tube is packed with an activated nickel/zinc/Pt-Pd catalyst powder. Column effluent is mixed with hydrogen gas at a rate of 20 ml/min before entering the methanizer. The methanizer converts the, CO and CO_2 to methane and can be detected by the FID. Hydrocarbons such as methane, ethane and propane pass through the methanizer unaffected. The response of CH_4 produced from CO_2 on the FID is much greater compared to methane in the sample. Methanizer tubes can be poisoned by large amounts of sulphur gas. Analysis of flux can be done similar to methane as discussed above

GHGs flux estimation by Eddy Covariance System

The eddy covariance is a micrometeorological technique to measure vertical turbulent flux of water, carbon dioxide, heat, methane, nitrous oxide, ozone, nitrate and volatile organic components in the boundary layer of atmosphere. The eddy covariance (also known as eddy flux) technique provides a direct measure of the turbulent flux of a scalar across horizontal wind streamlines (Baldocchi et al., 2000). It is a statistical method used in the meteorology and other sectors that analyze high-frequency wind and scalar atmospheric data series, and yields values of fluxes of these properties. Eddy covariance generally adapts in measurements of 3-dimensional wind speed and gas concentration. High speed, high precision instruments get critical for rapid measurement of small changes in the air samples to accurately determine the flux.

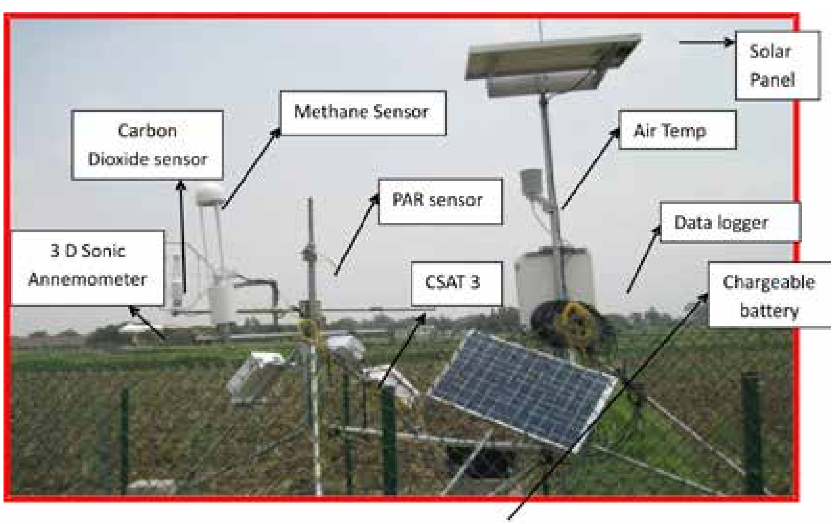

Figure 4 Labelled diagram of Open path Eddy Covariance System in Rice field

Organic farming and GHGs emission

It is expected that organic farming systems provide advantages concerning soil conservation and climate protection. Literatures investigate on measured soil-derived GHGs (CO_2, CH_4 & N_2O) fluxes under organic and inorganic management from farming system. Organic amendments added for improving soil fertility and enhancing crop productivity, can lead to GHGs emission by processes such as priming effect, methanogenesis, nitrification, and denitrification. Priming effect is the stimulation of soil organic matter (SOM) decomposition by the addition of organic amendments which can lead to CO_2, CH_4, and N_2O emissions. Methanogenesis is the production of CH_4 by microbes (methanogens) in soil under anaerobic condition. Nitrification and denitrification, the two contrasting microbial processes in soil N cycle can lead to N_2O emission. In the following section, we attempt to analyse these processes involved in GHGs emission from soil treated with different organic and inorganic amendments. Organic amendments contribute to GHGs emission directly through the release of CO_2, CH_4, and N_2O from C and N compounds present in these amendments, and indirectly through their effects on soil properties thereby inducing GHG emission from soil (e.g., priming effect).

GHGs emission in organic and inorganic farming

Fertilizer management includes changes in fertilizer types, fertilizer- nutrient ratios and the rates and timing of application. Interaction of fertilizer types with methanogenesis plays an important role in regulating methane emission in rice paddy and wet lands. Nitrogen fertilizers generally reduce CH_4 emissions to varying degrees. Organic sources for instance green manure and rice straw, in soils can stimulate methane emission (Denier van der Gon and Neue, 1995). However, when compared to burning of the straw, incorporation of rice straw before a wheat crop in Haryana (India) or vegetable crops in the Philippines and China has resulted in significant reductions of methane emissions (Wassmann and Pathak, 2007). Methane emissions in average were reduced by approximately 0.4 t carbon equivalent (CE) ha^{-1} compared to straw burning. Composting the straw before application could reduce CH_4 emissions by 58% compared to fresh straw under continuous flooding with non significant effect on yield (Wassmann et al., 2000). Complementary straw management with N fertilizer would supply desired N while at the same time increasing C sequestration due to higher organic matter addition and increased crop productivity. Some disadvantages might be considered like, to reach potential crop yield, the particular fertilizers and a supply of manure and soil amendments must be available at or just before transplanting or sowing of crop.

Balance fertilization of NPK along with sulphur has the regulatory effect of CO_2 emission, particularly in oilseeds and pulses by regulating carbon and sulphur mineralization and organic matter decomposition in soil. Use of compost in place of fresh farm yard manure could reduce CO_2 and CH_4 emissions. The addition of fresh organic manure to soil increases the availability of methanogenic substrates and there by enhances CH_4 production. Overall soil C: N ratio also plays an important role in CO_2 and CH_4 production in crop field.

Nitrogen management practices significantly influence the emissions of N_2O in agriculture. Different mitigation practices are fertilizer type, timing, placement, and rate of fertilizer application, as well as coordinating of timing for application with irrigation and rainfall events. In direct nitrogen management practice influences nitrous oxide emissions. Slow, control release and stabilized N fertilizer can enhance crop productivity and minimize the N_2O emissions were demonstrated by Snyder et al. (2007).

Organic and inorganic nutrient management in rice and its effect on carbon storage and GHGs emission: Studies in Eastern India

In eastern India under tropical submerged rice (cv. Gayatri) paddy system, the effect of urea alone and in combination with rice straw and green manure on the emission of CH_4, CO_2 and N_2O were quantified. On seasonal basis, cumulative emission of CH_4 was highest (122.7 kg ha^{-1}) under rice straw + green manure system. Cumulative seasonal emissions of CO_2-C ranged from 1100.3 kg ha^{-1} in the control (unfertilized treatment) to 1858.5 kg ha^{-1} in the rice straw + green manure system. Seasonal N_2O-N emission was found highest in rice straw + urea (0.84 kg ha^{-1}). The global warming potential (GWP) on CO_2 equivalent basis was in the order of rice straw + green manure (10,188 kg CO_2 equivalent ha^{-1}) > rice straw + urea (9418 kg CO_2 equivalent ha^{-1}) > urea (8084 kg CO_2 equivalent ha^{-1}) > control (5862 kg CO_2 equivalent ha^{-1}) (Figure 5 and 6).

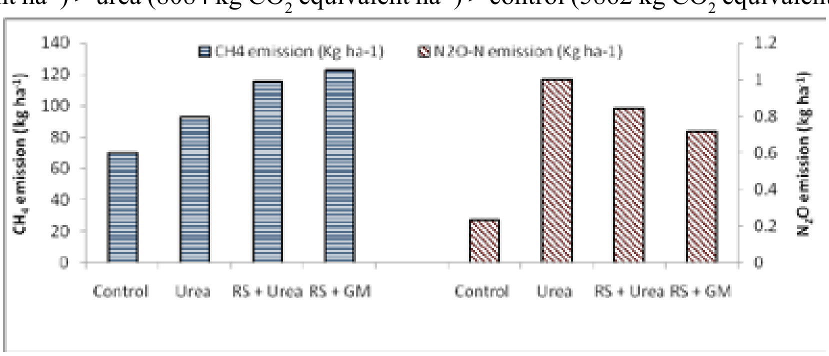

Figure 5 Methane and nitrous oxide emission from rice as affected by rice straw and green manuring. (RS and GM refer to rice straw and green manuring, respectively).

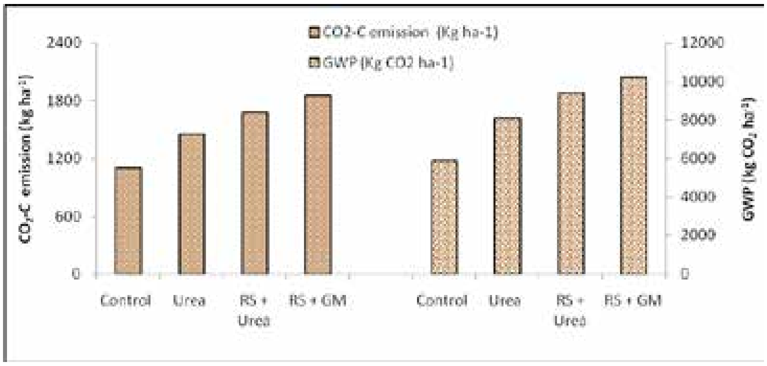

Figure 6 GWP and CO2 emission from rice as affected by rice straw and green manuring. (RS and GM refer to rice straw and green manuring, respectively).

Total SOC storage in the 60-cm soil profile in the rice-rice cropping system was significantly higher (1.39 Mg ha^{-1}) after the combined application of rice straw and urea, followed by rice straw + green manure (0.88 Mg ha^{-1}), and then urea (0.29 Mg ha^{-1}) (Figure 7). Interestingly, there was no build-up of carbon in the control plots. Carbon storage rate was also found to be significantly higher (0.35 Mg carbon ha^{-1} yr^{-1}) in the combined application of rice straw + urea.

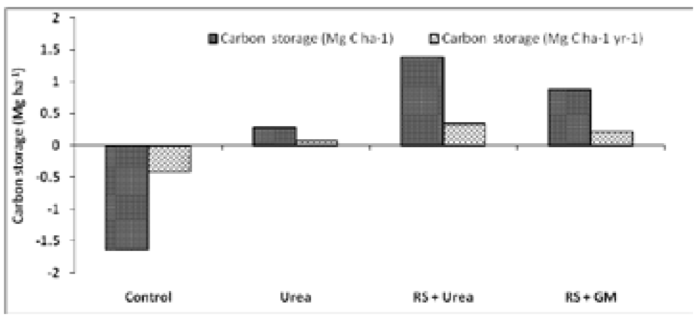

Figure 7 Soil carbon storage as affected by rice straw and green manuring. (RS and GM refer to rice straw and green manuring, respectively).

Therefore, combination of urea, with rice straw on a 1:1 nitrogen basis resulted in a significant build-up of soil carbon, enhancement of crop yield and lower GHG emission when compared to rice straw and green manure and it could be a viable option to mitigate global warming and maintain soil health (Bhattacharyya et al., 2012a).

Effect of organic amendments on GHGs emission on aromatic rice

The impact of long term (10 years) organic amendments on the soil carbon storage in relation to greenhouse gas (GHG) emission from rice (cv. Geetanjali) paddy was quantified in a tropical Aeric Endoaquept in Odisha, India. The treatments were unamended control, farmyard manure (FYM), green manure (GM) (*Sesbania aculeata*), FYM + GM and rice straw (RS) + GM combination. The maximum seasonal CH_4 emission was observed in FYM + GM (162 kg ha^{-1}) treatment. Cumulative N_2O-N emission was highest in the GM (0.72 kg ha^{-1}) treatment (Figure 8). The Cumulative CO_2-C emission followed the order FYM + GM (1910 kg ha^{-1}) > FYM (1480 kg ha^{-1}) > GM (1430 kg ha^{-1}) > RS + GM (1290 kg ha^{-1}) > Control (1000 kg ha^{-1}). Among the five treatments, the FYM + GM treatment has increased the global warming potential (GWP) by 110% (Figure 9) (Bhattacharyya et al., 2012 a, b).

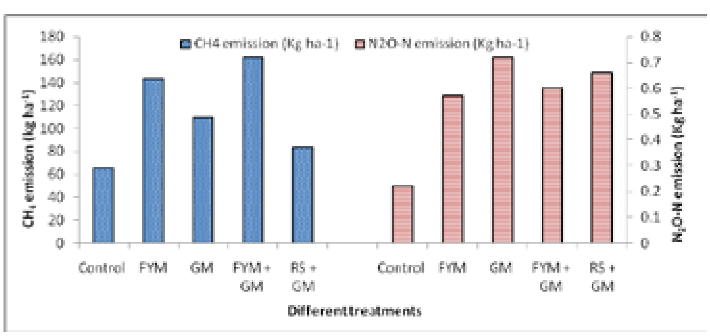

Figure 8 Methane and nitrous oxide emission under different organic manure treated soil in rice. (RS, FYM and GM refer to rice straw, farmyard manure and green manuring, respectively.)

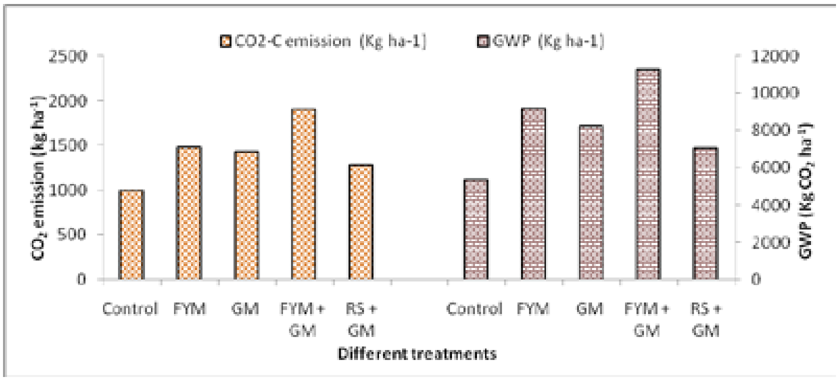

Figure 9. GWP and CO2 emission from rice as affected by rice straw, FYM and green manuring (RS, FYM & GM refer to rice straw, farmyard manure & green manuring).

In RS + GM treatment the soil organic C and total C contents were significantly higher in the order of 34 and 53%; respectively. The highest quantity (1.23 t ha^{-1} C) and rate of C sequestration on annual basis (0.12 t ha^{-1} yr^{-1} C) was under RS+GM (Figure 10).

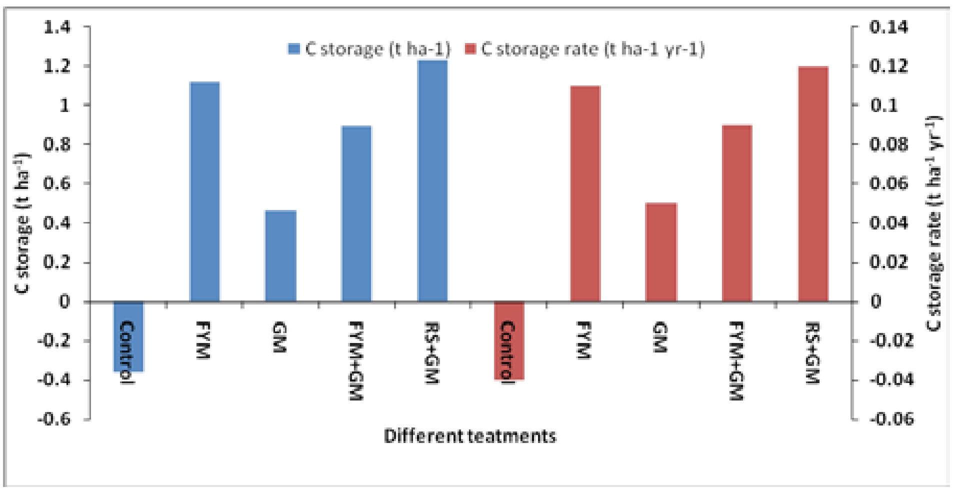

Figure 10. Soil C storage under different organic amendments to soil (after 10 years) planted to rice.

Organic amendment, singly or in combination enhanced SOC content over the years with a significant loss in soil C content in the unamended control (Purakayastha et al. 2008). Soil C storage was influenced to a maximum in the resource conservation techniques, like application of RS + GM at 1:1 [Nitrogen (N) basis] in rice-fallow cropping system in the tropical flooded soil planted to rice. From the environmental sustainability point of view, the implementation of RS + GM amendment techniques is the most adoptable option which gives relatively higher yield, reduced GHG emissions and high capacity to store C in the soil (Bhattacharyya et al., 2012 a, b).

Balanced nutrient management

Impacts of 39-years of fertilizer and manure application on greenhouse gas (GHG) emissions viz. methane, carbon dioxide and nitrous oxide, soil labile carbon (C) and nitrogen (N) pools, functional microbial diversity were investigated in a tropical flooded rice (*Oryza sativa L.*). The treatments included non-fertilized control, N, farmyard manure (FYM), FYM + N, NPK and FYM + NPK. Annual cumulative GHGs emissions after 39 years of intensive rice–rice cultivation were significantly higher in FYM + NPK treatments than other treatments. The global warming potential (GWP) in 100 years time scale and carbon equivalent emission (CEE) were increased significantly under the combined application of FYM + NPK by 88.4% over control. The carbon efficiency ratio (CER) was significantly higher (p-0.05%) in NPK as compared to others. The annual emissions of methane (CH4), nitrous oxide (N2O) and carbon dioxide (CO2-C) in FYM + NPK were 177.6, 1.28, 1407 kg ha^{-1}, respectively, in tropical rice–rice system (wet season rice-fallow–dry season rice-fallow) which were significantly higher than other treatments (Table 2). Although the GHGs emissions were more under FYM + NPK treatment, it helps to maintain soil fertility and supported sustainable rice yield. The soil labile C, N pools, soil enzymatic activities and microbial populations were significantly higher under this treatment which is the indicators of improved soil fertility (Bhattacharyya et al., 2013).

Table 2 Impact of long-term of fertilizer and manure application on annual greenhouse gas emission from flooded rice fields

Treatment	CH_4 emission (Kg ha^{-1})	CO_2-C emission (Kg ha^{-1})	N_2O-N emission (Kg ha^{-1})
Control	93.3^{a}	833.3^{a}	0.58^{a}
Nitrogen	107.3^{b}	1034.0^{b}	1.42^{c}
FYM	128.8^{c}	1106.3^{c}	1.15^{b}
FYM + nitrogen	160.2^{d}	1271.6^{d}	1.51^{d}
NPK	124.1^{c}	1210.1^{cd}	1.46^{c}
FYM + NPK	177.6^{e}	1407.0^{e}	1.82^{e}

Conclusion

Organic agriculture promotes sustainability and C sequestration irrespective of cropping and farming systems and soil types. However, at the same time it enhances GHGs emissions in most of the cases, particularly, in case of methane and carbon dioxide emission. So, there is a trade off. We have to estimate the GHGI i.e. greenhouse gases emission intensity. It refers, how much GHGs emissions taken place per unit of crop yield. And more so in case of organic farming, we have to consider the quality of food also in order to judge its environmental effect. Moreover, it must be noted that organic farming may not be promoted to each and every crop and every location of our country. It may be beneficial and worthy for high value vegetable and spices and in hilly region where inherent C content is high enough to support this system. In case of rice, wheat and maize balanced fertilization (including organic and inorganic) still a favourable option in vast areas of our country considering the demand of food, C foot print and GHGs emission. Availability of quality organic nutrients/ amendment is also an issue. All these triggers to better organic waste management both in rural and urban areas along with zonation of cropping/farming systems need to be considered for organic agriculture in India considering present day food security and climate change issues.

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Soil Quality Index under Organic Farming

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Assessing the quality of soil resources has been stimulated by increasing awareness that it is an important component of the earth's biosphere, functioning not only in the production of food and fiber but also in ecosystems services and the maintenance of local, regional, and global ecological balance (Glanz, 1995). Soil quality primarily describes the combination of chemical, physical, and biological characteristics that enables soils to perform a wide range of ecological functions (Karlen et al., 1997). The functions largely include, sustaining biological activity and diversity; regulating and partitioning water and solute flow; filtering, buffering, degrading, immobilizing, and detoxifying organic and inorganic toxic materials; storing and cycling nutrients in soil-plant-atmospheric continuum and providing support of socio-economic treasures. Another way we can tell the quality of a soil is an assessment of how it performs all of its functions now and how those functions are being persuaded in future.

Indiscriminate use of chemical fertilizers and pesticides in intensive agriculture resulted in several harmful effects on soil, water and air quality. This has reduced the productivity of the soil by deteriorating soil fertility and biological activity. However enhancement and maintenance of soil quality is essential for sustainable agriculture. Further, unscientific use of pesticides has led to the entry of harmful compounds into food chain, death of natural enemies and development of resurgence/resistance to pesticides. It is believed that organic farming can solve many of these problems as this system maintain soil productivity and pest control by maintaining natural processes in harmony with environment. Organic farming is defined as a production system which largely excludes or avoids the use of fertilizers, pesticides, growth regulators, etc. and relies mainly on natural organic sources to maintain soil quality, supply plant nutrients and minimize the infestation of insects, weeds and other pests.

Soil Quality

Soil quality has been defined by scientists as the "fitness for use" (Pierce and Larson, 1993), and by others as the as the "capacity of a soil to function" (Doran and Parkin, 1994). "The capacity of a soil to function within boundaries to sustain biological productivity, maintain environmental quality and promote plant and animal health", was the definition of soil quality put forth by Doran and Parkin (1994). Lal and Stewart (1995) described soil quality as the inherent attribute of soil and to characteristics and processes that determined the soil's capacity to produce economic goods and services and regulate the environment. The soil quality definition given by Karlen *et al.* (1997) mentioned as, "The capacity of a specific kind of soil to function within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation". It can be conceptualized as an integration of three major components - sustained biological productivity, environmental quality and plant and animal health.

Importance of Soil Quality and its Assessment

Soil quality is important for two reasons. First, unscientific use of soil can damage itself and the ecosystem; therefore we need to match the management of land to the soil's capability. Second, we need to establish a baseline understanding about soil quality so that we can recognize changes as they occur. Therefore, the ultimate purpose of assessing soil quality is to protect and improve long-term agricultural productivity, water quality, and habitats of all organisms including human being. In recent years, soil quality research has focused on the linkages among the following: management practices and systems; observable soil characteristics; and soil processes and performance of soil functions. Choosing the appropriate soil attributes to include in an index must include consideration of soil function and management goals that are site specific and user-oriented and must focus on sustainability rather than just crop yields. These indices would be useful in ascertaining the fragility of soil and for understanding how improved management might strengthen its resilience (Chaudhury *et al.*, 2005). The testing of soil for routine analysis can only provide a snap shot on soil fertility which is not able to identify the production constraints because of deterioration of other soil properties. Therefore, assessing soil quality is advantageous for its holistic way to judge the management-induced changes. This capacity of the soil to function can be assessed by physical, chemical, and/or biological properties, which is termed as soil quality indicators (Wander and Bollero, 1999). Individual soil properties/processes may not provide an adequate measure of soil quality and integrated soil quality indicators based on a combination of soil properties can better reflect the status of soil quality than individual parameters. Soil quality changes with time can indicate whether the soil condition is sustainable or not (Arshad and Martin, 2002; Doran, 2002). Soil quality cannot be measured directly however; it can be inferred by measuring soil physiochemical and biological properties that serve as quality indicator (Brejda et al., 2000, Diack and Stott, 2001). Therefore an integrated 'soil quality index' based on the weighted contribution of individual soil property to maintain the soil quality may serve better indicator of soil quality for different land uses.

Soil quality indicators

Soils have chemical, biological, and physical properties/ processes that interact in a complex way to give a soil its quality (Karlen et al., 1997). Thus, soil quality cannot be measured directly, but must be inferred from measuring changes in its attributes or attributes of the ecosystem, referred to as indicators. Indicators are measurable properties soil. The type of indicator chosen to evaluate soil quality depends on the soil function and the size of the area (i.e. field, farm, watershed, or region etc.) in which the evaluation is made. Considering basic soil functions i.e., provision of sufficient amounts of water, and nutrients, provision of resistance and resilience to physical degradation, and sustaining plant growth under an appropriate utilization, numerous soil analyses might be required to fully characterize the soil/plant system. Thus, broad soil quality indicators could be grouped, *viz*., (i) soil chemical quality and soil fertility indicators, (ii) soil physical quality indicators and (iii) soil biological quality indicators (Table 1).

Soil Quality Index

Four major tools have been used for soil quality assessment *viz*., Soil Conditioning Index (SCI), Soil Management Assessment Framework (SMAF), the Agroecosystem Performance Assessment Tool (AEPAT) and the New Cornell "Soil Health Assessment". Out of these, SMAF was developed as malleable tools for assessing soil response to management and is most widely used for the assessment of soil quality. The SMAF is an additive, non-linear indexing tool for assessing soil function (Andrews *et al.* 2004). The SMAF is intended for use by land managers and their advisors for use in assessing ongoing management practices. In determination of soil quality index (SQI) using SMAF, four main steps are followed (Fig. 1): (i) formulation of appropriate goals for desired outcomes of soil functions, (ii) selection of a minimum data set (MDS) of indicators that best represent soil function, (iii) scoring the MDS indicators based on their performance of soil function and (iv) integration of the indicator scores into a comparative SQI (Nayak et al., 2016).

Table 1. Soil quality indicators at different levels of soil management and planning

Physical indicators	Chemical indicators	Biological indicators
Field, Farm or Watershed indicators		
Passage of air	Base saturation percentage	Soil Organic carbon
Structural stability	Cation exchange capacity	Microbial biomass carbon
Bulk density	Contaminant availability	C and N/Oxidizable carbon
Clay mineralogy	Contaminant concentration	Total biomass
Colour	Contaminant mobility	Bacterial
Consistence (dry, moist, wet)	Contaminant presence	Fungal
Depth of root limiting layer	Electrical conductivity	Potentially mineralizable N
Hydraulic conductivity	Exchangeable sodium percentage	Soil respiration
Oxygen diffusion rate	Nutrient cycling rates	Enzymes
Particle size distribution	pH	Dehydrogenase
Penetration resistance	Plant nutrient availability	Phosphatase
Pore conductivity	Plant nutrient content	Arlysulfatase
Pore size distribution	Sodium adsorption ratio	Biomass C/total organic Respiration / biomass carbon/
Soil strength		Microbial community fingerprinting
Soil tilth		Substrate utilization
Structure type		Fatty acid analysis
Temperature		Nucleic acid analysis
Total porosity		
Water holding capacity		
Regional or National level		
Desertification	Organic matter trends	Productivity (yield stability)
Vegetative cover	Acidification	Taxonomic diversity at the group level
Water erosion	Salinisation	Species richness diversity
Wind erosion	Changes in water quality	Keystone species and ecosystem engineers
Siltation of rivers and lakes	Changes in air quality	Biomass, density and abundance
Sediment load in rivers		

Source: Singer and Ewing (2000); Nayak et al. (2016)

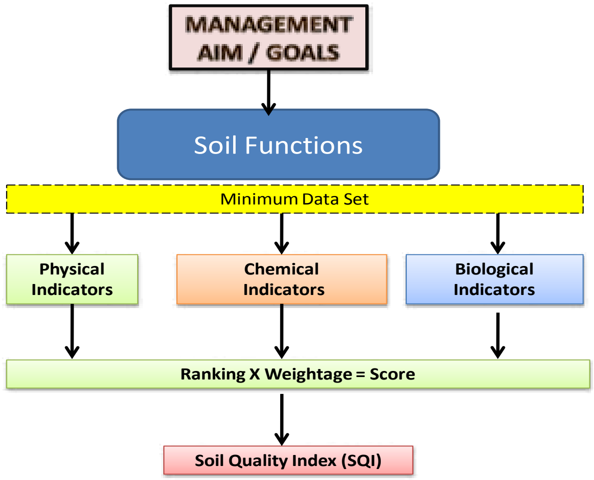


Figure 1. A generalized framework for developing soil quality indices

(i) Formulation of appropriate goals for desired outco*mes of soil functions*

Soil quality indices and indicators should be selected according to the soil functions of interest and the defined management goals for the system. Management goals are often individualistic, primarily focused on on-farm effects, but can also be societal, including the broader environmental effects of farm management decisions such as soil erosion, agrochemical contamination of soil and water, or subsidy imbalance (from over-use of fossil fuels or agrochemicals). Management goals may also differ by the interests and visions of different sections of people concerned with agriculture.

(ii) Selection of a minimum data set (MDS) of indicators

Once the system's management goals are identified, the next step for soil quality indexing is to choosing appropriate indicators for a minimum data set (MDS). It would be unrealistic to use all ecosystems or soil attributes as indicators, so a minimum data set (MDS) consisting of attributes encompassing chemical, physical and biological soil properties are selected for soil quality assessment. Nearly all of the physical, chemical, and biological attributes that comprise a minimum data set have established meanings and published procedures that predate the soil quality concept. A minimum dataset for assessing soil quality should have the characteristics (Doran and Parkin, 1994) like, easy to measure, detect changes in soil function, integrate soil physical, chemical, and biological properties and processes, accessible to many users and applicable to field conditions, sensitive to variations in management and climate, encompass ecosystem processes and relate to process-oriented modeling and where possible, be components of existing soil data bases.

Minimum data set components can be selected based on expert opinion (Karlen et al., 1996) and/or by using statistical methods. The physiological rhizosphere studies of Bachmann and Kinzel (1992) used principle component analysis (PCA), multiple correlation, factor analysis, cluster analysis and star plots to select characteristics for their diagnostic index. Bentham et al. (1992) used principal component analysis and other statistical clustering techniques to choose variables best representing the progress of soil restoration efforts. The principal component analysis generally relies less on any individual scientist making selections of goals, functions, and indicators. It uses a statistical technique to identify the indicators that best represent variability in a large existing data set. This technique affords less opportunity for disciplinary bias but does require a robust data set. Mechanistically, the data set must have a sufficient number of observations and variables. Functionally, whatever is measured must have potential value as an indicator (i.e., some relationship to the critical soil functions). After the data are analyzed and mean comparisons are made, only those indicators showing statistically significant differences are included in the PCA. The data are then analyzed using PCA to prioritize and reduce the number of indicators or variables that need to be measured in subsequent samplings. PCs receiving high eigenvalues best represent variation in the systems (Shahid et al., 2013). Therefore, only the PCs with eigenvalues ≥ 1 (Kaiser, 1960) are taken into consideration. Additionally, PCs that explain $\geq 5\%$ of the variability in the soils data (Wander and Bollero, 1999) could be included when fewer than three PCs had eigenvalues ≥ 1. Under a particular PC, each variable is given a weight or factor loading that represents the contribution of that variable to the composition of the PC. Only the highly weighted variables were retained from each PC for the MDS (Table 2). Highly weighted factor loadings were defined as having absolute values within 10% of the highest factor loading or ≥ 0.70 (absolute value, Shahid et al., 2013). When more than one factor was retained under a single PC, multivariate correlation coefficients were employed to determine if the variables could be considered redundant and, therefore, eliminated from the MDS (Andrews et al., 2002). Highly correlated variables were considered redundant and only one was considered for the MDS. If the highly weighted factors were not correlated (assumed to be a correlation coefficient <0.60) then each was considered important, and thus, retained in the MDS. Among well correlated variables, the variable with the highest factor loading (absolute value) was chosen for the MDS. The PCA loading value of the selected variables under the respective

PCs is used to provide "weighting factors" for the indicators included in the soil quality indices (Andrews et al., 2002). To check how well the MDS represented the management systems or goals, multiple regressions of both the EO selected and PCA-MDSs are performed using the indicators retained as independent variables and the end point measures (goals) as dependent variables. If any variable within the MDS did not contribute to the coefficient of determination from the multiple regressions, it was also ignored. After the MDS indicators were determined, results may be transformed using a linear or non-linear scoring method.

(iii) Scoring the MDS indicators based on their performance of soil function

After determining the variables for the MDS, every observation of each MDS indicator was transformed for inclusion in the SQI methods examined. Knowledge on the variations in soil quality indicators in similar type of soils under various distinct management systems is necessary to convert the raw data on soil parameters/soil quality indicators into unit less numerical scores. This will help us to set the limits or thresholds for the soil quality indicators (Table 2). Based on the range of each soil quality indicators and its measures and reported critical values, the limits/thresholds were fixed. As reported by Masto et al. (2007), the success and usefulness of a soil quality index mainly depends on setting the appropriate critical limits for individual soil properties. The optimum/critical values of soil quality could be obtained from the soils of undisturbed ecosystems (Warkentin 1996; Arshad and Martin 2002), where soil functioning is at its maximum potential to or in best managed systems or on critical values available in the literature. After finalizing the thresholds or limits the numerical score of each MDS variable is transformed using linear scoring or non-linear scoring functions.

(iv) Integration of the indicator scores into a comparative SQI

The last and final step will be integration of indicator scores into a comparative index of soil quality. Soil quality indicator values were normalized on a scale from 0 to 1. Two soil quality indexing methods are mostly used i.e. (i). Conceptual framework for analyzing soil quality and (ii). Principal component analysis based soil quality index.

Table 2. Soil quality indicators and scoring functions

Indicator	Scoring curve	Lower threshold	Upper threshold	Lower baseline	Upper baseline	Optimum	Source of limits
Clay (%)	More is better	0	40	20	-	-	
Bulk density (Mg/m3)	Less is better	1	2	1.5	-	-	Glover et al., 2000;
Hydraulic conductivity (cm/h)	Optimum	0.2	2	0.6	1.5	1.6	Lal (1994)
Clay dispersion index	Less is better	0	36	18	-	-	
pH	Optimum	4.5	9	5.5	7.5	6.5	
Electrical conductivity (dS/m)	Less is better	2	12	6	-	-	
Organic carbon (g/kg)	More is better	0	12	6	-	-	Rao (1995)
Microbial biomass carbon (mg/kg)	More is better	0	400	200	-	-	Haynes (2005)
Carbon mineralization (mg/kg)	More is better	0	1200	600	-	-	Haynes (2005)
Total nitrogen (mg/kg)	More is better	0	1200	600	-	-	
Available nitrogen (kg/ha)	More is better	0	400	200	-	-	
Microbial biomass nitrogen (mg/kg)	More is better	0	60	30	-	-	Haynes (2005)
Nitrogen mineralization (mg/kg)	More is better	0	60	30	-	-	Haynes (2005)
Bray's phosphorus (kg/ha)	More is better	0	50	25	-	-	
Available potassium (kg/ha)	More is better	0	400	200	-	-	
DTPA Zinc (mg/kg)	More is better	0	1.5	0.75	-	-	
DTPA Copper (mg/kg)	More is better	0	5	2.5	-	-	
DTPA Iron (mg/kg)	More is better	0	50	25	-	-	
DTPA Manganese (mg/kg)	More is better	0	20	10	-	-	
Urease (µg NH_4^+ /g/h)	More is better	0	200	100	-	-	
Dehydrogenase (µg TPF /g/h)	More is better	0	100	50	-	-	
Acid Phosphatase (µg PNP /g/h)	More is better	0	600	300	-	-	
Alkaline Phosphatase (µg PNP /g/h)	More is better	0	400	200	-	-	

Source: Shahid et al. (2013)

Conceptual framework

The Conceptual Framework model has been used to determine soil quality as described by Karlen et al. (1992) as follows:

Soil quality index (SQI) P = qnc(wt) + qpss(wt) + qwr (wt) + qrr (wt) (for productivity goal)

Soil quality index (SQI) EP = qnc(wt) + qpss(wt) + qwr (wt) + qrr (wt) + qfb (wt) + qbdh (wt)

(For Production (P), environmental protection (EP) goal)

Where, qnc is the rating for the soil's ability to nutrient cycling, qpss to facilitate physical stability and support, qwr to water relations, qrr to resistance and resilience, qfb to filtering and buffering, qbdh to sustain biodiversity and habitat and (wt) is a numerical weighting for each soil function. Weights for all soil functions sum to 1.00. An ideal soil would fulfill all the functions considered important and under the proposed framework will receive a SQI of 1.00. As a soil fails to meet the ideal criteria, the SQI would fall, with zero being the lowest rating. Associated with each soil function are soil quality indicators that influence, to varying degrees, that particular function. As with soil functions, numerical weights assigned to selected soil quality indicators must sum 1.00 at each level.

Principal component analysis

Principal component analysis (PCA) is the method for reducing correlated measurement variables to a smaller set of statistically independent linear combinations having certain unique properties with regard to characterizing individual differences. Principal components (PCs) for a data set are defined as linear combinations of the variables that account for maximum variance within the set by describing vectors of closets fit to the n-observations in p-dimensional space, subject to being orthogonal to one another (Dunteman, 1989). Each PC explained a certain amount of variation (%) in the total data set, this percentage provided the weight for variables chosen under a given PC. The final PCA based soil quality equation is as follows:

$$SQI = \sum_{i=1}^{n} Wi \ x \ Si$$

(for both productivity and environmental protection goal)

Where,

S = score for the subscripted variable

W = weighing factor derived from PCA

Soil Quality and Soil Health

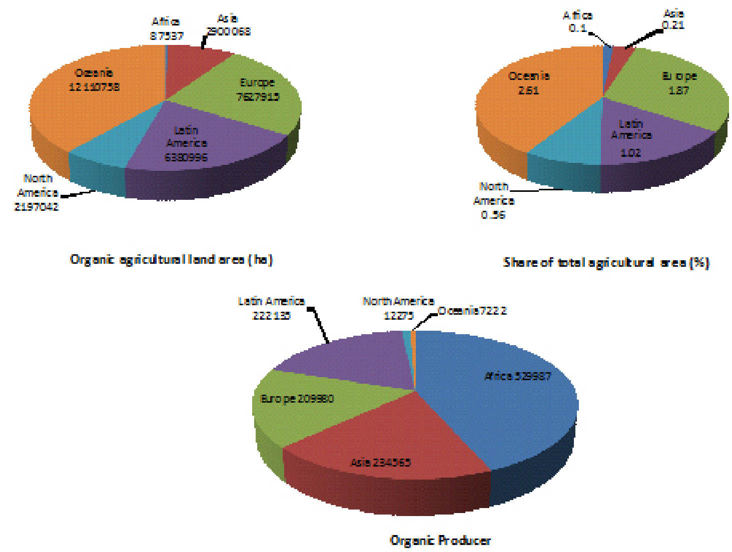
Soil quality and soil health are referred many times as same concept. However, there are differences. Few points are listed here. Soil health refers to the biological, chemical, and physical features of soil that are essential to long-term, sustainable agricultural productivity with minimal environmental impact. Thus, like soil quality, soil health also provides an overall picture of soil functionality. Similarly, it cannot be measured directly, soil health can be inferred by measuring specific soil properties (e.g. organic matter content) and by observing soil status (e.g. fertility). In general, healthy soils maintain a diverse community of soil organisms that help to: (i) control plant diseases as well as insect and weed pests; (ii) form beneficial symbiotic associations with plant roots (e.g. nitrogen-fixing bacteria and mycorrhizal fungi); (iii) recycle plant nutrients; (iv) improve soil structure with positive repercussions for its water- and nutrient-holding capacity; (v) improve crop production. Like soil quality, one of the most important objectives in assessing the health of a soil is the establishment of indicators for evaluating its current status.

Doran et al. (1996) presented a list of properties affecting soil ecological functions and quality, for example soil bulk density, water infiltration and holding capacity, total organic C and N, electrical conductivity, pH, plant-available nutrients, and measures of microbial biomass and activity. Although these properties may be useful as indicators for soil quality, they are not necessarily associated with soil health and the maintenance of essential soil ecological functions. The general approach to measure as many variables as possible and relate them to different uses (natural versus agricultural soil) or soil management practices (such as conventional versus alternative practices in terms of tillage, plant nutrition, or pest control) has not resulted in indicators that are consistently correlated with soil health (Pankhurst et al., 1995; Staben et al., 1997). One of the reasons for the inconsistencies may be the sensitivity of many of these measurements to the time of sampling in relation to significant management or environmental events (tillage, irrigation, residue incorporation, fertilization, rainfall, etc.).

Soil Quality and Organic Farming

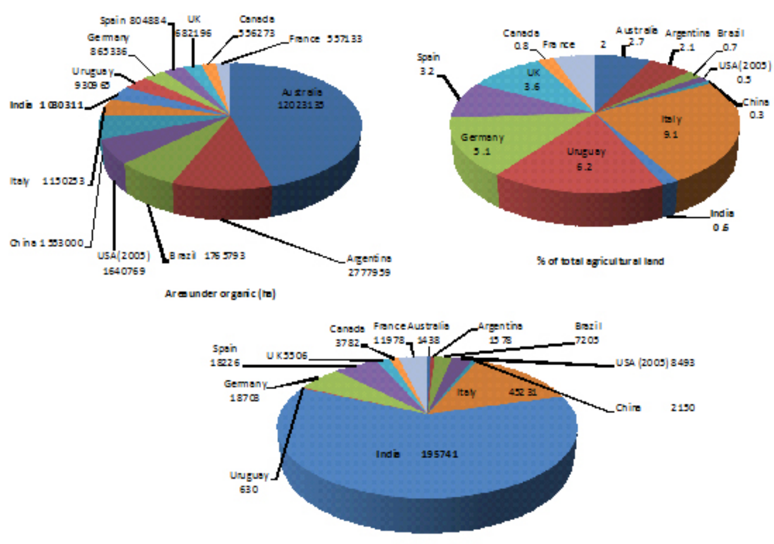
Organic farming is one of the several approaches found to meet the objectives of maintaining soil quality and sustainable agriculture. Many techniques used in organic farming like inter-cropping, mulching and integration of crops and livestock are not alien to various agriculture systems including the traditional agriculture practiced in old countries like India. However, organic farming is based on various laws and certification programmers, which prohibit the use of almost all synthetic inputs, and health of the soil is recognized as the central theme of the method.

Based on the global survey on organic farming carried out in 2009 by the Research Institute of Organic Agriculture (FiBL), the International Federation of Organic Agriculture Movements (IFOAM) and Foundation Ecology & Agriculture (SOEL), the organic agriculture is developing rapidly and is now practiced in more than 141 countries of the world. Its share of agricultural land and farms continues to grow in many countries. According to the latest survey on global organic farming, about 32.2 million hectares of agricultural land is managed organically as of 2007. Oceania has the largest share of organic agricultural land (37%), followed by Europe (24%) and Latin America (20%). The proportion of organically compared to conventionally managed land, however, is highest in Oceania and in Europe. In the European Union, 4% of the land is under organic management. Most producers are in Latin America (Figure 2 and 3). The total organic area in Asia is 2.9 m.ha. This constitutes 9% of the world's organic agricultural land. The leading countries are China (1.6 m ha) and India (1 m ha). The country with the largest organic area is Australia (12 million hectares)



Source : FiBL and IFOAM 2009

Figure 2. Organic agricultural land and farms by continent



Source: FiBL and IFOAM 2009

Figure 3. Land area of major countries under organic agriculture

SQI in Organic, Inorganic and Integrated Organic + Inorganic Farming: Few Case Studies

A study was carried out by Obriot et al. (2016) with the objective to develop a multi-criteria tool to compare fertilizing practices either based on mineral fertilizer (CONT + N) or repeated applications of exogenous organic matter (EOM) and considering the positive but also the negative impacts of these practices. Three urban composts (a municipal solid waste or MSW, a co-compost of sewage sludge and green waste (GWS), and bio-waste (BIO)) and farmyard manure (FYM) have been applied biennially over 14 years. Soils and crops were sampled repeatedly and >100 parameters measured. The development of different quality indices (QI) was used to provide a quantitative tool for assessing the overall effects of recycling different types of EOM. A minimum data set was determined and 7 indices of soil and crop quality were calculated using linear scoring functions: soil fertility, soil biodiversity, soil biological activities, soil physical properties, soil contamination ("available" and "total") and crop productivity. All QI varied between 0 and 1, 1 being the best score. They found that EOM amendments significantly increased soil biodiversity, biological activities and physical properties with intensity generally depending on their characteristics. FYM was the most efficient EOM to improve soil biological properties. EOM application lead to similar yields as mineral fertilizers but grain quality was slightly decreased. Thus, mineral fertilizers remained more efficient at improving crop productivity index (QI = 0.88) than EOM although BIO was not significantly different than CONT + N. All EOM improved soil fertility but only BIO was significantly higher (QI = 0.86). EOM added a range of nutrients but an excess of phosphorus negatively impacted the soil fertility index. Overall, they concluded the positive impact of repeated EOM applications on soil and crop quality in a loamy soil.

In an integrated organic + inorganic farming in eastern India under long-term experiment, Shahid et al. (2013) assessed the soil quality index (SQI). The treatments comprised chemical fertilizers and farmyard manure (FYM) either alone or in combination viz. control, N, NP, NK, NPK, FYM, N+FYM, NP+FYM, NK+FYM and NPK+FYM. Soil samples were collected after (40 years) the wet season rice harvest and were analysed for physical, chemical and biological indicators of soil quality. A SQI using principal component analysis (PCA) and nonlinear scoring functions were calculated. Selection of a soil quality indicator three PCs had Eigen values >1 that explained 86.8% of variation in the data. Among all the treatments, the SQI had wide variation (0.10– 0.74) for CDI and least (0.07–0.15) for Avail-K. The value of the dimensionless SQI varied from 1.46 in the control plot to 3.78 in NPK+FYM plot.

Similarly another experiment was conducted by Masto et al. (2007) with the objective to quantify the effects of 10 fertilizer and farm yard manure (FYM) treatments applied for 31 years to a rotation that included maize (*Zea mays*), pearl millet (*Pennisetum americanum*), wheat (*Triticum aestivum*) and cowpea (*Vigna unguiculata*) on an Inceptisol. A soil quality index (SQI) based on six soil functions (i.e. the soil's ability to: accommodate water entry, facilitate water movement and storage, resist surface degradation, resist biochemical degradation, supply plant nutrients and sustain crop productivity) was derived for each treatment using bulk density, water retention, pH, electrical conductivity (EC), plant available nutrients, soil organic matter (SOM), microbial biomass, soil enzymes and crop yield. Soil quality index (SQI) ratings ranged from 0.552 (unfertilized control) to 0.838 for the combined NPK fertilizer plus manure treatment.

In a study in China, Wang et al. (2017) assessed of effect of organic farming on soil quality and compared with conventional farming. Soil samples were collected from 14 farms (i. e. 7 organic farms and 7 neighboring conventional farms) for analysis of soil physic-chemical properties, i.e. bulk density, pH, organic matter, total N (TN), total P, readily available P and readily available K, and biological properties as well, i.e. microbial biomass carbon, diversity and dominance of microbial communities, and population, diversity and dominance of nematodes. Statistics of the 13 indices was done for principal components analysis. Out of the 13, 6 (TN, pH, bulk density, microbial biomass carbon, and population and dominance of nematodes) were cited to form a minimum data set (MDS). Soil quality index (SQI_6) based on MDS was in the range of 0.39-0.72 in the soils under organic farming and in the range of 0.18-0.54 in the soils under conventional farming. The concluded that based on the fact that the 6 indices in MDS, particularly dominancy of the nematode community, contributed 12.4%-21.8% to soil quality and that SQI_{13} (SQI derived from the 13 soil property indices) is significantly related to SQI_6 (r=0.89, P<0.05), so it is quite clear that MDS-based soil quality assessment is a workable and effective tool.

CONCLUSION

Soil quality index is a useful tool to assess soil health and well being. Few methods are available to estimate it. Among those PCA based scoring, ranking and weightage method gaining popularity. However, SQI assessment primarily depends on objectives of study or soil functions need to be addressed. Selection of MDS and its ranking play important role for determining SQI. As obvious organic farming has great influence on SQI. And more so inorganic and organic farming affect SQI differently. So they need to be assessed in site specific conditions keeping the goal in mind. In nutshell, SQI is a tool to quantitative measure of "soil condition: both in medium and long term". It has to be interpreted precisely, when comparing organic or inorganic farming keeping in view of spatial and socio-economic variations.

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Soil Carbon Sequestration and its Potential in Mitigation of Climate Change

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India has only 2.5% of the world's geographical area, but has about 17% of its population. India's population increased from 361 million in 1951 to nearly 1320 million at present, a more than three and half fold increase in a span of 66 years. Declining per capita availability of natural resources due to population growth, urbanization, industrialization, competing environmental demands and inclusive growth are major concerns of resource management and conservation. As of today, there is food sufficiency in the country, yet its availability to each citizen remains a problem due to disparity in purchasing power. By 2020, India needs about 300 million tonnes of food grains. The production in 2008-2009 was only 230 million tonnes, implying that about 70 million tonnes of food grains have to be produced from the same or lesser land, resulting in higher stress on soil system. Most of the intensive production systems in India are showing a yield plateau, and crop response to inputs is declining. It means that for each additional kg of yield, more and more nutrients are needed. This has negative economical as well as ecological implications in terms of low nutrient use efficiency, lesser biomass production per unit input and increased emission of green house gases (GHGs) like CO_2 and nitrogen oxides.

Out of the estimated 141 m ha net cultivated land in India, 85 m ha is rainfed which produces 40 per cent of the food grains in the country. Low and erratic rainfall, high temperature, degraded soils with low available water content and multinutrient deficiencies are important factors contributing to low crop yields in these regions. In India, the predominant production systems under rainfed agriculture are upland rice, sorghum, maize, pearlmillet, fingermillet, cotton, groundnut and soybean besides several pulses, oil seeds and cereals, which are characterized by diverse climate of arid, semi-arid (dry and moist) and sub-humid (dry and moist), with mean annual rainfall ranging from 412 mm to 1400 mm and spatial variability of soils consisting of Entisols, Inceptisols, Alfisols, Vertisols, Aridisols and Oxisols (Srinivasarao et al., 2006, 2009a, 2011a, b). On the other hand, irrigated systems are mainly rice, wheat, potato, jute, sugarcane mainly in Indo-Gangetic regions and rice based systems in Eastern and North Eastern agro ecosystems.

The most important reason for declining yield trends of various production systems in India is degraded soil health. Most of the agro ecological regions are showing reduction in soil organic carbon (SOC) with continuous cropping with improper crop management practices such as low biomass recycling, inappropriate tillage methods, harvest and removal of every small component of biological produce and virtually no return of any plant residue back to the soil, burning of the residues in the field itself for preparation of clean seed bed, open grazing, etc, that aggravate the process of soil degradation (Srinivasarao et al., 2012a, b). As a result of several above-mentioned reasons, soils encounter diverse constraints broadly on account of physical, chemical and biological soil health and ultimately end up with poor functional capacity. The first predominant cause of soil degradation in rainfed regions undoubtedly is water erosion. The process of erosion sweeps away the topsoil along with organic matter and exposes the subsurface horizons. The second major indirect cause of degradation is loss of organic matter by virtue of temperature mediated rapid decomposition of organic matter and leading to loss of rapid soil fertility. If one looks at the tenth five-year plan document of the Government of India, under chapter 5.1(5.1.72-74) on agriculture, it has been stated that, a sizeable quantity of organic farm waste is generated which could be utilized for providing nutrition to the crops after converting it into compost or manure.

Carbon sequestration potential and challenges

Soil carbon has gained increased interest in the recent past owing to its importance in carbon sequestration studies and its potential impact on sustainable crop production. Carbon sequestration implies removing atmosphere carbon and storing it in natural reservoirs for extended periods (Lal, 2011). Soil carbon sequestration is the process of transferring carbon dioxide from the atmosphere into the soil through crop residues and other organic solids, and in a form that is not immediately remitted. This transfer or "sequestering" of carbon helps off-set emissions from fossil fuel combustion and other carbon-emitting activities while enhancing soil quality and long-term agronomic productivity. However, accuracy in estimating soil carbon sequestration to determine best management practices is hindered by inherent variability of soil properties (Srinivasarao et al., 2008, 2009b).

Maintaining or arresting the decline in soil organic matter (SOM) is the most potent weapon in fighting against soil degradation and for ensuring sustainability of agriculture in tropical regions. In India, 65 per cent of agriculture is rainfed, covering the categories of arid, semi-arid and sub-humid climatic zones. Consequences of depletion of organic matter are poor soil physical health, loss of favorable biology and occurrence of multiple nutrient deficiencies. It was stated that in rainfed arid, semi-arid and sub-humid tracts, next to poor rain water management, depletion of nutrients caused by organic matter deficiency is an important cause of soil degradation. Improving organic matter is, therefore, crucial to sustenance of soil quality and future agricultural productivity. Humus is known to favor many useful physical, chemical and biological processes that occur within the soil (Srinivasarao et al., 2011c). Accordingly, SOM is a key element of soil management that prevents erosion and improves water availability. Other soil physical characteristics that are linked to SOM are: infiltration, water retention, bulk density and soil strength. When spread on the surface as mulch, organic matter moderates the bomb-like effect of falling rain drops and prevents dispersion-mediated erosion, surface crusting, and hard setting which contribute to realize the potential level SOC sequestration (Figure 1).

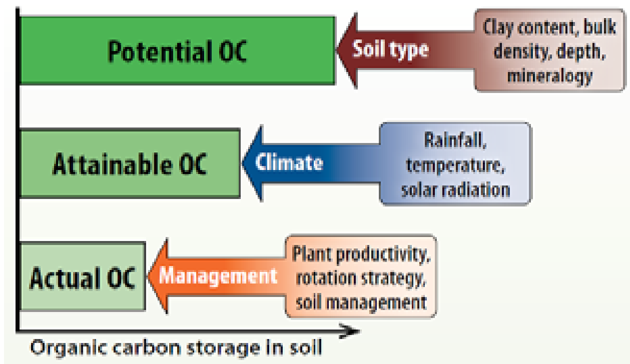

Figure 1. Attainable and potential pathways of organic carbon sequestration in soil

Soil carbon stocks

Soil carbon sequestration is yet another strategy towards mitigation of climate change. Soil carbon pool plays a crucial role in the soil's quality, availability of plant nutrients, environmental functions and global carbon cycle. Agricultural soils are among the earth's largest terrestrial reservoirs of carbon and hold potential for expanded carbon sequestration. They thus provide a prospective way for reducing atmospheric concentration of CO_2. Drylands are generally low in fertility, low in organic matter, and hence candidates for carbon sequestration (Srinivasarao et al., 2003, 2012c). Carbon storage in the soil profile not only improves fertility but also abates global warming. Several soils, production and management factors influence carbon sequestration; and it is important to identify production and management factors that enhance carbon sequestrations in dryland soils. In a study conducted in benchmark soils of major rainfed production systems covering 21 locations on dominant soil types, covering a range of climatic conditions in India, it was found that SOC stocks in the soil profiles across the country showed wide variations and followed the order Vertisols > Inceptisols > Alfisols > Aridisols (Table 1). Inorganic carbon and total C stocks were larger in Vertisols than in other soil types. SOC stocks decreased with depth in the profile, while inorganic carbon stocks increased with depth. Among the production systems, soybean, maize and groundnut based systems showed higher SOC stocks than other production systems (Figure 1 and 2). However, the highest contribution of organic carbon to total carbon stock was under upland rice system. SOC stocks in surface layer of the soils increased with rainfall (r=0.59*) while inorganic carbon stocks in soils were found in the regions with less than 550 mm annual rainfall. CEC showed better correlation with SOC stocks than clay content in soils. Results suggested that Indian dryland soils are low in organic carbon but have potential to sequester. Further potential of tropical soils to sequester more C in soil could be harnessed by identifying appropriate production systems and management practices for sustainable development and improved livelihoods in the tropics (Srinivasarao et al., 2009a, c).

Table 1. Organic, inorganic and total carbon stocks in tropical soils of India (Srinivasarao et al., 2009a).

Soil location	Production system	Carbon stocks (Mg ha^{-1})		
		Organic	Inorganic	Total
Inceptisols				
Varanasi	Rice	32.54	112.36	144.90
Faizabad	Rice	29.81	22.30	52.11
Agra	Pearl millet	26.69	26.76	63.45
Ballowal-Sauntri	Maize	56.73	72.21	128.94
Rakh-Dhiansar	Maize	59.71	45.75	105.46
Jhansi	*Rabi* sorghum	56.97	135.11	192.08
Alfisols/Oxisols				
Parbhani	Rice	23.28	8.81	32.10
Ranchi	Rice	49.83	23.35	73.18
Anantapur	Groundnut	25.41	57.02	82.43
Bangalore	Finger millet	24.75	17.88	42.63
Vertisols/Vertic groups				
Rajkot	Groundnut	58.02	154.77	212.79
Indore	Soybean	95.90	88.33	184.24
Rewa	Soybean	28.71	16.03	44.74

Akola	Cotton	28.60	367.63	396.23
Kovilpatti	Cotton	48.20	183.05	231.26
Bellary	*Rabi* sorghum	34.67	298.53	333.20
Bijapur	*Rabi* sorghum	36.60	326.06	362.67
Solapur	*Rabi* sorghum	49.73	106.70	156.42
Arjia	Maize	36.93	62.07	99.01
Aridisols				
Hisar	Pearl millet	20.10	14.27	34.38
SK Nagar	Pearl millet	27.36	20.50	47.86

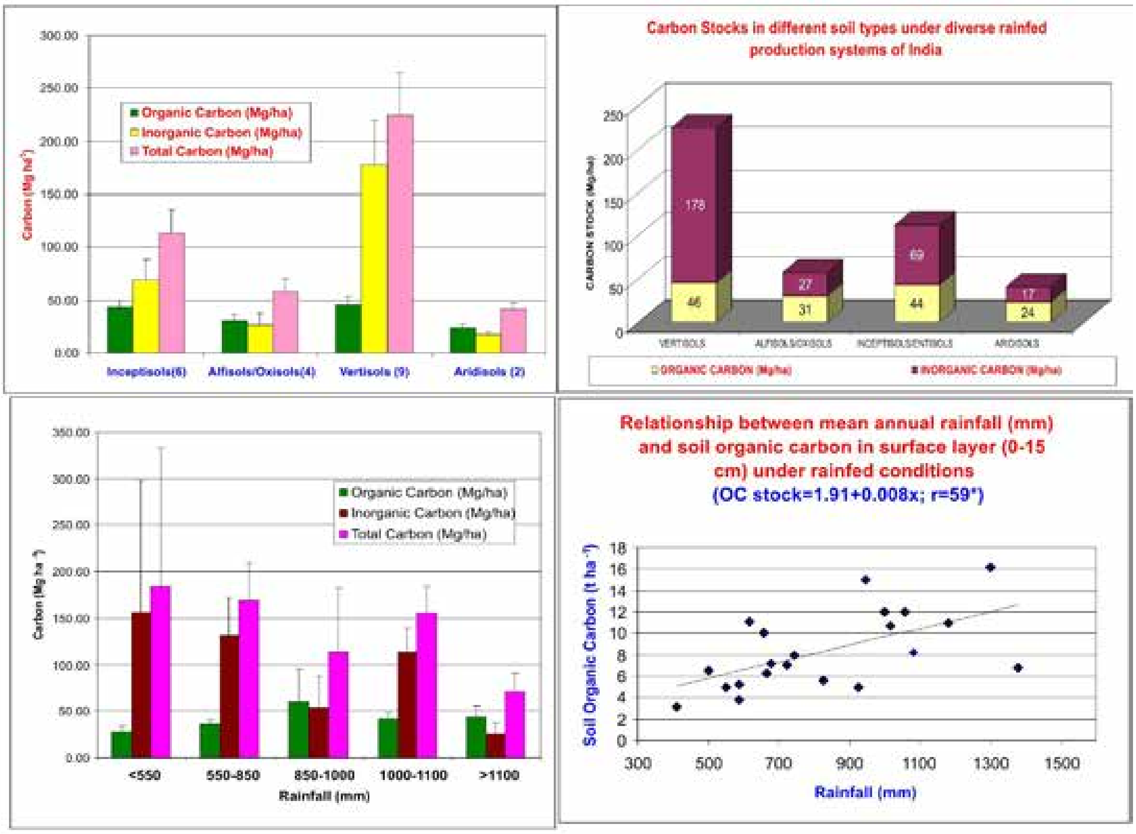

Figure 2. Carbon stocks in diverse soil types and rainfall zones (Srinivasarao et al., 2006, 2009a, 2011b)

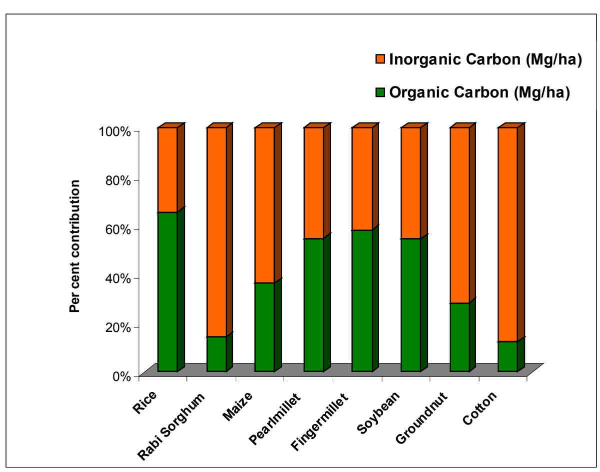

Figure 3. Distribution of organic and inorganic carbon in diverse rainfed production systems of India (Srinivasarao et al., 2009b)

In general, SOC stocks increased as the mean annual rainfall increased. Significant correlation ($p< 0.05$) was obtained between SOC stock and mean annual rainfall ($r=0.59^*$; Figure 2). On the other hand, soil inorganic carbon (SIC) stocks decreased with the increase in mean annual rainfall from 156 Mg ha^{-1} (<550 mm) to 26 Mg ha^{-1} (>1100 mm). As the SIC stocks were more dominant than SOC, total carbon stocks decreased with increase in mean annual rainfall from 184 Mg ha^{-1} in the arid environment (<550 mm) to 70 Mg ha^{-1} in sub-humid regions (>1100 mm). However, CEC showed significant positive correlation ($r=0.81^{**}$) while clay content in soil showed non-significant positive correlation with organic carbon stocks. This indirectly indicates type of clay mineral with larger surface area is largely responsible for higher carbon sequestration (Figure 2).

It has been postulated that aridity in the climate is responsible for the formation of pedogenic calcium carbonate and this is a reverse process to the enhancement in SOC. Thus, increase in C sequestration via SOC enhancement in the soil would induce dissolution of native calcium carbonate and the leaching of SIC would also result in carbon sequestration (Sahrawat, 2003). In the present scenario of differing climatic parameters such as temperature and annual rainfall in some areas of the country, it will continue to remain as a potential threat for carbon sequestration in tropical soils of the Indian sub-continent. Therefore, the arid climate will continue to remain as a bane for Indian agriculture because this will cause soil degradation in terms of depletion of organic carbon and formation of pedogenic $CaCO_3$ with the concomitant development of sodicity and /or salinity (Eswaran et al., 1993).

Although, tropical regions have limitation of sequestering carbon in soil due to high temperatures, adoption of appropriate management practices helps in sequestering reasonable quantities of carbon in some cropping systems particularly in high rainfall regions (Srinivasarao et al., 2009b, 2011b, 2012d). The potential of cropping systems can be divided in to that of soil carbon sequestration and sequestration in to vegetation. Tree based systems can sequester substantial quantities of carbon in to biomass in a short period. Total potential of soil C sequestration in India is 39 to 49 Tg $year^{-1}$ (Lal 2004a). This is inclusive of the potential of the restoration of degraded soils and ecosystems which is estimated at 7 to 10 Tg C $year^{-1}$ (Table 2). The potential of adoption of recommended package of practices on agricultural soils 6 to 7 Tg $year^{-1}$. In addition, there is also a potential of soil inorganic carbon sequestration estimated at 21.8 to 25.6 Tg C $year^{-1}$. Long term manurial trials conducted in arid regions of Andhra Pradesh (at Anantapur) under rainfed conditions indicate that the rate of carbon sequestration in groundnut production system varied from 0.08 to 0.45 Mg ha^{-1} $year^{-1}$ with different nutrient management systems (Srinivasarao et al., 2009a). Under semi arid conditions in Alfisol region of Karnataka, the rate of carbon sequestration was 0.04 to 0.38 Mg ha^{-1} $year^{-1}$ in finger millet system under diverse management practices. Under *rabi* sorghum production system in vertisol region of Maharashtra (semi arid) the sequestration rate ranged from 0.1 to 0.29 Mg ha^{-1} $year^{-1}$ with different integrated management options. In soybean production system in black soils of Madhya Pradesh (semi arid) the potential rate of carbon sequestration is up to 0.33 Mg ha^{-1} $year^{-1}$ in top 20 cm soil depth.

Recent studies on changes of carbon in soils of SAT have shown that over a period of nearly 25 years, SOC stock has increased from 34 to118%. This has been possible due to adoption of the management interventions. Thus appropriate management interventions in maintaining the capability of productive soils and also to raise the productivity of less productive soils are capable of enhancing organic carbon storage capacity of Indian soils. The sink capacity of SOM for atmospheric CO_2 can be greatly enhanced when degraded soils and ecosystems are restored, marginal agricultural soils are converted to a restorative land use or replaced to perennial vegetation and Recommended Management Practices (RMPs) adopted in agricultural soils (Table 2 and Figure 4) (Lal 1997, 2009). Soil carbon sequestration potential by restoring degraded soils is presented in Table 2.

Table 2. Soil organic carbon (SOC) sequestration potential through restoration of degraded soils

Degradation process	Area (m ha)	SOC sequestration rate (kg ha^{-1} y^{-1})	Total SOC sequestration potential (Tg C y^{-1})
Water erosion	32.8	80-120	2.62-3.94
Wind erosion	10.8	40-60	0.43-0.65
Soil fertility decline	29.4	120-150	3.53-4.41
Waterlogging	3.1	40-60	0.12-0.19
Salinization	4.1	120-150	0.49-0.62
Lowering of water table	0.2	40-60	0.01-0.012
Total			7.20-9.82

Table 3: Comparison between traditional and recommended management practices in relation to soil organic carbon sequestration

S.No.	Traditional methods	Recommended Management Practices (RMPs)
1	Biomass burning and residue removal	Recycling of residues
2.	Conventional tillage and clean cultivation	Conservation tillage, no till and mulch farming
3	Bare/idle fallow	Growing cover crops during off season preferably legumes
4	Continuous monoculture	Crop rotation with high diversity
5	Low input subsistence farming and soil fertility mining	Judicious use of farm inputs
6	Intensive use of chemical fertilisers	Integrated nutrient management with compost, bio solids and nutrient recycling, precision farming
7	Intensive cropping	Agro-Forestry, Argi-Sylvi-Horti systems etc wherever feasible
8	Surface flood irrigation	Drip, furrow or sub-irrigation
9	Indiscriminate use of pesticides	Integrated pest management
10	Cultivating marginal soils	Conservation reserve program. Restoration of degraded soils through land use change

(Lal, 2004b)

Figure 4. Scenerio of cotton crop residue burning (left) and incorporation of green manure crop (right) at farm level

Strategies to enhance soil organic carbon in India

Various management options which can improve the SOC status are crop residue recycling, farm yard manure, biofertilizers, inclusion of legumes in the cropping sequence or as intercrops, green manure crops, green leaf manuring, tank silt addition, vermicomposting along with chemical fertilizers besides improving crop productivity (Srinivasarao et al., 2011d; 2013a, 2014). The most important technological options for on farm generation of organic matter to improve soil health, crop productivity and mitigation of droughts are given below:

1) Crop residue recycling
2) Conservation agriculture
3) Green manuring/green leaf manuring
4) Composting (field crops, vegetable and fruit waste)
5) Silt recycling through tank silt
6) Pulses, Food legume and intercrops
7) Biochar (field crops, forest residue)
8) Cover crops and incorporation

Residue management

For sustainable rainfed agriculture, the management of crop residues must form an integral part of the future tillage practices. There are several options available to farmers for the management of crop residues, including burning-the common practice, baling and removal, incorporation and surface retention. Burning, in addition to promoting loss of organic matter, nutrients and soil biota, also causes air pollution and associated ill effects on human and animal health. Baling is not practiced at the farmer level. Removal of crop residues is a loss of organic sources for soil health but is necessary to feed livestock and sustain mixed farming. Incorporation is a better option but it requires large amounts of energy and time; leads to temporary immobilization of nutrients, especially nitrogen; and the C: N ratio needs to be corrected by applying additional amount of nitrogen at the time of incorporation.

Soil carbon sequestration through restoration of degraded soils

Although India receives relatively high rainfall, there are large temporal and spatial variations. Unlike temperate countries, rainfall occurs in high intensity storms carrying away top soil through runoff. Because of the skewed distribution of the rainfall, crops invariably experience water stress. Therefore, soil and water conservation and harvesting of surplus runoff are of paramount importance. The total water received through annual precipitation in India is estimated at 400 M ha m. About 300 M ha m is received during June to September, while another 100 M ha m during the rest of the year. About 20 M ha m of runoff is brought from outside India, thus making a total of 420 M ha m of water resource for use. The cardinal principles of soil and water conservation are: (i) conserve rainfall by reducing runoff losses and by storing as much as possible in the profile and (ii) adopt farm practices to make the most efficient use of the soil moisture by crops. In the beginning, physical structures like bunding were emphasized, but more recently the focus shifted to field- and community-based *in situ* conservation practices. The main aim of these practices is to reduce or prevent either water erosion or wind erosion, while providing the desired moisture for crop production. Based on past experiences, several field based soil and water conservation measures have been found promising for various rainfall zones in India (Table 4).

Table 4. Recommended soil and water conservation measures for various rainfall zones in India.

Seasonal rainfall (mm)			
<500	500-700	750-1000	>1000
Contour cultivation with conservation furrows Ridging Sowing across slopes Mulching Scoops Tied ridges Off-season tillage Inter row water harvesting system Small basins Contour bunds Field bunds Khadin	**Contour cultivation with** conservation furrows Ridging Sowing across slopes Scoops Tide ridges Mulching Zingg terrace Off-season tillage BBF Inter row water harvesting system Small basins Modified contour bunds Field bunds Khadin	**BBF (Vertisols)** Conservation furrows Sowing across slopes Tillage Lock and spill drains Small basins Field bunds Vegetative bunds Graded bunds Nadi Zingg terrace	**BBF (Vertisols)** Field bunds Vegetative bunds Graded bunds Chos Level terraces

(Srinivasarao et al., 2015a)

On-Farm Generation of organic matter

Green leaf manuring of *Gliricidia sepium* is the most promising and climate friendly technology. Green leaf manure plants such as *gliricidia* can play an important role in tropical farming systems for increasing the soil fertility. Commonly known as Kakawate, used as insecticide, repellant and rodenticide, can thrive in dry moist, acidic soils or even poor degraded, infertile soils under rain fed conditions. Green leaf manuring is one of the important farming practices for increasing organic matter content in the soil. In highly degraded soils, especially in the tropics, soils lack sufficient amount of nitrogen (N). Green leaf manure plants such as gliricidia can play an important role in tropical farming systems for increasing the soil fertility. Growing gliricidia plants on farm bunds serves dual purpose of producing green leaf manure rich in N, under field conditions and also helps in conserving soil through reduced soil erosion (Srinivasarao et al., 2012e).

Figure 5. Gliricidia plantation on field bunds at Gunegal Research Farm, CRIDA

Integrated Nutrient Management

Considerable research on Integrated Plant Nutrient Supply (IPNS) has been done in India. Long-term fertilizer experiments both under irrigated as well as rainfed conditions have shown that addition of organic manures in addition to NPK results in high yields over a long period of time as compared to a decline in yield over time when only chemical fertilizers are applied, besides improving SOC content. Though benefits of organic manure application at least to replace some of the nutrient requirements of crops were well established, its usage is declining over the years. Application and management of chemical fertilizers to crops is much easier and less labor intensive while organic manure preparation, storage, transport, application etc, are cumbersome. A number of organic resources are available in India such as FYM, crop residue, live stock dung, green leaf manures, compost and vermi-compost, farm waste, municipal waste, etc, accounting up to 1400 million tones annually.

IPNS is also relevant for rainfed agriculture. The practice of effective use of chemical and organic sources of nutrients in a proper proportion not only reduces the requirement of chemical fertilizers but also improves physical conditions of soil and enhances soil water retention. Grain yields of finger millet with optimum NPK application were similar to those obtained from 50 % NPK and 10 Mg ha^{-1} FYM in an Alfisol at Bangalore. A three year's study on an Alfisol at Hyderabad revealed that conjunctive use of organic sources of N such as loppings+ twigs of N fixing trees like *Gliricidia maculata or Leucaena leucocephala* + urea in 1:1 ratio (equivalent to 40 and 80 kg N ha^{-1}) gave 17.2 and 16.9 q/ha yield of grain sorghum, respectively which were equal to that obtained with 100% N applied through urea alone. The apparent recovery of N applied was more at 41.5% with conjunctive application. There are several other reports of better performance of fertilizers when used in combination with organic sources. The predominant integrated nutrient management (INM) recommendations for rainfed crops are listed in Table 5. The advantages of IPNS approach in arid region is also well documented. This practice also helped in improving N use efficiency of urea and fertility status of soil. Other studies on nutrient management in arid regions (rainfed) clearly indicate a positive effect of organic manures, legume based crop rotation and crop residue incorporation in maintaining soil fertility for a sustainable crop production.

Table 5. Effective Integrated Nutrient Management (INM) practices for rainfed crops across the country

Location		Fertilizer (kg ha^{-1})			
		N	P_2O_5	K_2O	
Jhansi	Cluster bean Sorghum + Dolichos	15 60	60 20	0 0	Inoculation with *Rhizobium*
Rajkot	Sorghum Pearlmillet Groundnut Cotton	90 80 12 40	30 40 25 0	0 0 0 0	FYM@ 6 t ha^{-1} FYM @ 6 t ha^{-1} FYM @ 6 t ha^{-1} FYM @ 6 t ha^{-1}
Solapur	Sorghum	50	0	0	9-10 t ha^{-1} subabul loppings can substitute 25 kg N ha^{-1}
Indore	General Soybean	(N plus P) 20	 13	 0	4-6 t ha^{-1} FYM in alternate years FYM@ 6 t ha^{-1}
Bijapur		(NP or NPK)			Mulching with tree lopping @ 5 t ha^{-1}
Arjia	Corn – pigeonpea Safflower and rapeseed-mustard	50 30	30 15	0 0	50 % N through organics. Reduction in N by half if these crops follow legumes such as greengram/chickpea
Agra	Barley	60	30	0	Use of FYM plus *Azotobacter*
Ranchi	Soybean Groundnut Pulses	20 25 20	80 50 40	40 20 0	Inoculation with *Rhizobium* Inoculation with *Rhizobium* Inoculation with *Rhizobium*
Dantiwada	Greengram	0	20	0	Inoculation with *Rhizobium*
Jodhpur	Pearlmillet	10	0	0	Addition of 10 t ha^{-1} FYM
Hoshiarpur	Corn Wheat Chickpea	80 80 15	40 40 40	20 0 0	Addition of FYM
Akola	Cotton + greengram	25	25	0	Along with FYM to meet 25 kg N ha^{-1}

Figure 6. Conservation agriculture systems in maize-horsegram system in rainfed Alfisols in Southern India

In rainfed dryland ecosystems, implementing these three components (reduced tillage, surface cover and legume crop rotation) is not possible unless some insurance of water availability is ensured. That is why successful CA system in rainfed regions need to have fourth component i.e., water conservation treatment (Figure 8). Such systems reduce soil loss, organic carbon loss and provides opportunity to include legume crop in the system.

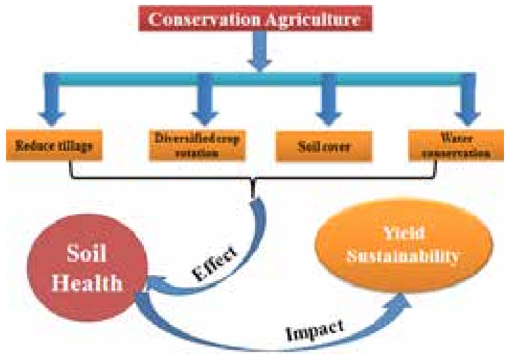

Figure 8. Modified conservation agriculture principles for rainfed–dryland ecosystems.

Biomass based biogas production

A large amount of energy is used in cultivation and processing of crops like sugarcane, food grains, vegetables and fruits, which can be recovered by utilizing residues for energy production. This can be a major strategy for climate change mitigation by avoiding burning of fossil fuels and recycling crop residues. The integration of biomass-fuelled gasifiers and coal-fired energy generation would be advantageous in terms of improved flexibility in response to fluctuations in biomass availability with lower investment costs. Waste-to-energy plants offer twin benefits of environmentally sound waste management and disposal, as well as the generation of clean energy (Srinivasarao et al., 2010).

Livestock production has been an integral part of agriculture in India. Livestock provides an excellent recycling arrangement for most of crop residue. Most by products of cereals, pulses and oilseeds are useful as feed and fodder for livestock while that of other crops like cotton, maize, pigeonpea, castor and sunflower and sugarcane are used as low calorie fuel or burnt to ashes or left in open to decompose over time. Ideally such residue is incorporated into soil to enhance physical properties of the soil and its water holding capacity. Lack of availability of proper chopping and soil incorporation equipment is one of the major reasons for the colossal wastage of agricultural biomass in India. Increased cost of labour and transport is another reason for lack of interest in utilizing the biomass. This is one area where little or no effort has gone in despite availability of opportunities for reasons such as aggregation, transport and investment in residue processing facilities. Many technologies like briquetting, anaerobic digestion vermi-composting and biochar etc. exist, but they have not been commercially exploited. This area is gradually receiving attention now as a means to producing clean energy by substituting forest biomass for domestic needs. Modest investments in decentralized facilities for anaerobic digestion of agricultural residue through vermi-composting and biogas generation can meet the needs of energy-deficit rural areas and simultaneously contribute to climate change mitigation. There is renewed interest in the use of anaerobic digestion processes for efficient management and conversion of cattle dung and other agro industrial wastes (livestock, paper and pulp, brewery and distillery) into clean renewable energy and organic fertilizer source. The biogas captured could not only mitigate the potential local and global pollution but could either be combusted for electricity generation using combined heat and power generator in large to medium enterprises or used for cooking and lighting for small households. A 2 m^3 digester can generate up to 4.93 t CO_2e $year^{-1}$ of certified emission reduction (CER). Animal wastes are generally used as feedstock in biogas plants. But, the availability of these substrates is one of the major problems hindering the successful operation of biogas digesters. It was reported that the availability of cattle waste could support only 12–30 million family-size biogas plants against the requirement of 100 million plants. A significant portion of 70–88 million biogas plants can be run with fresh/dry biomass residues. Of the available 1,150 billion tons of biomass, a fifth would be sufficient to meet this demand. Ultimately biogas residue need to be linked to composting or vermi-composting. Then, divert that compost to soil to improve SOC.

Biochar

When biomass is exposed to moderate temperatures, between about 400 and 500°C (a kind of low-temperature pyrolysis), under complete or partial exclusion of oxygen, biomass undergoes exothermic processes and releases a multitude of gases in addition to heat along with biochar. Pyrolysis produces biochar, a carbon-rich, fine-grained, porous substance and solid byproduct, similar in its appearance to charcoal, which when returned to soil, produces a range of environmental benefits, such as enhanced soil carbon sequestration and soil fertility improvement. Both heat and gases can be captured to produce energy carriers such as electricity, hydrogen or bio-oil which can be used as a fuel for various purposes in the process of manufacturing biochar. In addition to energy, certain valuable co-products, including wood preservative, food flavoring, adhesives etc. can be obtained (Venkatesh et al., 2011).

This is a novel approach to sequester carbon in terrestrial ecosystems which has several associated products in the process of its manufacture and also the end product. In India, it has been projected that about 309 Mt of biochar could be produced annually, the application of which might offset about 50 % of carbon emission (292 Tg C $year^{-1}$) from fossil fuel (Lal et al., 2003). Rice-wheat cropping system in the Indo-Gangetic plains of India produces substantial quantities of crop residues, and if these residues can be pyrolysed, 50 % of the carbon in biomass is returned to the soil as biochar, increasing soil fertility and crop yields, while sequestering carbon. Addition of biochar to soil has also been associated with enhanced nutrient use efficiency, water holding capacity and microbial activity. At CRIDA, research on biochar use in rainfed crops has been initiated. Biochar from castor, cotton and maize stalks was produced by using a portable kiln and used as an amendment for pigeonpea during *kharif* 2010. The crop growth was significantly superior in biochar applied plots from all three sources (Venkatesh et al., 2013).

Agroforestry

Agroforestry systems like agri-silvi-culture, silvipasture and agri-horticulture offer both adaptation and mitigation opportunities. Agroforestry systems buffer farmers against climate variability, and reduce atmospheric loads of greenhouse gases. Agroforestry can both sequester carbon and produce a range of economic, environmental, and socioeconomic benefits; the extent of sequestration can be upto 10 t ha^{-1} $year^{-1}$ in short rotation *Eucalyptus*, *leucaena* plantations. Agrisilviculture systems with moderate tree density with intercrops have however lower potential.

Critical carbon input requirement for organic carbon maintenance

A long-term field experiment conducted on an Aridisol in western India was used to examine the effects of chemical fertilizers and manuring on total organic carbon (TOC), microbial biomass carbon (MBC), and particulate organic carbon (POC) in relation to crop productivity and C sequestration. The 18 years study involved perlmillet (*Pennisetum glaucum*)-clusterbean (*Cyamopsis tetragonaloba*)-castor (*Ricinus communis*) rotation with different soil fertility management. The latter comprised of no fertilization, 100% recommended dose of N (RDN) through chemical fertilizers, 50% RDN, 50% RDN through farm yard manure (FYM), 50% RDN through chemical fertilizers + 50% RDN through FYM, and farmer's method (5 Mg of FYM ha^{-1} once in 3 years). The data showed that even the addition of 33.5 Mg ha^{-1} C inputs through crop residues as well as FYM could not compensate the SOC depletion by oxidation, and resulted in the net loss of 4.4 Mg C ha^{-1} during the 18 year period. Conjunctive use of chemical fertilizers along with FYM produced higher grain yields, reduced the rate of SOC depletion than in treatments without these amendments. For every Mg increase in profile SOC stock there was an overall increase of 0.46 Mg of crop yield, and also in individual grain yield of pearl millet (0.17 Mg ha^{-1} yr^{-1} Mg^{-1} of SOC), cluster bean (0.14 Mg ha^{-1} yr^{-1} Mg^{-1} of SOC) and castor (0.15 Mg ha^{-1} yr^{-1} Mg^{-1} of SOC). The magnitude of SOC build up (R^2=0.93; P<0.05) and SOC sequestration rate (R^2=0.93, P<0.05) were proportional to the C inputs (Table 6; Figure 9). Microbial biomass carbon (MBC) and particulate organic carbon (POC) were significantly correlated (P<0.05) with SOC, which increased with application of organic amendments. Microbial quotient (MQ) and POC/SOC ratio were significantly correlated (P<0.05) with sustainable yield index (SYI). Threshold amount of C input of 3.3 Mg C ha^{-1} $year^{-1}$ was needed to maintain the SOC at equilibrium (Srinivasarao et al., 2011b; Mandal et al., 2008).

Table 6. Relationships between different forms of carbon, carbon inputs, soil carbon sequestration rate and sustainable yield index (SYI) of pearl millet based systems in arid tropical conditions

Independent variable		Regression equation	Coefficient of determination (R^2)
Carbon sequestration rate		Y(Pearlmillet)=0.02X+0.34	0.67
		Y(clusterbean)=0.05X+0.84	0.77
		Y(castor)=0.01X+0.5	0.56
Total carbon inputs		Y(Pearlmillet) =0.003X+0.17	0.45
		Y(clusterbean)=0.008X-0.29	0.56
		Y(castor)=0.002X+0.36	0.45
Profile mean SOC content		Y(Pearlmillet) =2.01X-0.07	0.61
	SYI	Y(clusterbean)=5.99X-0.44	0.77
		Y(castor)=1.64X+0.16	0.64
Microbial biomass carbon		Y (Pearlmillet) =0.004X+0.004	0.74
		Y(clusterbean)=0.01X-0.22	0.95
		Y(castor)=0.003X+0.21	0.86
Particulate organic carbon		Y(Pearlmillet) =0.0002X-0.009	0.10
		Y(clusterbean)=1.81X-0.05	0.79
		Y(castor)=0.55X+0.013	0.79

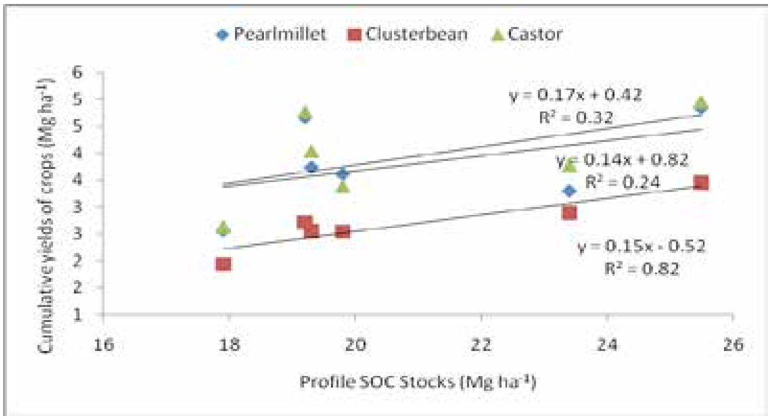

Figure 9. Influence of SOC stocks to 1-m depth on yields of individual crops in 18 year long term pearlmillet-clusterbean-castor rotation in arid condition (Srinivasarao et al., 2011b; 2012c).

Policy Issues

Apart from the use of technological advances to combat climate change, there has to be sound and supportive policy framework. The frame work should address the issues of redesigning social sector with focus on vulnerable areas/ populations, introduction of new credit instruments with deferred repayment liabilities during extreme weather events, weather insurance as a major vehicle to risk transfer. Government initiatives should be undertaken to identify and prioritize adaptation options in key sectors (storm warning systems, water storage and diversion, health planning and infrastructure needs). Focus on integrating national development policies into a sustainable development framework that complements adaptation should accompany technological adaptation methods (Venkateswarlu et al., 2009).

In addition, the role of local institutions in strengthening capacities e.g., SHGs, banks and agricultural credit societies should be promoted. Role of community institutions and private sector in relation to agriculture should be a matter of policy concern. There should be political will to implement economic diversification in terms of risk spreading, diverse livelihood strategies, migrations and financial mechanisms. Policy initiatives in relation to access to banking, micro-credit/ insurance services before, during and after a disaster event, access to communication and information services is imperative in the envisaged climate change scenario. Some of the key policy initiatives that are to be considered are: mainstreaming adaptations by considering impacts in all major development initiatives facilitate greater adoption of scientific and economic pricing policies, especially for water, land, energy and other natural resources. There is a urgent need for a national soil policy. Consider financial incentives and package for improved land management and explore Clean Development Mechanism (CDM) benefits for mitigation strategies. Establish a "Green Research Fund" for strengthening research on adaptation, mitigation and impact assessment.

Advances in carbon sequestration research

While several techniques of monitoring soil C stock and fluxes exist, and rapid advances are being made in measuring and scaling procedures. Recent new understanding of the chemical nature of SOM indicates that innovative and sustainable technologies may be applied to sequester carbon. Some of the advances in carbon sequestration are listed below:

- Developing a national database on current and potential rates of terrestrial carbon sequestration for diverse land uses and soil/vegetation/wetland management options.
- Establishing relationship between soil carbon and soil quality in relation to total biomass and economic productivity.
- Standardizing new and innovative methods of carbon determination in vegetation and soil.

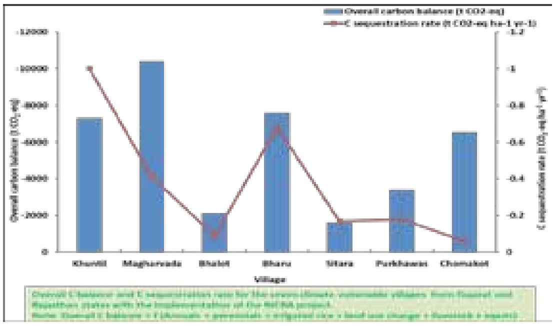

Figure 10. Village level carbon balance computed with Ex-Ante analysis with the climate resilient interventions

Future Line of work

1) Carbon stock monitoring in Indian soils should be taken at least 5 years interval. The locations, where organic carbon content is decreased, special attention should be taken in order to protect soil health and crop productivity.
2) Efforts are needed to create large scale awareness against burning of crop residues both in irrigated and rainfed agriculture.
3) CA practices and their promotion need higher priority.
4) Critical carbon input requirements for major agro ecological regions need to be computed and efforts should be on to promote organic matter additions where ever possible.
5) On-farm generation of organic matter in terms of gliricidia should be promoted.
6) Any conservation practice which reduces soil loss in North-East hill regions should be transferred to farmer fields and large scale on-farm adaptation of various conservation measures need urgent attention.

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Organic Farming Towards Climate Change Adaptation and Mitigation

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The current change in global climate is a phenomenon that is largely due to the burning of fossil energy (coal, oil, natural gas) and to the mineralization of organic matter as a result of land use. These processes have been caused by mankind's exploitation of fossil resources, clearing of natural vegetation and use of these soils for arable cropping. These activities have primarily led to a measurable increase in the carbon dioxide (CO_2)content of the atmosphere, an increase which results in global warming, as CO_2 hinders ther eflection of sunlight back into space, and thus more of it is trapped in the Earth's atmosphere (Srinivasarao et al., 2015b; Prasad et al., 2015). Molecules of methane (CH_4) and nitrous oxide (N_2O) have a similar, but far greater effect: the global warming potential of methane is twenty times that of CO_2, while that of nitrous dioxideis as much as 300 times greater. Intergovernmental Panel on Climate Change (IPCC, 2007) has reported greenhouse gas emissions classified by different sectors as shown in figure 1.

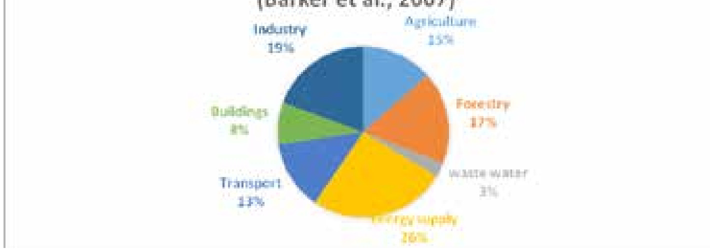

Figure 1: Greenhouse gas emissions by sectors (Barker et al., 2007)

When calculating the climate impact of a certain production type it is always a question, where to put the cut-off points of a particular system. For instance, agricultural emissions as shown in figure 1 do not comprise emissions from fertilizer production, which are counted under industry. This needs to be taken into account when comparing farming systems. When considering the total food chain from the farm to the consumer, emissions from all the other sectors need to be included. Thus, the greenhouse gas emissions from all sectors related to agriculture may potentially sum up to 25-30% of all GHG emissions. According to the Intergovernmental Panel on Climate Change (IPPC), the annual amount of greenhouse gases emitted by the agricultural sector is estimated at between 5.1 and 6.1 giga tonnes CO_2 equivalents (Barker et al., 2007). This represents approximately 10–12% of total greenhouse gas emissions. Agriculture is the main emitter of nitrous oxides and methane according to current practice and knowledge.

Agriculture is not only a fundamental human activity at risk from climate change, it is a major driver of environmental and climate change itself. It has the largest human impact on land and water resources. About 1.4 billion ha of arable land are used for crop cultivation and an additional 2.5 billion ha are used for pasture. In addition to land resources, agriculture is a major user of water. Over 200 million ha of arable land is under irrigation, utilizing 2 500 billion m^3 of water annually, representing 75 percent of fresh water resources withdrawn from aquifers, lakes and rivers by human activity. Irrigation sustains a large portion of total food supply – about 40 percent in the case of cereals. Finally, significant quantities of chemical inputs are applied to achieve high yields in intensive production systems including about 100 million tonnes of nitrogen used annually, leading to significant regional pollution (Tubiello, 2012).

As a result of these large-scale activities, agriculture is a significant contributor to land degradation and, in particular, a major emitter of greenhouse gases. It emits into the atmosphere 13-15 billion tonnes CO_2 per year, about a third of the total from human activities. Overall, agriculture is responsible for 25 percent of carbon dioxide (largely from deforestation), 50 percent of methane (rice and enteric fermentation), and more than 75 percent of N_2O (largely from fertilizer application) emitted annually by human activities (Figure 2). If emissions of greenhouse gases, including those from agriculture, are not controlled in the coming decades, continued growth of their atmospheric concentrations is projected to result in severe climate change throughout the twenty-first century (Smith *et al.*, 2007).

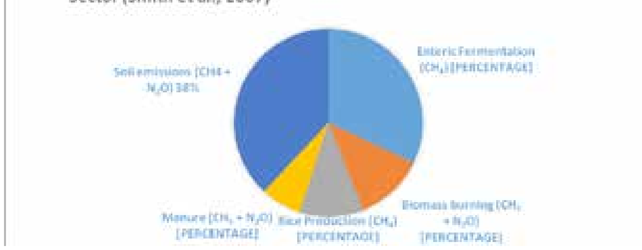

Figure 2: Main Sources of Green Gas Emissions in Agricultural Sector (Smith et al., 2007)

2.Effect of Climate Change on Agriculture

Climate change has both direct and indirect effects on agricultural productivity including changing rainfall patterns, drought, flooding and the geographical redistribution of pests and diseases (IPCC, 2013). Climate change hampers the food production systems and thereby the livelihoods and food security of billions of people across the globe (Srinivasarao et al., 2015a; 2011). Marginalized populations in developing economies will suffer from climate change impacts disproportionately in comparison with wealthier and industrial countries (IPCC, 2007). Coupled with these imminent threats, these countries lack the resources to prepare for and cope with environmental risks. Further agriculture sector is most vulnerable to climate change due to its high dependence on weather and because people involved in agriculture tend to be poorer compared with their urban counterparts (Srinivasarao, 2016; 2011).

Climate change projections for Indian sub-continent indicate an increase in temperature by 3.3 – 4.8^0 C by 2080s relative to pre-industrial times. There are already evidences of negative impacts on yields of wheat and paddy in some parts of India due to increased temperature, water stress and reduction in number of rainy days. Under medium-term (2020 – 2039) climate change scenario, crop yield is projected to reduce by 4.5 to 9%, depending on the magnitude and distribution of warming (NICRA, 2013). In view of the climate change implications, enhancing and sustaining agricultural productivity, is critical for ensuring food and nutritional security of future generations in India. Climate risks are best addressed through increasing adaptive capacity and building resilience that reduce adverse impacts of climate change (FAO, 2013).

Climate risks are best addressed through increasing adaptive capacity and building resilience, which can bring immediate benefits and can also reduce the adverse impacts of climate change. Climate resilient agriculture (CRA) encompasses the incorporation of adaptation and resilient practices in agriculture, which increases the capacity of the system to respond to various climate-related disturbances by resisting damage and ensures quick recovery (Srinivasarao et al. 2016).

3.Concept of Organic Farming

Organic farming is one among the broad spectrum of production methods that are supportive of the environment. Organic production systems are based on specific standards precisely formulated for food production and aim at achieving agro ecosystems, which are socially and ecologically sustainable. It is based on minimizing the use of external inputs through the use of on-farm resources efficiently compared to in conventional agriculture (Ramesh et al., 2005). Thus the use of synthetic fertilizers and pesticides is avoided. The basic principles and aims of organic farming are listed below:

1. Organic farming is a holistic production management system, which promotes biodiversity and biological activity. It actually promotes and enhances ecosystem health, while at the same time producing food. It is based on the low use of external inputs and non-use of artificial fertilizers and pesticides. It also takes into account the fact that regional conditions require locally adapted systems.
2. Organic farming develops a system that ensures that all forms of life, from microbes to livestock, are conserved, productively utilized and are also treated with respect and concern, keeping in view their health, safety and natural behavioral needs.
3. Organic farming as far as possible employs farm inputs which can be reused or recycled, are generated on-site and which cause minimal pollution in the local external environment. It specially excludes all products and processes of genetic engineering and related technologies.
4. Organic farming produces food diversity that is free from toxins and of high nutritional value and good shelf life adequate quantities and of a quality suitable for direct consumption and small scale processing.
5. Organic farming protects and promotes all forms of diversity, social, cultural (the biodiversity knowledge base inclusive of arts, crafts, music etc.) along with systems of organizational and political governance especially at local level.

According to Codex Alimentarius Commission (FAO/WHO, 1999), “Organic agriculture is defined as a holistic production management system which promotes and enhances agro-ecosystem health, including biodiversity, biological cycles, and soil biological activity. It emphasises the use of management practices in preference to the use of off-farm inputs, taking into account that regional conditions require locally adapted systems. This is accomplished by using, where possible, agronomic, biological, and mechanical methods, as opposed to using synthetic materials, to fulfil any specific function within the system.”

According to National Programme for Organic Production (NPOP) of Agricultural & Processed Products Export Development Authority of India (APEDA, 2008), “organic farming is defined as a system of farm design and management to create an eco-system, which can achieve sustainable productivity without the use of artificial external inputs such as chemical fertilizers and pesticides.” Organic products are grown under a system of agriculture without the use of chemical fertilizers and pesticides with an environmentally and socially responsible approach. This is a method of farming that works at grass root level preserving the reproductive and regenerative capacity of the soil, good plant nutrition, and sound soil management, produces nutritious food rich in vitality which has resistance to diseases.

Currently, organic agriculture is being adopted in 179 countries across the globe with a total cultivated area of 50.0 m ha (2015-16). India’s rank in terms of world’s organic agricultural land was 15 as per 2013 data (FIBL & IFOAM

Year, 2015). The total area under organic certification in the country is **5**.71 m ha (2015-16). This includes 26% cultivable area with 1.49 million Hectare and rest 74% (4.22 million Hectare) forest and wild area for collection of minor forest produces. India produced around 1.35 million MT (2015-16) of certified organic products which includes all varieties of food products namely Sugarcane, Oil Seeds, Cereals & Millets, Cotton, Pulses, Medicinal Plants, Tea, Fruits, Spices, Dry Fruits, Vegetables, Coffee etc. The production is not limited to the edible sector but also produces organic cotton fiber, functional food products etc.

4.Characteristics and Advantages of Organic Farming

4.1 Limited External Input

The use of external inputs is limited in organic farming systems. Synthetic inputs like mineral fertilizers and chemical pesticides are banned. The energy used for the chemical synthesis of nitrogen fertilizers, which are totally excluded in organic systems, represent up to 0.4–0.6 $GtCO_2$ emissions. This is as much as 10% of direct global agricultural emissions and around 1% of total anthropogenic GHG emissions (EFMA, 2005). The reduced dependency on energy inputs in organic agriculture reduces vulnerability to rising energy prices, and hence volatility of agricultural input prices. Nitrogen fertilizer prices rose by 160% during the first quarter of2008 (FAO, 2008), and price hikes are expected to recur with peak oil and climate change, further limiting the access for poor rural populations to agricultural inputs. Organic agriculture can be a promising approach to sustain food security by supplying alternatives to agricultural inputs.

4.2 Crop Diversification

By abstaining from synthetic input use, organic agricultural systems cannot but adapt to local environmental conditions. Therefore, species and varieties are chosen for their adaptability to the local soil and climate and their resistance to local pests and diseases. Organic farmers prefer not to use uniform crops and breeds and opt for more robust traditional species, which they tend to conserve and develop. Additionally, growing different assemblages of crops in time and space seeks to enhance the agro-ecosystem resilience to external shocks such as extreme weather events or price variation (Smith and Lenhart, 1996; Thimmagowda et al., 2016), which are all risks most likely to increase as the climate changes (Smith et al., 2007). The diversification of cropping systems also makes more efficient use of available nutrients, with improved productivity and economic performance, which is of high importance in times of limited nutrients and financial constraints (Zhang and Li, 2003).

4.3 Integrated Livestock Production

To be successful, organic agriculture must integrate plant and livestock production to the extent possible to optimize nutrient use and recycling (Gopinadh et al., 2014; 2012). Landless livestock production systems can rarely be found in organic agricultural systems. According to the EU regulations on organic production, livestock units must not exceed 2 units per hectare, which is equivalent to approximately 170 kg N. Therefore, manure input is tailored to plant uptake capacities, an aspect which is recommended as a mitigation strategy by the IPCC in order to reduce N2O emissions and leaching (Smith et al., 2007). But, this aspect of organic standards of other regions needs to be further developed to meet the International Federation of Organic Agricultural Movements (IFOAM) principle of a harmonious balance between crop production and animal husbandry.

4.4 Production and Productivity

Conversion to organic farming affects the crop productivity, and the yields depend upon the farming situation:

i. In intensive farming systems, organic agriculture decreases yield, the range depends on the intensity of external input use before conversion (Stanhill, 1990).

ii. In the green revolution areas (irrigated lands), conversion to organic farming usually leads to almost identical yields (Rajendran et al., 2000).

iii. In traditional rain-fed agriculture (with low external inputs), organic farming has shown the potential to increase yields (Huang, 1993).

In general, the productivity of crops in organic farming is lower compared to the conventional chemical farming. This raises the issue whether India can afford to adopt organic farming? However, field experiments conducted in the last few years on the productivity of crops in organic farming (Ramesh et al., 2006, 2007, 2008 and 2009) and the data obtained from the survey of certified organic farms in India may give certain answers in this direction. The results of the long-term experiments at Bhopal, Madhya Pradesh (Ramesh et al., 2009) revealed that the productivity of soybean under organic manuring is lower (7.8 and 5.3 % less) in the initial two years (2004 and 2005) compared to chemical fertilizers, but in the subsequent years (2006 and 2007), the productivity was improved by 10.6 and 11.1 %. Similar results were also reported with reference to the productivity of crops such as wheat, mustard, chickpea and isabgol. It is also reported that a suitable combination of organic manures as nutrient source is better for sustaining crop productivity under organic nutrition compared to chemical fertilizer application (Ramesh et al., 2009).

4.5 Soil Quality and Fertility

Long-term application of organic manures for the production of crops in organic farming is known to improve the soil quality and fertility. Experiments conducted at Bhopal, Madhya Pradesh revealed that organic manures application significantly improved the soil physical, chemical and biological parameter compared to the chemical fertilizer application in different cropping systems (Ramesh et al., 2006, 2008, 2009, 2010, Panwar et al., 2010).

In a survey conducted on certified organic farms in India (Ramesh et al., 2010) showed that, on an average there was 29.7 % increase in organic carbon of soils in organic farms (1.22 %) compared to the conventional farms (0.94 %), which is a good indicator of soil quality as it works as a sink for all nutrients and known for improving all soil physical and biological properties of soil. Soil quality indicative enzymes like dehydrogenase, alkaline phosphatase and microbial biomass carbon were higher in organic soils by 52.3, 28.4 and 34.4 % respectively compared to conventional farms.

4.6 Crop / Food Quality

There is a growing demand for organic food driven primarily by the consumer's perception of the quality and safety of these foods and to the positive environmental impact of organic agricultural practices. The 'organic' label is not a health claim; it is a process claim. It has been demonstrated that organically produced foods have lower levels of pesticides and veterinary drug residues and in many cases lower nitrate contents (Woese et al., 1997). No clear trend has, however, been established in terms of organoleptic quality differences between organically and conventionally grown foods.

4.7 Economics of organic farming

Studies have shown that the common organic agricultural combination of lower input costs and favorable price premiums can offset reduced yields and make organic farms equally and often more profitable than the conventional farms (Hansen et al., 1997). Studies that did not include organic price premiums have mixed results on profitability (Welsh, 1999). A survey on the certified organic farms in India showed that on an average, there was a reduction in the cost of cultivation by 11.7 % compared to conventional farming. However, due to the availability of premium price (20- 40 %) for organic produce in most cases, the average net profit was 22 % higher in organic compared to the conventional farming (Ramesh et al., 2010).

4.8 Environmental Benefits of Organic Farming

The impact of organic agriculture on natural resources favours interactions within the agro-ecosystem that are vital for both agricultural production and nature conservation (Gopinadh et al., 2011). Ecological services derived include soil forming and conditioning, soil stabilization, waste recycling, carbon sequestration, nutrient cycling, predation, pollination and habitats (IFOAM, 1998). The environmental costs of conventional agriculture are substantial, and the evidence for significant environmental amelioration via conversion to organic agriculture is overwhelming (Kler et al., 2001).A review of over 300 published reports (Stolze et al., 2000) showed that out of 18 environmental impact indicators(floral diversity, faunal diversity, habitat diversity, landscape, soil organic matter, soil biological activity, soils tructure, soil erosion, nitrate leaching, pesticide residues,CO2, N2O, CH4, NH3, nutrient use, water use and energy use),organic farming systems performed significantly better in12 and performed worse in none.

Organic Farming and Climate Change

Organic Agriculture has a role to play in climate change adaptation and mitigation, including avoided damage and many farming practices contribute to both processes. Agriculture also has the potential to avoid climate change through emission reductions and mitigate climate change through carbon sequestration. While individual practices could be implemented on almost any farm, organic agriculture is unique in creating a whole system of agriculture based on ecological principles from production to consumption by privileging closed energy and nutrient cycles at the farm and by promoting short supply chains. While agriculture's mitigating potential is not nearly enough to prevent climate change from happening, its potential to reduce climate change is quite significant.

Organic agricultural systems have an inherent potential to both reduce GHG emissions and to enhance carbon sequestration in the soil (Table 1). An important potential contribution of organically managed systems is the careful management of nutrients, and hence the reduction of N_2O emissions from soils, which are the most relevant single source of direct GHG emissions from agriculture. More research is needed to quantify and improve the effects of organic paddy rice production and to develop strategies to reduce methane emissions from enteric fermentation (e.g., by promoting double-use breeds). Indirect GHG emissions are reduced inorganic systems by avoidance of mineral fertilizers.

Table 1: Mitigation potential of organic agriculture (Scialabba and Lindenlauf, 2010)

Source of GHG	Share of total anthropogenic GHG emissions	Impacts of optimized organic management	Remarks
Direct emissions from agriculture	10 -12 %		
N_2O from soils	4.2 %	Reduction	Higher N-use efficiency
CH_4 from enteric fermentation	3.5 %	Opposed effects	Increased by lower performance and lower energy concentration in the diet but reduced by lower replacement rate and multi-use breeds
Biomass burning	1.3 %	Reduction	Burning avoided according to organic standards
Paddy rice	1.2 %	Opposed effects	Increased by organic amendments but lowered by drainage and aquatic weeds
Manure handling	0.8 %	Equal	Reduced methane emissions but no effect on N_2O emissions
Direct emissions from forest clearing for agriculture	12 %	Reduction	Clearing of primary ecosystems restricted
Indirect emissions: Mineral fertilizers	1 %	Totally avoided	Prohibited use of mineral fertilizers
Carbon sequestration: Arable lands	-	Enhanced	Increased soil organic matter
Grasslands	-	Enhanced	Increased soil organic matter

The highest mitigation potential of organic agriculture lies in carbon sequestration in soils and in reduced clearing of primary ecosystems. The total amount of mitigation is difficult to quantify, because it is highly dependent on local environmental conditions and management practices. Should all agricultural systems be managed organically, the omission of mineral fertilizer production and application is estimated to reduce the agricultural GHG emissions by about 20% — 10% caused by reduced N_2Oemissions and about 10% by lower energy demand. These avoided emissions are supplemented by an emission compensation potential through carbon sequestration in crop lands and grasslands of about 40–72% of the current annual agricultural GHG emissions (Niggli et al., 2009). However, further research is needed to confirm these figures, as long-term scientific studies are limited and do not apply to different kinds of soils, climates and practices. To date, most of the research on the mitigation potential of agricultural practices has been carried out in developed countries; dedicated investigations are needed to assess and understand the mitigation potential in tropical and subtropical areas and under the predominant management practices of developing countries.

More importantly, the adaptation aspects of organic agricultural practices must be the focus of public policies and research. One of the main effects of climate change isan increase of uncertainties, both for weather events and global food markets. Organic agriculture has a strong potential for building resilience in the face of climate variability (Table 2).

Table 2: Adaptation potential of organic agriculture (Scialabba and Lindenlauf, 2010)

Objectives	Means	Impacts
Alternative to industrial production inputs (i.e. mineral fertilizers and agrochemicals) to decrease pollution	Improvement of natural resources processes and environmental services (e.g. soil formation, predation)	Reliance on local resources and independence from volatile prices of agricultural inputs (e.g. mineral fertilizers) that accompany fossil fuel hikes
In situ conservation and development of agrobiodiversity	Farm diversification (e.g. poly-cropping, agro-forestry and integrated crop/livestock) and use of local varieties and breeds	Risk splitting (e.g. pest and diseases), enhanced use of nutrient and energy flows, resilience to climate variability and savings on capital- intensive seeds and breeds
Landscaping	Creation of micro-habitats (e.g. hedges), permanent vegetative cover and wildlife corridors	Enhanced ecosystem balance (e.g. pest prevention), protection of wild biodiversity and better resistance to wind and heat waves
Soil fertility	Nutrient management (e.g. crop rotations, coralling, cover crops and manuring)	Increased yields, enhanced soil water retention/drainage (better response to drought and floods), decreased irrigation needs and avoid land degradation.

The total abstention from synthetic inputs in organicagriculture has been a strong incentive to developagricultural management practices that optimize the naturalproduction potential of specific agro-ecosystems, based ontraditional knowledge and modern research. These strategies can be used to enhance agricultural communities that have no access to purchased inputs, which is the case of the majority of the rural poor. The main organic strategies are diversification and an increase of soil organic matter, which both could enhance resilience against extreme weather events and are recommended by the IPCC. These strategies have, in particular, a high potential to enhance the productivity of degraded soils, especially in marginal areas, while enhancing soil carbon sequestration. The adaptive approach inherent to organic agriculture offers simultaneous climate mitigation benefits.

Conclusions

The benefits of organic farming regarding climate change can be summarized as follows:

- Organic agriculture has considerable potential for reducing emissions of greenhouse gases.
- Organic agriculture in general requires less fossil fuel per hectare and kg of produce due to the avoidance of synthetic fertilizers. Organic agriculture aims at improving soil fertility and nitrogen supply by using leguminous crops, crop residues and cover crops.
- The enhanced soil fertility leads to a stabilization of soil organic matter and in many cases to a sequestration of carbon dioxide into the soils.
- This in turn increases the soil's water retention capacity, thus contributing to better adaptation of organic agriculture under unpredictable climatic conditions with higher temperatures and uncertain precipitation levels. Organic production methods emphasizing soil carbon retention are most likely to withstand climatic challenges particularly in those countries most vulnerable to increased climate change. Soil erosion, an important source of CO_2 losses, is effectively reduced by organic agriculture.
- Organic agriculture can contribute substantially to agro forestry production systems.
- Organic systems are highly adaptive to climate change due to the application of traditional skills and farmers' knowledge, soil fertility-building techniques and a high degree of diversity.

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THEME VI:
ORGANIC FARMING: EDUCATION AND SOCIO-ECONOMICS

Educational and Employment Opportunities, and Human Resource Development in Organic Farming in India

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Introduction

Green revolution has undoubtedly changed the scenario of food grain production from 'ship-to-mouth' status to self-sufficient and surplus status in India with the increased use of synthetic agro-chemicals such as fertilizers and pesticides, adoption of nutrient-responsive high-yielding varieties of crops, and greater exploitation of irrigation potential, etc. The continuous and indiscriminate use of these high energy inputs under intensive agriculture has led to the deterioration of soil health and the environment, and food safety has become a major concern. Consequently in post-Green revolution era, there has been widespread occurrence of second-generation problems, such as over-mining of soil nutrients, decline in factor productivity, occurrences of multi-nutrient deficiencies, reduction in profitability, lowering of groundwater tables and buildup of pests including weeds, diseases and insects in most of the intensively cultivated, high-productivity, cereal-based production systems, which are threatening the sustainability (Gangwar and Prasad, 2005).Food security is not simply a function of production or supply but also of availability, accessibility, stability of supply, affordability, the provision of adequate quantity and quality and safe nutritious food for all at all times (Boon, 2007; Mclntyre, 2009). Nowadays, awareness of consumers is increasing about food quality and safety. It is due to these problems and concerns, the echo of sustainable and eco-friendly agriculture became louder. Organic farming addresses soil, human, and environmental health, and is eco-friendly, and thus may be one of the options for sustainability (Singh, 2007). In the name of sustainability and eco-friendliness, various new farming concepts, viz., organic agriculture, natural farming, biodynamic agriculture, eco-farming, do-nothing agriculture, homa-farming etc. collectively known as 'organic farming' have been proposed in recent years, with the essential feature remaining same i.e. back to nature (Saini and Pandey, 2009).

Historical farming systems in India were by and large organic, where crop rotation, choice of cultivar for region, and utilization of solar radiation for soil sterilization were used, and soil fertility was maintained through organic manure and symbiotic soil micro-flora. Even presently, much of the forest produce of economic importance, such as herbs, medicinal plants, etc., fall in this category. India, the land of 21 agro-ecological zones already has an added advantage in agriculture due to its different climate and soil patterns facilitating the production of different variety of crops which is definitely a plus point from the view of diversity in organic product and market (Gurung *et al*., 2013). Other additional advantages for going into organic in India are: i. Certain areas referred as "organic by default" like hills, north-east and dryland/rainfed areas as they use traditional agriculture practices for years and have proved to be very good in production of crops as compared to the conventional farming ii. India already holds a very strong position in the market for the quality of certain products like tea, spices, rice specialties and herbs so it works as an additional credit in international market and iii. Cost of labour is relatively cheap than the cost of input, in organic farming farmer is independent of the input cost but it is more labour intensive system. Present paper deals with the opportunities of organic farming in education and employment, and human resource development in India.

Current Status

The total area under organic certification is 5.71m ha (2015-16). This includes 26% cultivable area with 1.49 m ha and rest 74% (4.22 million Hectare) forest and wild area for collection of minor forest produces (APEDA). Sikkim has become India's first fully organic state by implementing organic practices on approx. 75,000 ha of agricultural land (Anonymous, 2016). There has been a consistent increase in the number of certified farmers in the country every year. India has the largest number of organic producers in the world mostly with small holdings. During 2013–2014, India exported 135 products valued at USD 403 million. Major destinations for organic products from India were the U.S., the EU, Canada, Switzerland, Australia, New Zealand, South-East Asian countries, West Asia, and South Africa. Organic farming is growing rapidly among Indian farmers and entrepreneurs, especially in low productivity areas, rainfed/drylandareas, hilly areas, and the NE states, where fertilizer consumption is less than 25 kg/ha/year. Nine states in India have promoted policies and programs on organic farming. Uttrakhand has made organic a thrust for improving its mountain agriculture farm economy and livelihood. Mizoram and Sikkim declared their intentions to move to total organic farming. Karnataka has formulated organic policies, and Maharashtra, Tamil Nadu, and Kerala have supported public–private partnerships for the promotion of organic farming.

By the combined effort of farmers, the government, NGOs, and market forces, the Indian organic movement has reached a stage where it can swiftly move to occupy a desired space in Indian agriculture. Today, India is alongside the EU, the U.S., Japan, Brazil, Argentina, and Switzerland, which have adopted organic standards and put in place an inspection and certification mechanism (Chadha, 2008).

Educational opportunities

Organic Farming (OF) is an integrated part of agriculture education in India and of late it has been an integral subject under "Principles of Agronomy" course at UG level in all SAUs. Recently, as per the Deans' Committee Report adopted from 2016-17, the UG Programme include following courses:

i. Principles of Organic Farming (Cr. 1+1)

ii. RAWE Component - II includes a Module on "Organic Production Technology" (Cr. 0+10) under Skill development and Entrepreneurship

At Masters and Doctorate level, it comes under Agronomy discipline, where a separate course 'Principles and Practices of Organic Farming' is being taught. Recently, Punjab Agricultural University (PAU) has established the School of Organic Farming, under the College of Agriculture for carrying out multidisciplinary research, training and extension for the development and dissemination of scientific knowledge on the organic and integrated agriculture.Although it is not a separate subject at masters levels in all SAU's as degree programme but some open and private Universities are providing degree programme in organic agriculture in India. Number of universities are providing one or two years diploma in organic farming (Table 1). In view of increasing area under OF, there would be opportunities for more Certificate or diploma courses or degree programmes under organic farming in future.

Employment opportunities

3.1 As Producers

India is bestowed with a lot of potential to produce all varieties of organic products due to its varied agro-climatic conditions. In several parts of the country, farmers plan to grow their crops without the use of chemical fertilizers and harmful chemical pesticides and organic ranchers and dairymen raise their livestock free of drugs and animal hormones. Consumers believe that food produced in this manner is of higher quality and possesses higher nutritional value in comparison to food produced under conventional chemical base farming. With all this, Indian organic agriculture is becoming a mainstream agriculture and occupy desired space in Indian agriculture. Currently, India ranks 33rd in terms of total land under organic cultivation and 88th position for agriculture land under organic crops to total farming area.

Table 1: Institutes/Universities having Certificate or Diploma Course/Degree programmes in Organic Farming in India

S.No.	Name of Institute/University	Certificate or Diploma Course/Degree
1.	TNAU, Coimbatore	PG Diploma in Organic Farming (2 years)
2.	National Centre of Organic Farming (NCOF), Ghaziabad, UP	Diploma Course in Organic Farming (03 months)
3.	IGNOU, Delhi in collaboration with Agricultural and Processed Food Products Export Development Authority (APEDA), Ministry of Commerce, Govt. of India	Certificate Programme in Organic Farming (6 months to 2 Years)
4.	Global Open University, Nagaland	M.Sc. in Organic Farming
5.	Amity University, Noida	M.Sc. in Organic Agriculture & Resource Biotechnology
6.	Adarsh Community College,Gangoh, Saharanpur, Uttar Pradesh	Certificate Course in Organic Farming
7.	Mahatma Gandhi University, Kottayam, Kerala	Certificate Course in Organic Farming
8.	Pdt. Poornanand Tiwari Government Degree College Haldwani, Nainital, Uttarakhand	Certificate Course in Organic Farming
9.	Uttar Pradesh Rajarshi Tandon Open University Allahabad, Uttar Pradesh	Certificate Course in Organic Farming
10.	Uttarakhand Open University, Kusumkheda, Haldwani, Nainital, Uttarakhand	Certificate Course in Organic Farming

Certain areas which are "organic by default" like hills, north-east and dryland/rainfed areas as they use traditional agriculture practices for years with minimal/no use agro-chemicals have good potential to turn into organic production systems. In Madhya Pradesh, about 6000 farmers are improving their income by 10 to 20% from organic cotton due to a business model that builds networks, market knowledge and partnerships among farmers, spinning and processing companies and retailers (FAO, 2007). Organic production systems contribute to:

- Offer employment opportunities, as it requires 30 percent more labour input per ha
- Generate sustainable rural livelihoods, as it provides better return on labour
- Rural development, as rural economies are revitalized
- More social well-being, through fair wages and non-exploitive work that improve control over resources.

3.2 As Laborers

In developing countries, where three out of four poor people live in rural areas and where more than 80% of rural people live in households that are involved in agriculture, improving poor farmers' livelihoods is central for addressing rural development (World Bank, 2007).One of the major issues of developing countries is the problem of unemployment especially for a large sector of less skilled group. Organic farming requires over 15% more labour than traditional farming and therefore, provides rural job opportunities (Pimental*et al*., 2005). Some of the commonly used organic farming techniques such as strip farming, non-chemical weeding, and production, collection and transportation of organic supplements including manures all requires significant labour. The labour scarcity and cost involved therein, may constrain adoption of organic farming in developed countries and also for cash-poor farmers in developing countries. However, for countries like India, labour as well as the cost involved there in is not a constraint. Instead, organic farming can generate employment opportunity for a vast section of rural communities. In India, women constitute an important component of labour work force in agriculture.

Rural areas benefit from the creation of employment in labour-intensive organic agriculture (Bray *et al.*, 2002; Bakewell-Stone *et al*., 2008). Organic agriculture can also facilitate the participation of women who have less access to the formal credit market and often cannot purchase agricultural inputs.

As Entrepreneurs

There are opportunities for development of entrepreneurship in various activities related to organic product production, input production, value addition, sale and export etc. Small groups or self-help groups can be made for a particular aspect.

Organic product production

Central Govt. is giving special emphasis to promote production of organic produce which is healthier for consumer and profitable and sustainable to the producer. Realizing the importance of organic farming in hilly, tribal and rainfed areas where usage of chemical fertilizers and pesticides is less, the government has launched dedicated schemes like *Paramparagat Krishi Vika sYojana* (PKVY), Mission Organic Value Chain Development for North Eastern Region (MOVCDNER) under National Mission for Sustainable Agriculture (NMSA).

Under RKVY scheme, the assistance is provided to the farmers for cluster formation, mobilization of farmers, participatory guarantee systems (PGS) certification and quality control, conversion of land to organic farming, green manuring/biological nitrogen harvest planting, establishment of vermi-compost unit and transportation of organic products, packing, labeling and branding or organic products among others.Under MOVCDNER central sector scheme, the assistance is provided for cluster development, on/off farm input production, setting up of functional infrastructure, land holdings, organic certification through third party and mobilization of farmers/processors among others.

Many states have already started earmarking exclusive organic farming zones, with Maharashtra leading the pack with 932 exclusive clusters followed by Madhya Pradesh (880), Rajasthan (755), Uttar Pradesh (575), Uttarakhand (550) and Karnataka (545). The centre's overall plan is to develop 10,000 clusters (one cluster of 20 hectare each) across the country for promoting organic farming to cater to growing domestic demand and the high export potential of such crops. The aim is to increase cultivated area under organic farming from nearly 8 lakh hectares at present to 10 lakh hectares by 2017-18. Under this plan, 50 or more farmers can form a cluster. Every farmer will be provided Rs 20,000 per acre in three years for seed, harvesting of crops and transporting produce to the market under the `*Paramparagat Krishi Vikas Yojana*' (traditional agriculture development plan) of the Agriculture Ministry. The government has allocated Rs 297 crore under the scheme for 2016-17. The method is expected to increase domestic production and certification of organic produce. Since organic products are grown without the use of chemical fertilizers and pesticides with an environmentally and socially responsible manner, it is important to adopt this approach by involving farmers at grassroot level.

Central Government has notified bio-fertilizers like *Rhizobium*, *Azotobacter*, *Azospirillum*, *Acetobacter*, PSB, KMB, Zinc Solubilizing bacteria under Fertilizer Control Order (FCO). Similarly, under Initiative for Nutritional Security through Intensive Millets Promotion (INSIMP) Programme, Phosphate Solubilizing Bacteria/*Azotobacter* culture is provided to the farmers as part of technology demonstration. Further, under National Project on Management of Soil Health and Fertility (NPMSH&F) financial assistance of Rs 500/ha is provided to promote use of organic manure.

Organic input production

With increase in area under organic would increase the need of organic inputs like seed, organic manures, bio-fertilizers, bio-pesticides etc. Govt. of India and other agencies like NABARD are also supporting to set up of units for bio-compost, bio-pesticides and seed production. Under National Programme for Organic Production (NPOP), GOI, financial Support is provided to input Production Units. Financial support restricted to 25% of total financial outlay is being provided for the establishment of i. Vegetable market waste compost, ii. Bio-fertilizers and iii. Vermiculture hatcheries. Non-government agencies, companies, entrepreneurs and individuals can avail the facility through credit linked subsidy scheme. Loan can be availed from NCDC. Government and semi-government bodies (including municipalities) can avail the subsidy directly by application to Department of Agriculture and Cooperation.

Under National Project on Organic Farming (NPOF) scheme, assistance upto 25% and 33% of financial outlay upto a ceiling of Rs. 40 lakhs and Rs. 60 lakhs ,respectively is provided as back ended subsidy through NABARD for establishment of bio- pesticides/bio-fertilizers production units, and vermiculture hatcheries and agro-waste compost production units respectively. Under National Horticulture Mission (NHM) Scheme, assistance for adoption of organic farming @ Rs.10, 000/ha for maximum area of 4 ha per beneficiary, for setting up of vermicomposting units @ 50% of the cost, subject to a maximum of Rs. 30,000/- per beneficiary, and for organic farming certification @ Rs.5.00 lakh for a group of farmers covering an area of 50 ha.

Organic products outlets

Organic produce farmers may come together and go for small scale value addition, packaging and sale of their products. India's organic industry is just beginning to gain attention in the market of urban areas, primarily with small shops and groceries. Today, every supermarket has an organic food section, and every large city in India has numerous organic food stores and restaurants in the background that the first organic food store in Mumbai was started in 1997. The pattern of organic food consumption in India is much different than in developed countries. In India, consumers prefer organic fruits, vegetables, spices, strawberry, tea, organic marmalade, organic honey, organic butter, and various organic flours. However, there are many consumers who are unaware of the difference between natural and organic food. Many people purchase products labeled as "Natural" thinking that they are organic. However, consumers are not aware of the certification system, since certification is not compulsory for domestic retail in India. The overall growth in the market of organic products was estimated at 14% for spices, 15% for banana, 14% for tea, 11% for rice, 8% for fruit, 8% for herbal extracts, 8% for cotton, and 4.5% for turmeric. Organic production is not limited to the foods sector, but also applies to significant amounts of organic cotton fiber, garments, cosmetics, functional food products, and body care products.

Export

The total volume of export during 2015-16 was 2,63,687 MT. The organic food export realization was around 298 million USD. Organic products are exported to European Union, US, Canada, Switzerland, Korea, Australia, New Zealand, South East Asian countries, Middle East, South Africa etc.Oil seeds (50%) lead among the products exported followed by processed food products (25%), Cereals and Millets (17%), Tea (2%), Pulses (2%), Spices (1%), Dry fruits (1%), and others (APEDA).Domestic market is also growing at an annual growth rate of 15-25%. As per the survey conducted by ICCOA, Bengaluru, domestic market during the year 2012-13 was worth INR 600 Crores. India's organic export markets would grow with the support of the industry, government, and NGOs coming together to work with farmers. The future for markets for organic foods is definitely bright, as it is growing rapidly in the EU, in the U.S. and Canada, and in Japan and Australia, as well as in some developing countries. With growing consumer awareness of food safety, health, and environmental issues, the organic food sector has become an attractive opportunity for export from developing countries.

Table 2: Major products produced in India by organic farming

Type of Product	Products
Commodity	Tea, Coffee, Rice, Wheat
Spices	Cardamom, Black pepper, white pepper, Ginger, Turmeric, Vanilla, Tamarind, Clove, Cinnamon, Nutmeg, Mace, Chili
Pulses	Red gram, Black gram
Fruits	Mango, Banana, Pineapple, Passion fruit, Sugarcane, Orange, Cashew nut, Walnut
Vegetables	Okra, Brinjal, Garlic, Onion, Tomato, Potato
Oil seeds	Mustard, Sesame, Castor, Sunflower
Others	Cotton, Herbal extracts

India is one of the leading fruit producers in the world, producing about 10% of the world's fruit production (Anonymous, 2015). Most of the produce is consumed domestically as fresh. The main destinations are the Middle East, Europe, and Southeast Asia. India is the largest mango producer in the world. However, a negligible amount of fresh (42,998.31 MT) and processed mangoes are exported due to huge domestic demand (Palanivel, 2015). The UK, Netherlands, and Germany have a high demand for organic mangoes, which could be exploited by India. Indian organic banana exports are negligible in relation to the world trade. India needs to follow a two-pronged strategy for increasing organic banana exports i. target the processed organic banana market (pulp, purees, and concentrates), and ii. focus on the geographically closer Japanese market and the EU (Mitra, 2013). India has good potential for the export of organic pineapples, as three major importing markets are the U.S., EU, and Japan. As is the case with most other fruit exports from India, the prime export destination for Indian grapes is the Middle East, but it offers limited opportunities for organic grapes. The main target destination market for Indian organic grapes is the EU, especially the UK and the Netherlands. Moreover, there is a current consumption trend increasingly favoring organic wine, further increasing the demand for organic grapes. Other organic fruits which could be successfully exported include litchi, passion fruit, pomegranate, sapota, apple, walnut, and strawberry (Mitra, 2013).

India is the second largest producer of vegetables in the world after China followed by the Middle East, Singapore, Malaysia, Sri Lanka, Bangladesh, Nepal, the EU, and Australia. Traditional vegetables like onion, potato, okra, bitter gourd, and green chilies, and non-traditional vegetables like asparagus, celery, paprika, sweet and baby corn, and cherry tomato are all exported. Global demand is increasing for organic vegetables and Indian organic vegetable producers would be in a position to expand their market in the EU, Australia, and Singapore. India is also the largest producer and exporter of organic tea. With the European Commission having granted "equivalence" status to Indian organic certifying agencies, Indian organic tea producers are in a position to expand their markets in Europe, one of the leading tea consuming regions. Organic coffee is mainly consumed by the developed countries namely, the U.S., Germany, France, Italy, Japan, and the EU. India accounts for 1% of the estimated world organic coffee market so there is exceptional potential to increase its exports in the near future. India currently accounts for over 12% (in terms of quantity) of the world spice market. The main consumers of organic spices are Germany, the UK, France, Japan, and the U.S. However, organic spices in India represent a very negligible part of total spice production. Organic spices produced by India and having export potential include pepper, ginger, turmeric, cloves, mace, nutmeg, vanilla, cardamom, chili, mustard, tamarind, camboge, thyme, rosemary, oregano, marjoram, parsley, and sage (fresh, dehydrated, and oil). India is a significant supplier of certified organic ingredients to the global organic cosmetics and health care industries, and has a vast area under herbal and aromatic plant production. India is also a significant producer of essential oils in world. In view of these, India could become one of the leading suppliers of organic ingredients to the global organic cosmetic and health care industry.

Human Resource Development

The Government of India has taken many initiations to promote organic farming in the country. National Programme for Organic Production (NPOP) was launched in April 2000 and notification was effective from 1 October, 2001. National Project on Organic Farming (NPOF) is a continuing central sector scheme since 10th Five Year Plan. Planning Commission approved the scheme as PILOT project for the remaining two and half years of 10th plan period with effect from 01.10.2004 with an outlay of Rs. 57.04 crore. The scheme is continuing in the 12th Plan.National Project on Organic Farming is being operated by the Integrated Nutrient Management Division of Department of Agricultural and Cooperation, GoI, and headed by Joint Secretary (INM). The project objectives are being implemented and monitored through National Centre of Organic Farming (NCOF) at Ghaziabad as Headquarters with its six Regional Centres of Organic Farming (RCOF) located at Bengaluru, Bhubaneswar, Hisar, Imphal, Jabalpur and Nagpur. The GoI, ICAR and many other agencies are doing concerted efforts for training, capacity building and financial support through various schemes and activities to promote the organic farming in India as given below.

1. *Capacity Building through Service Providers*: Govt. and non-government agencies, capable of forming farmer groups and well versed with certification system and internal control systems management are being provided necessary technical support for optimum productivity and facilitate certification through grower group certification process.
2. *Training*: Four different types of trainings, with different course contents are being arranged under NPOF through NCOF, RCOF and various government and non- government agencies. These are i. Training for inspection and certification agencies and service providers, ii. Training on production and quality control of organic input iii. Training for field functionaries and extension officers on organic management and iv. Training for farmers on organic farms.
3. *Demonstrations*: Field demonstrations-cum-farmer fairs are organised on i. Organic inputs and ii. Enriched biogas slurry are being organized through NCOF, RCOF and various government and non-government agencies to prove the potential of organic management systems and different quality organic inputs.
4. *Model Organic Farms*: It is proposed to establish large number of model organic farms on government and government institutions farms for demonstration of organic packages, development organic systems and production of organic seeds.
5. *New Initiatives and Market Development*: Under the component, funds are being provided to various government and non-government agencies for development of packages, evaluation of organic practices, development of market linkages and marketing initiatives. Funds are also being provided for documentation of practices and technologies and publicity of proven technologies.
6. *Awareness Creation*: Funds are also being provide to NCOF, RCOF and various government and non-government agencies for organization of international/national seminars, conferences, workshops, exhibitions etc and publicity through print and electronic media for mass awareness creation.

Macro-management of Agriculture (MMA) Assistance @ 25% of total cost limited to Rs. 1000/- per ha is being provided for integrated nutrient management in conjunction with organic sources of nutrients like FYM, Compost, Vermi-compost, Biofertilizers etc. Government is spreading awareness about organic farming through various extension activities such as exhibitions and fairs, Agri-clinic and Agri-Business Centre, mass media support activities, radio talks, Kisan Melas, etc.

ICAR Contribution in Promoting Organic Farming

All India Network Project on Soil Biodiversity-Bio-fertilizers is implemented for R&D on bio-fertilizers. Improved and efficient strains of bio-fertilizers specific to different crops and soil types are being developed under NetworkProject on bio-fertilizers. ICAR has developed technologies to prepare various types of organic manures such as phospho-compost, vermicompost, municipal solid waste compost, etc. The financial assistance is provided on the basis of project proposals received from states including Maharashtra. ICAR under Network Project on Organic Farming, with lead center at Indian Institute of Farming Systems Research, Modipuram is developing package of practices of different crops and cropping system under organic farming in different agro-ecological regions of the country. This has helped the country to export agri-organic products of total volume of 160276.95 MT and realization of around Rs.1155.81 crores in year 2012-13.

ICAR provide training and capacity building opportunities to scientists of ICAR, SAUs and CAUs every year through Winter/Summer Schools and Short-term Courses on organic farming. In last 5 years, 06 programmes have been organized in which 145 Scientists have been trained. Besides, 03 Experiential Learning (EL) Units are operating in 02 SAUs and imparting hands-on-training on production of bio-agents, bio-pesticides, bio-fertilizer and vermicompost to students every year.National Organic Farming Research Institute (NOFRI) at Gangtok, Sikkim is being established.

Conclusion

Though the green revolution has undoubtedly changed the scenario of food grain production from 'ship-to-mouth' status to self-sufficient and surplus status in India with the increased use of synthetic agro-chemicals such as fertilizers and pesticides, adoption of nutrient-responsive high-yielding varieties of crops, and greater exploitation of irrigation potential. The continuous use of these high energy inputs has led to the deterioration of soil health and the environment, and food safety has become a major concern. India has brought 5.71million hectare area under organic certification (2015-16). This includes 26% cultivable area with 1.49 million hectare and rest 74% (4.22 million hectare) forest and wild area for collection of minor forest produces. Organic farming is growing rapidly among Indian farmers and entrepreneurs, especially in low productivity areas, rain-fed zones, hilly areas, and the north-eastern states, where fertilizer consumption is less than 25 kg/ha/year.

Organic farming is an integrated part of agriculture education in India and of late has been an integral subject under "Principles of Agronomy" course at UG level in all SAUs. Recently, as per V Deans' Committee Report adopted from 2017-18, the UG Programme included a separate course as "Principles of Organic Farming" along with RAWE Component - II included a Module on "Organic Production Technology" under Skill development and Entrepreneurship. At Masters and Ph.D. level programmes, it comes under Agronomy discipline, where a separate course 'Principles and Practices of Organic Farming' for strengthening the theoretical as well practical aspects of OF are being taught. Many universities provide one or two years diploma course for organic farming. The employment opportunities in organic farming are immense as producer, labourer, Entrepreneur as Organic product production, Organic input production, Organic products outlets and exporters. India's organic export markets would grow with the support of the industry, the government, and NGOs coming together to work with farmers. The future for markets for organic foods is definitely bright, as it is growing rapidly in the EU, U.S., Canada, Japan and Australia, as well as in some developing countries. With growing consumer awareness of food safety, health, and environmental issues, the organic food sector has become an attractive opportunity for export from developing countries.The GoI, ICAR and many other agencies are doing concerted efforts for training, capacity building and providing financial support through various schemes and activities to promote the organic farming in India.

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Economics of organic farming cultivation in India: Some example of organically cultivated crops

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Introduction

The green revolution is the name given to the changes that revolutionized agriculture in the twentieth century. Scientists discovered that fertilizing plants with N-P-K fertilizers in combination of irrigation facilities stimulated plant growth and increased crop yields. Highly yielding and hybrid crop varieties were developed that enhanced crop yield. The combination increased food production per acre up to 10 times or even more. The productive capacity of soil is started deteriorating with excessive mining of minerals by plant in order to produce more food to satisfy human needs. The successive crops were weaker and more vulnerable to pests and diseases. Researcher then developed modern pesticides to kill the pests. Along with high-yield crops and chemical sprays, mechanization was introduced in agriculture. Monoculture crop farming was supported by farm mechanization one side but other side it became more vulnerable to pests, which further increased the use of the toxic chemical sprays.

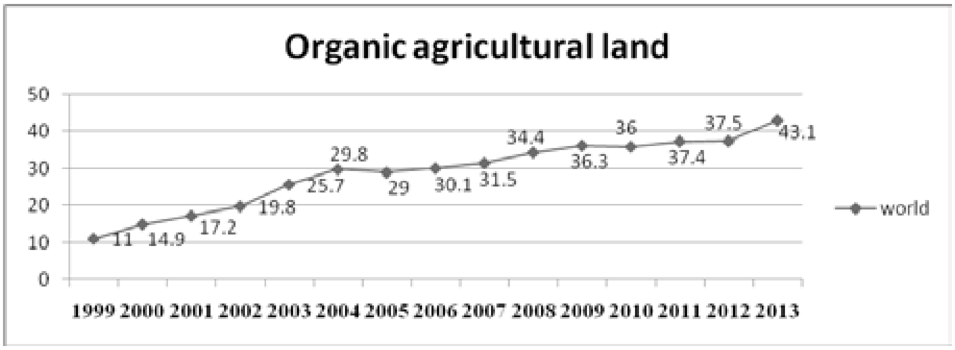
The mechanized farms were more efficient and pro large land holding, so small farmers began to go out of agriculture and the big industry have consolidated to take benefits of growing agriculture at cost of environment. With passes of time, human realized the damage made to themselves and environment and became conscious about these. Human started thinking about organic agriculture which was done earlier by their ancestor which was more sustainable and healthy methods for nature prosperity. Organic agriculture is system of agriculture without the use of chemical fertilizers and pesticides with an environmentally and socially responsible approach. This is a method of farming works at grass root level preserving the reproductive and regenerative capacity of the soil and produces nutritious food rich in vitality which has resistance to diseases. The concept of 'organic' may mean different things to different people. Standard procedure is essentially needed to which producers has to be consistently adhere in farm production system. As organic agriculture is system approach, it become difficult for the consumers to recognize organic product at the point of sale. Standards specification show the consumer what is meant when the word organic is used. The farmers who are producing organic products as per the standard specifications can be certified and logo to be used to differentiate from general products in the market.

Organic agriculture, however, is one of the most important subjects, if not the most important next to water, for human health. At present scenario, ithas become indispensable in human growth and development organically.The American Cancer Society estimates that 85% of cancers are environmentally caused. This may contribute to a doubling or the birth defect rate in America since 1950. By killing soil microorganisms, herbicides and pesticides contribute to massive soil erosion and loss of precious top soil around the world, even creating deserts in some areas. People have realized how devastating chemical agriculture has been to the nutrient content of our food. Researcher and technocrats are realizing that costly epidemics of heart disease, cancer, diabetes, AIDS, mental illness and even violence are related to the nutritional content of the food, and toxic substances in the food, water and air. The various research study findings have indicated that excessive use of chemicals in agriculture results in adverse effects on human health, animals, biodiversity and contribute to degradation of land, water and environmental resources (Ghosh, 2004; Maiti, 1999; Pachauri and Sridharan, 1998). Farming has also forced millions of people off their land and into the cities seeking work. Life on the farm was not easy, but living on the land provided a source of security, and a far healthier environment than many city environments. The worst aspect, from perspective, is the destruction of the old seeds and the fertile land.

The organic methods build up the soil, produce hardier crops that resist pests, preserve the environment, and provide more nutritious food. The food may not look different, but it has a longer shelf life and is nutritionally superior, as revealed in several studies. More small farmers are finding a niche catering to the needs of the local community. Farmer's markets and local buying clubs help address the problem of the loss of the family farm. Communities are reaping the benefits of supporting local farmers by getting fresher and often better quality produce. The locally grown movement also fosters a greater sense of community, and contributes to local self-sufficiency and sovereignty. However, we are not going back to farming as it was done a century ago but it is possible to use modern technology wisely to produce pure, nutritionally superior food without damaging the environment. This is the challenge for agriculture in the 21st century.

World had 43.1 m ha of organic agricultural land including inconversion areas in 2013 which is 0.98 % of total agricultural land in comparison to 11 m ha in 1999. Non-agricultural organic areas were 35.1 m ha for the same year. Global sale of organic food and drinks reached 72 billion US dollars in 2103, increased almost five fold since 1999 (FiBL& IFOAM-Organic International, 2015). The growth of Organic Agricultural Lands of worlds is presented in graph 1.

Graph 1: Trend of Organic Agricultural Land in world (in million ha)



The total organic area in Asia was 3.4 m ha in 2013 which constitute about 8 % to world's organic agricultural land. The leading countries were china (2.1 m ha) and India (0.5 m ha). There was nearly 2 million producers in the world and Indian producers constitute nearly 0.65 million securing top ranking in number of producers in 2013 (FiBL& IFOAM-Organic International, 2015). The growth of Organic Agricultural Lands of Asia and India is represented in Table 1. The share of different crops in organic agricultural land is been represented in figure1 and 2 for world and Asia.

Table 1: Area of organic Agricultural Land (in thousand ha.)

Year	Asia	India	China	Nepal	Bangladesh	Pakistan
2005	2680	-	-	-	-	-
2007	2900	-	-	-	-	-
2009	3380	-	-	-	-	-
2010	-	780	1390	9.8	.8	22
2011	3690	1084	1900	8.7	6.8	25
2012	-	500	1900	10.3	6.8	22
2013	3430	510	2094	9.4	6.8	22

Figure 1: Crops share in total Organic Agricultural Land cultivated in World

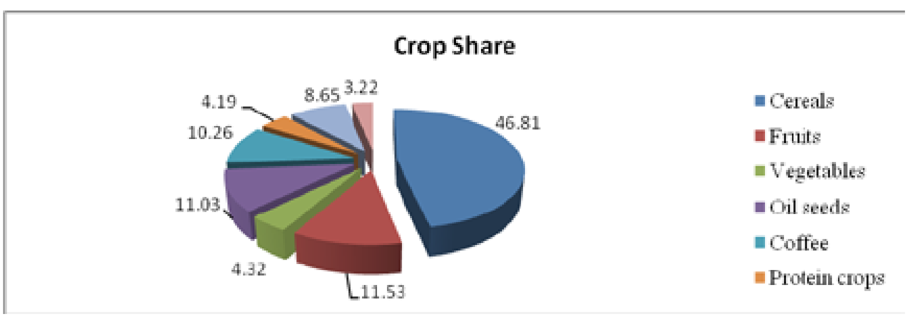
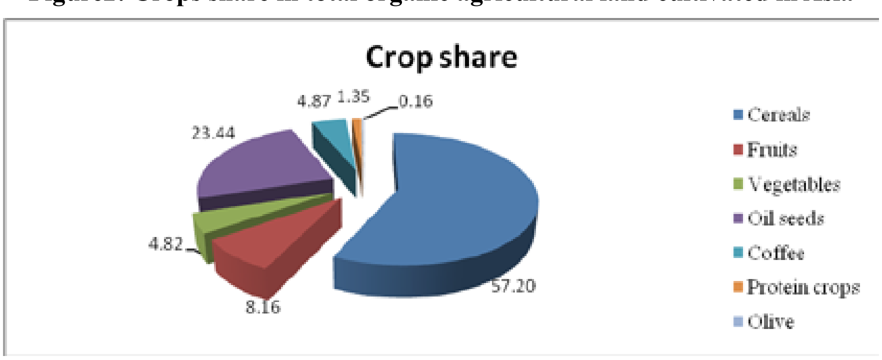


Figure2: Crops share in total organic agricultural land cultivated in Asia



Government policy for organic agriculture

India is bestowed with lot of potential to produce all varieties of organic products due to its various agro climatic regions. Seeing all these, the National Program for Organic Production (NPOP) was approved in May 2001 by the National Steering Committee for Organic Products (NSCOP), under the Ministry of Commerce. The NSCOP consisted of representatives from the Ministry of Agriculture, Commodity Boards, Food Processing Industries, Forests and Environment, Science & Technology, Rural Development & Commerce, and Trade & Exports. The main of objectives of the NPOP have centralized around the export market. The aims of the National Program for Organic Production include providing the means to evaluate certification programmes for organic agriculture and products as per the approved criteria; developing policies for the certification and development of organic products; producing the National Standards for Organic Products (NSOP); formulating the National Accreditation Policy and Programme (NAPP); accrediting certification programmes to be operated by Inspection and Certification Agencies; facilitating certification of organic products in conformity to the NSOPs; developing regulations for the use of the National Organic Certification Mark; encouraging the development of organic farming and organic processing. In October 2000, the Ministry of Agriculture developed an organic agriculture task force that was separate from the NSCOP. The objectives of this separate task force include advising the Ministry of Agriculture on all aspects of organic agriculture; promoting general awareness of organic agriculture; developing a map for organic agriculture. State governments have initiated a number of projects throughout the 26 states of India. These governments have been involved with setting up organic farm models, providing guidance about certification, promoting composting, and other practices relevant to organizing conferences, extending subsidies and providing training. Government financial support is provided to organic farmers during the period of conversion (3 years) and for a period beyond. Approximately, Rs.10,000 / ha is provided as an incentive to adopt organic agriculture. The programme is very limited in scale and can be pursued under particular schemes only. Financial support is targeted to compensate for potential losses, to promote organic agriculture, to support and develop infrastructure, to conduct feasibility studies and to prepare guidelines for "package of practices." Other specific incentives exist for organic farmers. For example, organic farmers growing spices can receive support towards the costs of certification; however, pricing policy for organic products is non-existent.

In year 2015-16, India have total area under organic certification is 5.71 m ha which includes 26% cultivable area with 1.49 m ha and rest 74% (4.22 m ha) forest and wild area for collection of minor forest produces. India produced around 1.35 m t (2015-16) of certified organic products which includes all varieties of food products. Among all the states, Madhya Pradesh has covered largest area under organic certification followed by Himachal Pradesh and Rajasthan. The total volume of export during 2015-16 was 263687 MT and export revenue was around 298 million US dollars. Organic products are exported to European Union, US, Canada, Switzerland, Korea, Australia, New Zealand, South East Asian countries, Middle East, South Africa etc. Oil seeds (50%) lead among the products exported followed by Processed food products (25%), Cereals & Millets (17%), Tea (2%), Pulses (2%), Spices (1%), Dry fruits (1%), and others (APEDA, 2017).

Economics of organic produce

Application of higher doses of chemical and fertilizer by farmers certainly improved the production and productivity of agriculture crops. But it is at the cost natural resource base depletion, degradation of soil health and human & animal health hazards. There is an urgent need to go for organic farming to sustain living beings on earth. The producers will only go for organic if it is economical by means of reduction in input cost or increased in income in terms of improved productivity or better return. Therefore, organic farming needs to be evaluated by means of economic viability. This book chapter aim to understand the cost and return from the organic cultivation. The example used in this chapter from the studies conducted by several researchers in different part of the country. To carry out the economic analysis, costs and benefits stream should be derived very carefully by taking into account all possible costs and benefits. There are no single methods which can take up into account all the variables since organic farming is a dynamic situation. Hence, certain assumption needs to make where in some components are assumed variable and other remain constant.

Cost stream of organic products based on the research studies

Organic products typically cost 10 to 40% more than similar conventionally produced products. For example if a consumer spent on conventional produce Rs. 10000/ month for his consumption and switching entirely to organics would raise their cost of groceries by Rs. 11000 to 12000 per month. Some research studies reported that change from conventional farming to organic may reduce yield, at least during the initial years (IFAD, 2005; Rajendran et al., 2000). The study conducted in Maharashtra shown that the average yield of organic sugarcane crop was 6.79 per cent lower than inorganic sugarcane crop. However, the organic sugarcane growers were confident (Kshirsagar,2008) and it has also been reported by some scholars that in subsequent years organic farming is able to reduce this yield gap (Rajendran et al., 2000) and sometimes had also given higher yields than conventional methods. Processed organic foods vary in price when compared to their conventional counterparts. A study of 100 farmers in Himachal Pradesh during a period of 3 years found that the total cost of production of maize and wheat was lower under organic farming and the net income was 2 to 3 times higher. Both productivity and premium prices contributed to the increased profitability (Thakur and Sharma, 2005). Another study of 100 farmers of organic and conventional methods in five districts of Karnataka indicated that the cost of organic farming was lower by 80 per cent than that of the conventional method of farming (Thakur, et. al., 2003). The cost benefit ratios for Crops like groundnut (1:1.26), Jowar (1:1.36), cotton (1:1.34), Coconut (1:1.70) and Banana (1:3.66) in organic cultivation which was higher than conventional cultivation except for groundnut (1:1.31). Therefore, organic farming found to be economical. Indicators to be tested are given below.

Productivity Indicators

(a). Crop yield index: A measure of comparison of the yield of all the crops in a given organic farm with the average yield of these crops in the locality/taluk/district/state/country. The relationship is expressed in per cent.

$$Crop\ Yield\ Index = \frac{Average\ yield\ of\ organic\ crops\ (q/ha)}{Average\ yield\ in\ the\ area\ (q/ha)} \times 100$$

Apart from annual crops, yield of fruit, fodder and fuel wood may also be measured similarly.

(b). **Crop diversification index (DI):** a measure of diversification of crops under organic farming and under

$$Crop\ Diversification\ Index = \sum_{i=1}^{n} P_i^2$$

$$P_i = {A_i}/{\sum A_i}$$

Where P_i = Proportion of Area under i[th] crop, A_i = Actual Area under i[th] crop, $\sum A_i$ = Total cropped Area

c) **Cropping intensity:** The CI can be worked out with and without organic crops as per given formula and can be expressed in percent.

$$Cropping\ Intensity\ (CI) = \frac{Cropped\ area\ of\ ith\ farm\ under\ Organic}{Total\ area\ of\ ith\ farm} \times 100$$

Economic Indices

Economic indices/measures evaluate the project worth by comparing the values of goods and services produced or conserved with the cost for assessing its effect on social welfare needs and viability. The following discounting techniques can be used for this purpose.

(i) **Net present worth (NPW) method**

This is the most widely used measure. This is the difference between the discounted value of gross benefits and the discounted value of gross costs of the project over its life.

The general formula for NPW is,

$$NPW = \sum_{t=1}^{n} \frac{B_t - C_t}{(1+r)^t}$$

Where, B_t = Gross benefits from the a project in year t

C_t = Gross costs from the project in year t

r = Discount rate

t = time, year 1 to n (life of the project)

The decision rule is to select the projects when NPW is greater than zero, otherwise reject. Higher the NPW, better is the project. Select that project which has highest NPW.

(ii) Internal rate of return (IRR)

Internal rate of return is frequently used in the evaluation of projects by banks and other organizations. It is the rate of discount, which makes the present value (value today), of benefits equal to present value of costs, thus, IRR does not use a pre- determined discount rate.

The IRR is the discount rate, r such that,

$$IRR = \sum_{t=1}^{n} \frac{B_t}{(1+r)^t} = \sum_{t=1}^{n} \frac{C_t}{(1+r)^t}\ OR \sum_{t=1}^{n} \frac{B_t - C_t}{(1+r)^t} = 0$$

In an analysis using IRR measure, the calculated IRR is compared to some prescribed discount rate (generally the interest rate chargeable on money to be invested or the value that invested resources would earn in other opportunities (the opportunity cost of capital) to decide whether the project is worth to take or not? The decision rule applied is to select the project if calculated discount rate IRR is greater than predetermined discount rate, otherwise reject it.

The advantages of this measure are: IRR is well known; often used and easily understood; and ranking of projects can be done easily on this basis. However, IRR has some disadvantages too. It may be misleading in a situation where selection has to be made among mutually exclusive projects. The reason is that IRR may be higher for project `A' that in fact produces less benefit than project `B' having lower IRR but produces more benefits. Calculation of IRR is shown in Example.

(iii) Benefit-cost ratio (BCR)

This ratio simply compares the present value of benefits to present value of costs, obtained by dividing the present value of all benefits (sum of discounted benefits) by the present value of all costs (sum of discounted costs).

$$BCR = \sum_{t=1}^{n} \frac{B_t/(1+r)^t}{C_t/(1+r)^t}$$

The decision rule applied is, if the B:C ratio is greater than unity (1), select the project otherwise reject it. The advantages of this measure are: easily understood; easy to convince the planner or decision maker; easy to compute; and it can easily see how much cost is to be allowed to increase before a project is to be rejected. The use of B:C ratio has two disadvantages.

If we are to simply evaluate one project, the decision criterion is to accept the project as economically feasible if its net present worth (NPW) is greater than zero. Equivalently, the project is accepted if its benefit-cost ratio (B:C) is greater than one or its internal rate of return (IRR) exceeds the appropriate (pre-determined) rate of discount.

Other cost concepts like Total costs and total returns, net return, gross margin, marginal return etc. can be used. Since, organic farming gives direct returns slowly and buildup the soil health in sustainable manner, farmers may not realize the immediate benefits. However, long term intangible benefits can also be assessed by using economic criteria.

Economic Analysis of paddy cultivation in Punjab & UP

The economics of paddy cultivation per hectare (ha) in Punjab state under organic and conventional farming is presented in table 2. The cost of production (variable) per quintal of paddy was Rs.701 under organic farming (OF) whereas Rs.427 in conventional farming (CF). It is almost 64 per cent higher in OF than CF. The average cost of cultivation of paddy in OF was Rs.23312.5/ha while the same in CF was Rs.19545/ ha. The cost of cultivation was nearly 19 per cent higher in OF when compared to CF. Average yield of paddy was 3.338 and 4.590 t/ha, respectively in OF and CF. The absolute difference between the yield levels was 1.252 t/ ha. But, the unit price of paddy was higher (30 per cent) in OF relative to CF. There was no significant unit price differences in fodder prices. The average net returns per ha of paddy cultivation were Rs. 44570 and Rs. 52242.5, respectively in OF and CF. However, the differences between the gross returns per ha of these farming were Rs. 3905 only. Among different cost break-ups, the actual costs on weeding and harvesting operations were significantly higher in OF when compared to CF. It clearly indicates the more labor incentive nature of OF than CF. The relative costs on fertilizer application was higher in OF while the same on plant protection was higher in CF. The costs on the remaining cost items were more or less equal in both types. Since, many organic farmers are started practicing organic methods from last two or three years, it takes some more time to stabilize or increase the yields further under organic farming. The premium prices for paddy helping the organic farmers in Punjab to cover their higher costs to some extent.

Similarly in UP the costs and returns of paddy (basmati) cultivation both under organic and conventional farming types are presented in Table 3. Most of the sample organic farmers are practicing the method of 'Natural farming' or Zero-budgeting concept in their farms. The most common basmati varieties growing in this region are Pusa–1 and Pusa -1121.The average cost of production per quintal of paddy (basmati) under organic farming was Rs.870 while the same in conventional farming was Rs.803. The cost of production per quintal under OF was 8 per cent higher than CF. The mean yield per ha in OF accounted for 84 per cent of the conventional farming yield. The average gross returns per ha of conventional farming were nearly 28 percent higher than organic farming. The average net returns per ha of paddy cultivation were Rs. 28720 and Rs. 42975, respectively for OF and CF. No premium prices were available for organic paddy in Uttar Pradesh. The yield levels under organic farming were lower (16%) than conventional farming. Among different cost items, weeding cost was significantly higher in organic farming. The costs on plant protection chemicals and irrigation were significantly higher in conventional farming. It clearly indicates that organic farming increased water-use-efficiency of the farm. Lack of premium prices as well as absence of export market channels limits the expansion of organic farming in the state.

Table 2: Economics of Paddy cultivation in Punjab & UP (Rs./ha)

	Punjab			Uttar Pradesh		
	Organic Farming	Conven-tional Farming	Conven-tional Farming =100	Organic Farming	Conven-tional Farming	Conven-tional Farming =100
Land preparation	3162.5	3267.5	97	8705	8610	101
Seed cost	800	697.5	115	1252.5	1277.5	98
Sowing cost	4475	4537.5	99	2840	3500	81
Fertilizer cost	4887.5	4400	111	2705	2325	116
Inter cultivation/Weeding	3112.5	1177.5	264	1555	937.5	166
Plant protection cost	775	2320	33	875	1302.5	67
Irrigation cost	775	180	431	5702.5	8250	69
Harvesting cost	2950	1927.5	153	5205	5535	94
Threshing cost	1275	750	170	3887.5	4177.5	93
Marketing cost	1100	287.5	383	350	200	175
Total cost of cultivation	23312.5	19545	119	33077.5	36115	92
Yield (Kg)	3337.5	4590	73	3795	4517.5	84
Price (Rs)	19.5	15	130	15.8	16.9	93
Fodder (Qtl)	28	31.25	90	26.25	29.5	89
Price (Rs)	100	94	106	70	93	75
Total revenue	67882.5	71787.5	95	61797.5	79090	78
Net returns	44570	52242.5	85	28720	42975	67
Cost of production (per Qtl)	701	427	164	870	803	108

Source: Charyulu and Biswas (2010) and authors own calculation

Economics of wheat cultivation in Punjab & UP

The comparison of crop economics of wheat cultivation between organic and conventional farming systems is presented in table 3. Most of sample organic farmers in the state were cultivating 'Bansi' (local) variety of Wheat. The cost of production per quintal was Rs.1610 under OF. But, the same in case of CF was Rs. 787.5. The cost of production per quintal of wheat was more than double in OF. It was due the lower (nearly half) yields under organic farming. But, the overall cost of cultivation per hectare was slightly higher (17 per cent) in OF when compared to CF. The market price realization of per kg wheat was significantly higher in OF (117 per cent). However, the gross returns per hectare of wheat cultivation in Punjab were Rs.71867.5 and Rs.61887.5, respectively for OF and CF. The data indicates almost 16 per cent higher gross returns per hectare of wheat under OF over CF. However, per ha net returns difference between OF and CF was Rs.7222.5. It clearly shows the high profitability of wheat cultivation under organic farming in Punjab. As the organic farmers gains more experience under OF, higher yields can be expected on par with CF. Among different crop operations, the higher costs under organic farming were observed in weeding, harvesting and threshing. Most of sample organic farmers are following manual harvesting and threshing practices for good quality of wheat grains and straw. Due to that the costs on labor per acre was higher under OF. The costs on fertilizers and plant protection chemicals were significantly higher under conventional farming. Overall, there is huge potential for domestic as well as export market for organic wheat from Northern states.

Table 3: Economics of Wheat cultivation in Punjab and UP (Rs./ ha)

Particulars	Punjab			Uttar Pradesh		
	Organic Farming	Conven-tional Farming	Conven-tional Farming =100	Organic Farming	Conven-tional Farming	Conven-tional Farming =100
Land preparation	2625	2525	104	5745	6427.5	89
Seed cost	3100	3212.5	96	3202.5	2585	124
Sowing cost	687.5	652.5	105	1657.5	1685	98
Fertilizer cost	2907.5	3800	77	2452.5	2635	93
Inter cultivation/Weeding	3375	1237.5	273	1640	1080	152
Plant protection cost	230	1087.5	21	212.5	535	40
Irrigation cost	355	325	109	2485	3830	65
Harvesting cost	3250	2100	155	3775	4185	90
Threshing cost	1775	825	215	2110	2197.5	96
Marketing cost	542.5	325	167	265	397.5	67
Total cost of cultivation	18847.5	16090	117	23545	25557.5	92
Yield (Kg)	2925	5105	57	3797.5	4205	90
Price (Rs)	22.3	10.3	217	13.4	10.5	128
Fodder (Qtl)	28.5	41	70	35	34.5	101
Price (Rs)	233	227	103	222	193	115
Total revenue	71867.5	61887.5	116	58657.5	50810	115
Net returns	53020	45797.5	116	35112.5	25252.5	139
Cost of production (per Qtl)	1610	787.5	204	1550	1522.5	102

Source: Charyulu and Biswas (2010).

Economics of sugarcane cultivation in Uttar Pradesh

The detailed break-up of the cost of cultivation of sugarcane in Uttar Pradesh state is presented in table 4. Most of the sample organic farmers were growing *CoS 88230* variety of sugarcane while majority of conventional growers were using *CoS 88230 or CoS 767* varieties. The cost of production of sugarcane per ton was Rs. 1472.5 under organic farming which was 21 % lower than conventional farming. The mean yield per ha was marginally high (1%) higher under organic farming. The average cost of cultivation per ha of organic farming was 20 % lower than the conventional farming cost. The gross returns per ha of organic farming was 8% higher than conventional method of sugarcane cultivation. However in case of the net returns per ha, this value was 35% higher. The results conclude that the cultivation of sugarcane was more profitable under organic farming than conventional farming. Premium prices did not exist for organic sugarcane production in U.P. Creation or addition of premium prices would further increase the profitability of organic sugarcane production. Among different cost components, the costs were more or less equal in both farming systems. One of the major benefits under organic sugarcane cultivation was the crop can thrive for more than three years without any yield loss.

Table 4: Economics of sugarcane cultivation in Uttar Pradesh (Rs./ha)

Particulars	Uttar Pradesh		Conventional Farming =100
	Organic Farming	Conventional Farming	
Land preparation	9187.5	10250	90
Seed cost	12062.5	13250	91
Sowing cost	3282.5	2800	117
Fertilizer cost	5860	13625	43
Inter cultivation/Weeding	8282.5	10750	77
Plant protection cost	687.5	3875	18
Irrigation cost	8970	7600	118
Harvesting cost	5937.5	6750	88
Threshing cost	2095	1900	110
Marketing cost	0	0	-
Total cost of cultivation	56365	70800	80
Yield (Kg)	95937.5	95000	101
Price (Rs)	4	3.75	107
Fodder (Qtl)	0	0	-
Price (Rs)	0	0	-
Total revenue	153500	142500	108
Net returns	97135	71700	135
Cost of production (per Qtl)	1472.5	1862.5	79

Authors own calculation and adopted Charyulu and Biswas (2010).

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Climate Smart Agricultural Technologies for Island Ecosystem – An Organic Way

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It has long been recognized that greenhouse gas emissions from small islands are negligible in relation to global emissions, but that the threats of climate change and sea level rise to small islands are very real (IPCC, 2014). Hence it is pertinent to evolve appropriate adaptation measures to ensure the food security of islanders whose livelihood is predominantly dependent on agriculture, fisheries and tourism. Although crop insurance is being promoted as an institutional mechanism to overcome the adverse impacts of climate change, producing sufficient quantities of diversified food commodities like cereals, pulses, vegetables, fruits, fish and meat through efficient management of natural resources holds the key for the sustainable food production of the fragile island ecosystem.

Agriculture in Andaman & Nicobar Islands

The Andaman & Nicobar archipelago is a group of 572 picturesque islands located strategically between 06°-14°N latitude and 92°-94° E longitude in the south eastern Bay of Bengal. It is one of the most important biodiversity centers of the world harbouring multitude of land and marine bio-resources. It enjoys a tropical and humid climate by receiving an annual rainfall of around 3,000 mm between May and December from both southwest and northeast monsoons. The average mean temperature varies from 23°C to 32°C with 70-90% humidity.

More than 85% of the 8,249 sq.km total geographical area is covered by forests leaving only 6% area for cultivation. Topography is undulating and climate is congenial for plantation crops like coconut, arecanut and cashew; spices; field crops like paddy, pulses and oilseeds; and tropical fruits and vegetables. The Islands being the biodiversity rich one are the veritable treasure house of valuable medicinal, aromatic and dye herbs, trees and shrubs. There is good scope for the production of tropical fruits like mangosteen, durian, dragon fruit, rambutan, grape fruit, pomelo and longan which have high export potential. Such 'High Value Agriculture Programme' through organic farming should be promoted and product certification system should be developed to help farmers fetch relatively higher prices for their products.

Though coconut and arecanut are commercially important crops in the Islands, their yield is however low due to low input management and senility. Training farmers in modern techniques of cultivation will improve the yield of these crops; and multi-tier cropping with pepper, cloves and nutmeg will increase the value of produce per unit area. Modern methods for processing of copra should be used. In order to exploit the export potential, commercialisation of identified products needs to be encouraged by investing in marketing and storage facilities, promoting/developing linkages with food processing industries and creating efficient transport facilities. Over all agricultural extension services should be strengthened.

Agricultural productivity growth in Andaman & Nicobar plays a particularly important role in increasing the efficiency in production of agriculture products and maintaining National competitiveness in the face of declining terms of trade, increasing climate variability and tightening constraints on natural resource use. Besides, changing community attitudes and values are also emerging as important factors governing the farm production systems.

Decreasing land holding and increasing food demand

During the Settlement, each settler had been distributed with 2 ha of cultivable land and 0.4 ha of homestead land. However with time, this holding has been fragmented to the extent that 16,567 cultivators own 11,803 farm holdings wherein small and marginal farmers have 57% of the land holdings but own only 25% of total area, while 43% of the land holdings owned by medium and big farmers have 75% of the area. Presently, the average landholding size in the Islands is only 1.89 ha which is declining rapidly. Rainfed agriculture carried out on such small holdings is posing limitations over large scale investments.

The human population in the Islands is about 3.80 lakhs with a growth rate of about 6.7% during the last decade (Census, 2011). Assuming the prevalence of same growth rate, it is projected that the population in the Islands will increase to nearly 8.50 lakhs by the year 2050.

With the limited land availability, the requirements of growing population and burgeoning tourists in terms of drinking water, food including animal products need to be met through Island-specific technological innovations. Therefore, to meet the challenge of growing food demand against the adversities of climate change, various climate smart agricultural technologies involving field crops, horticultural crops, animal husbandry and fisheries as components have been developed and disseminated among the farmers in order to get maximum output per unit area while ensuring sustainable livelihood to farmers. As the major constraint towards enhancing profitability is the cost of inputs which have to be imported from mainland and its timely availability, thrust is given for organic farming with major focus on technological backstopping in water, soil nutrients, feed and fodder from local resources.

Climate smart agricultural technologies

In this milieu, ICAR-Central Island Agricultural Research Institute (CIARI) has developed various location-specific climate smart agricultural technologies suitable for Andaman & Nicobar Island ecosystem and disseminated among the farmers, unemployed youth, women self-help groups *etc*. through three of its Krishi Vigyan Kendras (KVK) located across the Islands. The provided technologies were proven effective in the field and generated multi-fold profits to the stakeholders while conserving the pristine environment of the Islands. Few of the technologies developed and disseminated by CIARI with some success stories are discussed hereunder.

I. Broad Bed Furrow System (BBFS)

Since vegetables are fetching higher price during monsoon season, BBFS developed for growing vegetables in the bed and paddy+fish in furrows gives better option for farmers to realize higher income from unit land area. While okra-amaranthus-okra recorded maximum net return of Rs.1,06,134 from 4,000 m^2 area of beds in one ha, Rs.10,840 was obtained from furrows. Thus, from 1 ha of BBFS comprising okra-amaranthus-okra in beds, brinjal+moringa+banana in border areas and rice+azolla+fish in furrows, Rs.1,17,532 has been obtained, which is 11 times higher than the normal cropping of paddy followed by pulses/fallow.

BBFS Success Story 1

Shri Alok Biswas had 1 ha each of low land and hilly land. Being progressive with good leadership quality, the Out Reach Centre (ORC) of CIARI selected and designated him as Opinion Leader of Madupur panchayat. In September, 2010 he was selected for taking up demonstration of paddy under System of Rice Intensification (SRI) with hybrid variety US 312 in an area of 1 ha. By following the scientific methods, he raised paddy seedlings and planted the 14 day-old seedlings in the main field. With proper management he could get an yield of 6.2 t, beside an additional yield of 1.12 t from ratoon crop.

As he also wanted to develop his existing arecanut garden with intercropping of fruits and spices, proper layout was made and the crops like pineapple, tree spices, sapota, banana and coconut were introduced in 1 ha of land. With the joint support of KVK for garden development, induced breeding and NAIP for Broad Bed Furrow System in 2012, he has started getting returns ranging between Rs.15,000 and 20,000 from an investment of Rs.5,000 by cultivating cucumber, okra, brinjal on the beds initially and anticipated more returns in future. Through induced breeding, he is earned Rs.2,50,000/year with investment of Rs.50,000 only. He sold the fish seeds @ Rs.3.00 in the early stages and big size at Rs.150.00/kg. He added 30 Nicobari fowls, the eggs of which were sold @ Rs.6.00 and few were hatched for multiplication. The best part of his farming was that he advocates use of only composting and FYM for his crops and does not allow use of inorganic fertilizer. For his innovativeness to take up SRI for the first time in the area he was bestowed with best farmer award during the Kisan Mela 2011.

BBFS Success Story 2

Shri D.N. Madhu of Chouldari village, South Andaman having 1 ha of valley land was cultivating only paddy under traditional method and harvesting only 2.0 t/ha with gross return of about Rs.15,000. But after Tsunami 2004, sea water inundated his field and left it uncultivable for the next two years. However on the third year, he has grown the paddy but recorded low yield to the extent that he could not even recover his investment. At that time, Shri Madhu approached CIARI for “demonstration of BBFS for crop diversification in low lying valley areas” after witnessing the same in CIARI’s research farm at Bloomsdale, Chouldari and neighbours’ field where BBFS technology was demonstrated through Farmer Participatory Action Research Programme (FPARP).

Shri Madhu adopted BBFS for growing vegetables in the bed and fish in furrows. He grew vegetables such as amaranthus, chillies, okra, radish and other cucurbits in beds as rotation throughout the year. In the furrow, he cultivated fresh water fishes like grass carp and cat fishes like singhi and magur. Further, Swamp Cabbage (*Nali Bhazi*) was grown in the furrows which served as feed for grass carp. His net return was Rs.1.19 lakhs/year/ha from sale of vegetables and fish from the same piece of land, wherein he was growing only paddy from which he was getting Rs.15,000 only. In recognition of his interest, innovativeness and adoption of technology he has been bestowed with "Best Farmer Award" in 2010 during the Island Kisan Mela.

II. Integrated Farming System (IFS)

Multiple land use through integration of crops, livestock and aquaculture can give the best and optimum production from unit land area. The concept of faming system, which brings together all these components to make it wholesome system is of paramount importance as it ensures optimum land use, maximum return, soil conservation, build up of soil fertility, better use of production resources, recycling of wastes and freedom from pollution. Besides, it also provides year round employment for farming family, risk management, reduction in the cost of production and supply of essential commodities throughout the year. Agro-ecosystem analysis of the farming systems in these Islands revealed 4 distinct Micro Farming Situations (MFS) in the farmers’ field .They are MFS I: Hilly, MFS II: Slopping hilly upland, MFS III: Medium upland valley and MFS IV: Low lying valley. Farmers are getting additional income of Rs.30,000 to Rs.50,000 per year from 0.20 ha depending upon the technology and Rs.2.55 lakhs/ha/annum.

IFS Success Story 1

Shri Ashok Sarkar is a resident of Govindpur village in North and Middle Andaman. In the 2.15 ha land allotted by Government, he was already practicing fish rearing with over stocking of rohu in 0.06 ha of pond. Under such circumstance, he came to know about Composite Fish Culture through the visiting scientists of CIARI and KVK.

He was motivated to adopt a large pond (66m x 30m x 3m) based Integrated Farming System involving the components of horticulture, agriculture, livestock and fisheries. Seeing the technology as very promising, he has increased the area gradually to 1.5 ha and is presently harvesting an average return of 2.5 to 3.0 t/ha/year. He could sell 1.5 to 2 t of fish per year and earn an income of Rs.1.85 to 2 lakhs. The fertility and moisture content of soil at his farm has also improved by mulching and application of vermicompost. He was able to generate an income with a B-C ratio of 2.07 from the farm produce. Shri Ashok Sarkar has been awarded for his excellent exhibits and contribution in the field of agriculture during Kisan Sammelan, 2016.

IFS Success Story 2

This is the story of Shri Manindra Mistry, a resident of Deshbandhu Gram Village, Diglipur in North & Middle Andaman district. He is a progressive farmer blessed with an improvised mind. He earned his livelihood by cultivating traditional crops like paddy, rearing *desi* poultry birds and fish culture on his allotted land. Since 1987 he was a member of Institute Management Committee (IMC) of CIARI and used to have regular contact with the scientists for the development of his agricultural land for maximizing returns. Subsequently, he had undergone few trainings on farm improvisation. Armed with the training inputs, Shri Maninder Mistry meticulously began to put into practice all that he had learnt.

Initial orientation from scientists and their frequent visits set him on the path towards progress. Soon, he had implemented IFS on his land that maximized inputs from an indigenous system of raising crops, cattle, goat, poultry and fish as each acted as an input for the rest in terms of feed, manure *etc*. He also took the initiative to introduce new high yielding varieties of paddy in combination with vegetables and flowers. As a result, his land yielded crops throughout the year.

He learnt the technique of fish seed production and became the first farmer of the Islands to start the entrepreneurship in fish seed trade. He wasted nothing and made optimum use of all farm wastes. Very soon, his farm became a complete self sustaining model. He had developed a part of his paddy land into fish culture pond and his income multiplied to more than Rs.5 lakh per year. He is a recipient of Jagjivan Ram Puruskar (2010) from ICAR for his success in achieving self sustainability in farming under the vulnerable island ecosystem**.**

IFS Success Story 3

Shri Panchu Ram Joydhar of Chouldari, South Andaman was practicing Composite Fish Culture since 1988. Before adoption of the technology he was rearing fish in unscientific way with over stocking of catla and mrigal fishes in his 0.06 ha of pond with production of 40- 50 kg/ha fetching very meagre returns. He got the knowledge of technology from CIARI in the year 1988, since then he is into it. He adopted suitable IFS with rice–fish-duck–azolla-swamp cabbage- colocasia and increased the area of the pond to 1.5 ha with catch to the tune of 300–400 kg/ha/year which gave him an average return of Rs.22,500 through the sale of fish as additional income from his IFS model.

III. Homestead based Integrated Farming System for tribals

The model aims at improving the nutritional security of tribal households besides improving the farm production and employment generation. A small scale homestead based IFS model, comprising Home garden (400m^2), backyard poultry (25), goatery (3) and composting has been developed in participatory mode for tribals at Car Nicobar. In the home gardens, 100 m^2 area is allotted for growing seasonal vegetables *viz.,* okra, brinjal, tomato, green amaranthus, cucumber, bitter gourd, bottle gourd and sweet corn. In another 125 m^2 area, fruit crops like banana, pine apple and papaya are grown. Tuber crops *viz*., tapioca, sweet potato, greater yam and colacasia are grown in 150 m^2 area. Besides, fruit trees like *Pandanus sp*., *Morinda citrifolia* and guava are grown in the corners of the field. *Sesbania grandiflora* (agathi) and *Gliricidia sepium* are grown as border trees to act as bio-fence besides serving green fodder and green leaf manure. Compost tanks are made at a corner of the homestead garden for composting crop residues and farm wastes. Above the compost tank, a pandal is made with local materials and perennial crops like coccinia are grown. The manure obtained from goat and poultry along with crop residues are used for making vermicompost. After such intervention, the frequency of consumption of food items *viz.* greens, vegetables, fruits, meat, poultry and egg by the tribal farm families has increased.

Homestead Gardening Success Story 1

Since 2011, KVK, Nicobar has conducted many training programs on scientific vegetable and fruit cultivation for the establishment of organic kitchen gardens to ensure the nutritional security of tribal people. A total of 325 farmers and rural youths including 224 men and 101 women got benefitted.

In 2012, KVK, Nicobar adopted traditional farmer Shri Petrik of *Turhato Tuhet*, Tapoiming village, Car Nicobar to establish organic nutritious kitchen garden. The entire programme gave emphasis on practical skill and knowledge development to start scientific vegetable cultivation with full confidence. The programme components included various techniques of landscaping, layout planning, growing vegetable nursery, sowing methods, application of organic manure (goat and poultry manure), composting, vermicomposting, plant protection measures *i.e.* neem oil, neem leaf extract, *Trichoderma viride*, kernel extract of *Barringtonia asiatica* and also seed production of vegetables.

Through the intervention, he fulfilled his daily needs and sold the surplus to villagers and Anganwadi for mid-day meals and earned Rs.18,421 and Rs.22,657 during 2013-14 & 2014-15 respectively. After technological intervention by KVK, visible impact has been seen in adoption of technologies demonstrated, increase in income, providing livelihood, nutritional security, employment generation and improvement of socio-economic conditions of Shri Petrik and his *tuhet*. Now, he is a model farmer for the entire village.

Homestead Gardening Success Story 2

Shri Ramachandran is a Primary School Teacher in Rangachang village of South Andaman. He was producing vegetables for his own consumption using organic manures from his small piece of vacant land (200 sq.m.) with indigenous techniques using own seeds without any chemical fertilizers and pesticides. He came in contact with CIARI-KVK in 2010 and shown interest for organic farming. On his request, the Subject Matter Specialists visited his farm and after inspecting the available resources in his field, he was advised to undergo the trainings conducted by KVK for skill development and better utilization of limited land for more production per unit area.

These trainings enabled him to acquire scientific knowledge on organic farming. He showed interest for developing a multi-tier cropping system which generate income round the year with pineapple, papaya, banana, tree spices like clove, cinnamon, ginger under his coconut plantation. In this venture, his mother and family were fully involved and with their support he was able to increase the area of vegetable and fruit cultivation to 1 ha. Surplus farm produce were sold in the village itself. Through sale of produce, he earned an additional income of Rs.62,000 as net profit per year. He has also constructed one pond (30 m x 20m x 3 m) for harvesting rainwater for fish culture and giving irrigation to intercrops during summer months. His hard work and sincerity brought laurel to his family and he became a role model for the youth and farmers of his area.

Homestead Gardening Success Story 3

Shri Gedion Lynus, a traditional farmer of village Tapoiming grows *Dioscorea* spp. (Nicobari Aloo), *Colocasia*, Tapioca, *Xanthosoma*, banana, pineapple, papaya, pigeon pea, cowpea and some other traditional plantation crops in his garden under traditional shifting cultivation with community based approach, in which several families of *Tuhet* work together. The KVK, Nicobar during April 2012 adopted him and provided technological advice for promoting organic cultivation of vegetable crops. 150 m^2 land area was prepared and locally available organic manure was incorporated in the soil. He developed vegetable nursery of chilli, tomato and brinjal in his garden. He has taken all the tips of growing seedlings of vegetables *viz.* preparation of bed, depth of sowing, spacing, covering seeds, mulching, watering, removal of mulch at right stage, hardening of seedlings *etc.* from time to time and successfully grew seedlings of chilli, tomato and brinjal. He has harvested cowpea, okra, brinjal and radish (as leafy vegetable and root crop) at right stage by judging the maturity. The over production of vegetables after home consumption was sold to shopkeepers at Car Nicobar which was a small beginning by a tribal farmer.

Homestead Gardening Success Story 4

Generally, Nicobari tribals are not much fond of leafy vegetables and fruits but prefer root and tuber crops. They do not have the culture of vegetable gardening in their backyard. Lack of knowledge on vegetable cultivation and its management practices are the main problems identified by them. Among the tribal community, Shri Lionlad used his small area of 2 bigha for different vegetable cultivation. He grew dolichos lab-lab, cow pea, amaranths, radish, okra, chillies and tuber crops in the same field with different technologies. He use to collect decomposed leaves from the forest and mix it in the prepared land. Thereafter he put three seeds of cucurbits like cucumber, ridge gourd and sponge gourd together in single pit. By doing so he saved his time and choice of the vegetables are not so far from his kitchen.

IV. Earthworm rearing as business opportunity

Organic manure in the form of vermicompost obtained through earthworms is one way to overcome the problems of low productivity. The organic waste materials consumed by earthworms are digested by microbes present in their guts and gets out in a granular form (cocoons) known as vermicompost. Vermicompost made from the mix of dung, crop residues and kitchen wastes is rich in terms of nutrient availability compared to FYM which is from mere decomposition of dung. About 2-3 kg of earthworms is required for 1,000 kg of biomass, whereas about 1,100 earthworms are required for 1 m^2 area. Non-burrowing species are mostly preferred for compost making. Red earthworm species like *Eisenia foetida* and *Eudrillus enginae* are most efficient in compost making.

Flower pots or abandoned buckets can be used for small scale multiplication of worms. Make small holes on the side of pot/bucket and put 3-4 big size gravels into it to enable aerobic condition. Fill the pot/bucket with well chopped (4-5 cm length) organic wastes for about 2 cm thickness. Above that, spread 2 cm thick layer of fresh cow dung (2-3 days old). In this pattern, fill the organic wastes and cowdung alternatively till the pot is filled. Then, introduce red earthworms (10 to 20) and cover the pot with gunny bag. Sprinkle water once in a day on the gunny bag to keep it sufficiently moist. Once decomposing process starts, space will be available on the top. Fill it with organic wastes and cowdung alternatively to give sufficient feed to earthworms. Within 2 months, 4-5 kg of worms can be produced from 10 to 20 worms, which can be utilized for farm scale vermicompost production.

Success Story

Shri Shyampada Roy came for a customized training conducted by CIARI-ORC during the month of July, 2010. He was imparted training on making vermicompost and rearing of worms by the scientists of CIARI. He learned all the aspects involved in rearing the worms. He collected 3 worms and managed to carry it to his residence with a motive to multiply the same and start an income generation activity. He was in constant touch with the scientists and staff, who motivated him all the way. After a period of 6 months he could rear quite a good amount and started to sell the worms to his neighbours.

He took a loan of Rs.11,000 from Department of Agriculture under RKVY and built 2 pits of size 7 X 15 ft and 6 X 20 ft respectively. He used split slates of bamboos on the sides, aluminium sheet as roof with black polythene sheets as the base material, for which he spent Rs.20,000. He used to add cow dung, hay, dried leaves and other materials as bed material for the earthworms, wherein he incurred an expenditure of Rs.52,000 annually. He has already sold earthworms to the farmers in neighbouring areas up to Diglipur to the tune of more than 300 Kg at the rate of Rs.400/kg. Presently he is able to sell around 15 to 20 Kg of earthworms per month and earn an additional income of Rs.15,000-20,000. He was bestowed with "Best Farmer Award" during Island Kisan Mela, 2012 for his entrepreneurship.

Conclusion and policy implication

Andaman and Nicobar Islands is known for its natural resources and biodiversity. Agriculture has always been a challenge for the people in the Islands, both due to limited cultivable area and low productivity which is further constrained due to reduction of cultivable land after tsunami, 2004. Initially, intensive farming technologies, use of chemical fertilizers and pesticides were promoted to attain self suffciency in food production. Subsequently, the Islands have been identified as a potential area for organic farming. Considering the limited area under crops, the Islands can be brought under 100% organic farming with available plant residues, animal wastes and forest litters from buffer zone. Since both area and productivity are constrained, farmers income can be enhanced through organic farming based agricultural products that fetch higher prices.

The situation in the Islands is even more peculiar, wherein the first generations of settlers who were either freedom fighters/convicts or displaced persons from Bangladesh/Myanmar/Sri Lanka took up farming as it was the only source of livelihood then. However with globalization and information explosion, the aspiration level of today's youth has risen. Thus our agricultural production system has to be reoriented by appropriate interventions for reducing drudgery, more value addition, increased productivity and enhanced profits to match their aspiration.

Agricultural transformations have to occur at the level of small holding farmers so that the farming systems can be made more productive and efficient in the use of resources. Even in these Islands there is an alarming increase in population and the production of various commodities are falling short of demand.

Hence, it is necessary to develop appropriate developmental strategies to improve the economy of the rural sector through convergence of suitable, time tested agricultural technologies and sustainable use of natural resources for ensuring Climate Smart Agriculture in the island ecosystem in an organic way.

Thus, the following policies are proposed to improve the agricultural production in the Islands while generating gainful self-employment for small farmers, self help groups, rural youth and other stakeholders of the society:

- Increase food grain production to subsistence level; vegetables, oilseeds and perishables to semi-commercial level; and coconut, arecanut and spices to commercial level.
- Promote organic farming and organic product certification system to help farmers fetch relatively higher prices for their products through exports. Thrust to be given for multi-tier cropping (with pepper, cloves and nutmeg) which will increase the value of produce per unit area.
- Develop suitable technological innovations for enhancing rice and pulse production; and efficient processing and storage facilities to meet the Island-level food requirement in view of the Food Security Act.
- Develop modern methods/technologies for processing of copra.
- Encourage commercialization of identified products by investing in marketing and storage facilities, promoting/developing linkages with food processing industries and creating efficient transport facilities in order to exploit the export potential.
- Promote Transfer of Technologies in agri-business modules to create a production to consumption chain involving SHGs, Farmers Producer Organizations, farmer cooperatives, retailers and processors.
- Impart training to farmers on modern precision farming techniques of cultivation, soil health improvement, pest and disease management which will improve the yield of field and plantation crops.
- Considering the remoteness and inter-Island connectivity, the focus should be to reorient techno-delivery system

through participatory and tele-agricultural communication system with the involvement of local Administration and NGOs to bridge the demand and production.

- Reorientation of agricultural production system to meet the demand for perishable products *viz*. milk, egg, meat, fish, fruits, vegetables and flowers with specific reference to the booming tourism industry. Keeping this in view, demand driven technologies have to be identified and effective delivery system should be developed in public-private partnership mode.
- Linking CIARI and its KVKs with other educational institutions for creating local level skilled human resources in the field of agriculture and allied sciences; and also for post-disaster restoration of agriculture in the Islands.
- Creation of local level processing technologies and cold chain storage facilities to enhance the shelf life, reduce losses and value addition for plantation and horticultural crops, animal and fish products.
- Water resource management for sustainable crop production like land shaping techniques for *in-situ* rainwater harvesting, soil management, crop diversification and livelihood security in degraded areas.
- Innovate location specific agricultural machinery to suit the island ecosystem and terrain to minimize the drudgery and efficient utilization of energy in view of shortage of labour, and
- Prioritize convergence of overall agricultural extension services.

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