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ICAR-Indian Institute of Maize Research
PAU campus, Ludhiana, Punjab-141004
Phone: +91-161-2440048, Fax: +91-161-2430038 Mobile: +91 9492430207
Email: pdmaize@gmail.com; s.rakshit@icar.gov.in. Website: www.iimr.res.in

Model Training Course on

Maize Production Technology and Management Strategies for Fall Armyworm

(04th-11th November, 2019)

Course Director:
Sujay Rakshit

Course Coordinators:
J. C. Sekhar, N. Sunil
P. L. Soujanya, K. R. Yathish
S. B. Suby and S. L. Jat

भाकृअनुप-भारतीय मक्का अनुसंधान संस्थान
ICAR-Indian Institute of Maize Research
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Maize Scenario in India-Opportunities and Challenges

Sujay Rakshit and Chikkappa G. Karjagi
ICAR-Indian Institute of Maize Research, Ludhiana 141004, Punjab (INDIA)
Email: s.rakshit@icar.gov.in

Abstract

The requirement of maize is increasing due to burgeoning population.In order to meet the growing demand, there is need to increase maize production. The maize area, production and productivityof India have increased by 1.97, 15.62 and 4.6 timesduring 1950 to 2017. However, achieving such progress in future is the major challenge considering depleting land and water resources on one hand, and increased biotic and abiotic stresses on the other hand. In spite of above major challenges, there are opportunities to enhance the productivity of maize provided the strategy must involve all stakeholders like researchers, planners, farmers, maize based food, feed and other processing industries and consumers,who are directly or indirectly responsible for enhancing the maize production. The most important among several strategies would be bringing maize area under single cross hybrids from present 60% to100%,development of climate resilient hybrids through germplasm diversification, accelerated development of new and improved hybrids through application of advanced tools and techniques like doubled haploids, marker assisted election, genomic selection, genetic engineering techniques like CRISPR-Cas9 etc. Thus, it is possible to increase the maize production to meet the growing demand.

Keywords

Genetic improvement, single cross hybrids, climate resilient cultivars, mechanization, production and protection technologies, backward and forward linkages, utilization pattern, value addition,

Introduction

The world population is increasing exponentially and food requirement is also increasing proportionately. Hence, , and this is to be achieved under the scenario of changing climate and depleting availability of arable land and water (Rakshit et al. 2014). Climate change is evident in every sphere of life including agriculture. Its impact on production of agricultural commodities is likely to be the most drastic in tropical and subtropical regions of the world. South Asia with low adaptive capacity is the most vulnerable region for multiple stresses (IPCC, 2007; ADB, 2009; Rodell et al. 2009; Niyogi et al. 2010). Ground water level at various parts of Asia more particularly in north western Indo-Gangetic plains is at very critical level.al.The challenge of increasing food production from depleting land and water resources on one hand, and increased biotic and abiotic stresses on the other can be achieved through higher crop yields per unit area (Foulkes et al. 2011) and developing and growing climate resilient crops (Rakshit et al. 2014). Among the principal cereals, water requirement of maize is the lowest (500 mm) compared to rice (2100 mm) and wheat (650 mm).Beside this maize has the versatility to beused as food, feed, fodder and raw material of over three thousand industrial products.

Maize scenario

India produced over 281 million MT food grains in 2018-19, out of which cereals share the major part. Among cereal grains rice represent 44% of the gross cultivated area followed by wheat (30%), maize (9%), pearl millet (8%) and other millets. Rice and wheat constitute 44%

and 39% of cereal production, respectively while maize represents little over 9% of cereal production (Rakshit et al. 2017).

Maize production between 1950-51 and 1958-59 almost doubled from around 1.73 million MT to 3.46 million MT. This happened due to nearly 35% increase in area and 48% in yield (Yadav et al. 2015). With the level of 1950s the production has increased by 15.62 times. This has happened due to 1.97times increase in area and 4.6times increase in productivity. They dynamics of yield gain and productivity in India has always remained very intriguing (Fig. 1). Annual increment in maize area during 1949-60 was 109 thousand ha per year, while the productivity enhanced by 24.7 kg/ha/year. The corresponding figures in the 1960s were 168 thousand ha/year and 7.4 kg/ha/year, respectively. During 1970s and 1980s the maize area was almost stagnant, while in 1980s India experienced significant yield increment at 29 kg/ha/year. During 1990s the figure was 37 kg/ha/year. From 2000-10 the yield gain was over 46 kg/ha/year, while current figure is nearly 52 kg/ha/year. Though during 1980-90 there was a slowdown in area increase, the maize area has increased substantially and maintaining a growth rate of around 200 thousand ha per since beginning of this millennium. The five yearly average areas under maize is 9.2 million ha and production is 23.3 million MT.

Maize was a rainy season (*kharif*) crop predominantly in India. It was largely grown in northern India the states of Uttar Pradesh, Bihar, Rajasthan and Madhya Pradesh. After 1980s a significant shift in area towards peninsular region was noticed. "Currently this region represents nearly 40% of the total area under maize and over 52% of production. The major maize growing states are Karnataka (14.8%), Maharashtra (10.9%), Madhya Pradesh (10.8%), undivided Andhra Pradesh (10.4%), Rajasthan (10.6%), Uttar Pradesh (8.3%), Bihar (7.9%), Gujarat (5.0%) and Tamil Nadu (3.6%), accounting for nearly 80% of the total maize area of the country. However, productivity of maize in many of these states like in Rajasthan (1.6t/ha) and Gujarat (1.6 t/ha) are quite low, while that in Uttar Pradesh (1.7 t/ha), Madhya Pradesh (1.9 t/ha) and Maharashtra (2.3 t/ha) are below the national average of 2.6 t/ha" (Rakshit 2018).

Maize with its wide adaptability is cultivated throughout the country during all the three seasons. However, in few states like Kerala and Goa has very little area under maize, where specialty corns have more presence. The kharif maize is cultivated almost across the country winter or *rabi*maize is cultivated more in Bihar, West Bengal and Peninsular India. Summer maize is gaining popularity in Punjab, Haryana and western Uttar Pradesh. Kharif maize represents around 80% of maize area while rabi maize represent 19% of area. Summer maize occupies 1-2% of total maize area in India. Out of three maize seasons nearly 80% of kharif maize is cultivated under rainfed condition, while rabi and summer maize is cultivated under assured ecosystem. Thus rabi maize has yield level of over 4.0 t/ha, while kharif maize has little over 2 t/ha productivity. To increase the yield level of maize productivity of kharif maize needs to be augmented.

Out of 24 million MT requirement of maize in India around 60% is used as feed, 14% for industrial purposes, 13% directly as food, 7% as processed food and around 6% for export and other purposes (Fig. 1). The demand growth trend suggests an increase in demand of 7.18%, leading to targeted demand for maize of 50-60 million MT by 2025 (Rakshit 2018). Not only domestic demand the international demand for maize is also increasing and will continue to increase. Thus, maize opens up a unique opportunity not only to supplement the maize-based industry but the export as well. The demand for maize is increasing not only as grain but for specialty purposes as well. Among specialty corns, sweet corn, baby corn and pop corn have not only immense market potential but can contribute significantly towards crop diversification and doubling farers income.Maize is extensively being used in dairy industry not only as feed stock but the as fodder, which is used as both green fodder and silage.

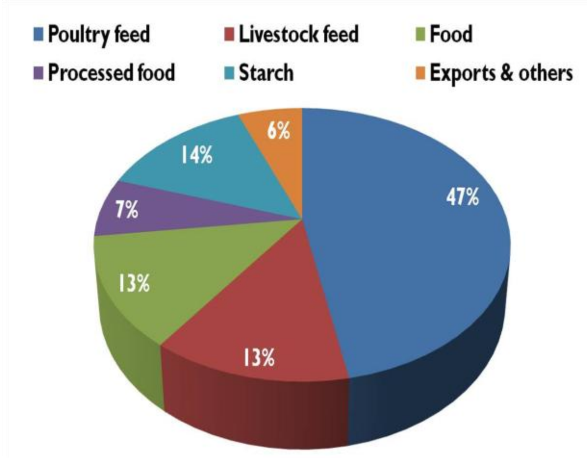

Fig. 1. The usage pattern of maize in India

Progress in maize research

Genetic improvement

The All India Coordinated Research Project (AICRP) on Maize was initiated in 1957 and showed its significant impact in increasing maize production in India. Rightly during the initial period the emphasis was on hybrid research. This led to release of first set of double cross hybrids, *viz*., Ganga 1, Ganga 101, Ranjit and Deccan in 1961. However, slowly the main focus diverted towards composite breeding, leaving hybrid research in the backburner. This may be considered as a major setback to progress of maize research and development in India. Some centres under AICRP on Maize continued their focus of research on hybrids, this lead to release of first single cross hybrid, Paras by Punjab Agricultural University in 1996. This was followed by shifting of maize research on single cross hybrids alone. This may be evident from the significant increase in maize yield gains post 2000 (Fig. 2). During late 1960s onwards focus of research was also diverted towards development of quality protein maize (QPM). The initial QPM varieties did not gain success due to chalky grain, susceptibility to storage pests etc. However, with availability of hard endosperm QPM sources first three-way cross QPM hybrid, Shaktiman 1 was released in India in 2001. Since then though several QPM hybrids (mainly single cross hybrids) have been released in the market by various AICRP centres, in roads of these hybrids remained restricted due to non-availability any additional price to QPM produce, with little yield penalty to QPM hybrids and non-cultivation of QPM in large contiguous field leading to reduction in quality of the

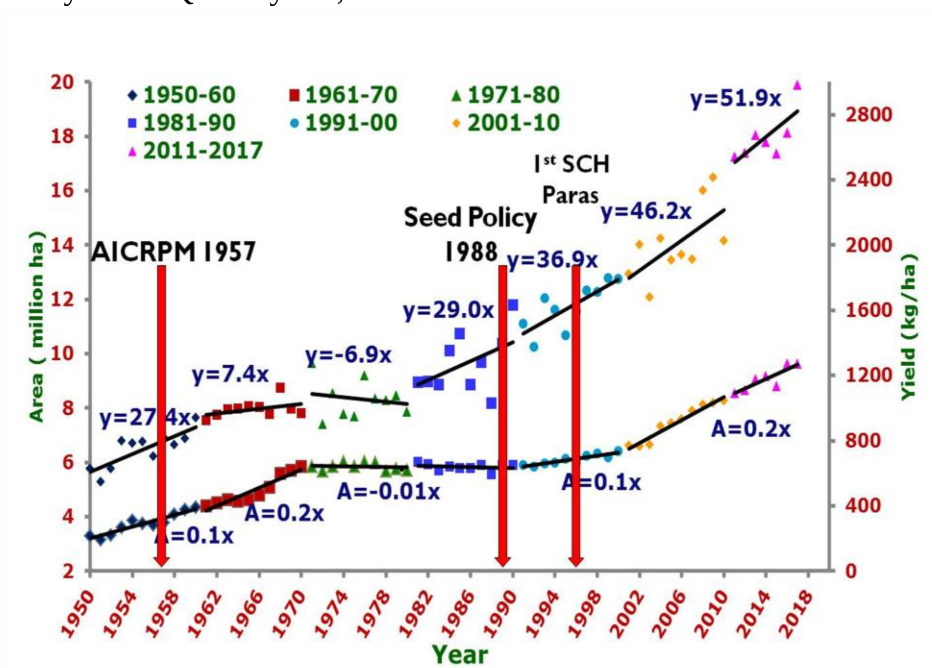

Fig. 2. The scenario of maize area and productivity in India during 1950-2017

produce. Since 2000 a total of 237 cultivars have been released in India, out of which 82% (195) are hybrids. Public sector contributed 50% of released hybrids, while remaining have been released by private sector companies. In the public maize breeding except QPM none of the specialty corns received focused attention until recently.

Crop production and management

No yield gain in any crop is achieved through genetic gains alone but effective crop production technology and management practices play a very important role in this regard. Right plant stand for different growing conditions,method of sowing, **s**ite-specific nutrient management, intercropping with various crops (particularly rabi maize), weed management etc. have been proved significant intervention to increase productivity of maize. Consistent research efforts on resource conservation technology (RCT), particularly Zero tillage (ZT) technology and crop residue incorporation in maize-based cropping system have been found to be highly remunerative. Maize system productivity of 11.3–12.9 t/ha with reduced water requirement by 40–65 ha-mm under ZT has been reported in maize (Parihar et al. 2016). RCT practices are becoming popular in the Indo-gangetic region and in peninsular India. Effective plant protection is key to sustainable production. Over period of time the project as strive hard to contain the onslaught of various biotic and abiotic stresses. Sources of resistance against major diseases and insect pests have been developed and deployed to strengthen host plant resistance (HPR) to combat these stresses. Effective chemical and cultural control measures have been developed against these stresses in an integrated manner.

Mechanization

With reduced availability of labour farm mechanization from land preparation, sowing to post-harvest handling play a very important role. Unlike other cereals mechanization in maize cultivation is not much in practice except land preparation. In recent past combined harvesters are being introduced on hire and use basis in southern states. But this needs much popularization with governmental support. Dehusker cum sheller and grain driers need to be integrated with maize production and processing system. Unlike rice and wheat maize is more prone to damage during storage due to aflatoxin infection and damage by rice weevil. This problem is more severe if grains are not dried properly (<14%).

Value addition

Over period of time maize has maize being a food crop has gained its popularity as feed crop. However, considering the low glycemic index of maize it can be an important part of dietary component as well. Many maize-based ready-to-cook (RTC) and ready-to-eat (RTE) products can be developed. QPM grains may further add value to these products. Rajendra Agricultural University, Dholi and University of Agricultural Sciences, Mandya have made significant contribution in this direction. In recent past UAS, Mandya is marketing many of the value added products in the brand name of ‘Maizy’ in the state of Karnataka.Besides grain corn, specialty corns – sweet corn, baby corn and pop corn assumes immense potential in terms of value addition.

Strategies for enhancing maize production

The strategy must involve all stakeholders who are directly or indirectly responsible for enhancing the maize production. The main stakeholder is the farmer, the actual producers of maize. However, farmer needs technology and policy support; the extension personnel located at krishi vigyan kendras, department of agriculture of different states can take an active role in transfer of technology whereas the planners and government can devise policies to provide financial security to farmers involving in maize cultivation. The backward and forward linkages through Public-Private-Producer Partnership (PPPP) can go a long-way to sustain the interest of farmers in maize cultivationwhich is the back-bone for enhancing the maize production through increasing the maize productivity in a sustainable manner. The following strategies could be adopted to bring sustainable increase in maize productivity:

- Development of high-yielding climate resilient cultivars
- Expansion of area under hybrid cultivars
- Production and protection technologies
- Development of backward and forward linkages
- Policy interventions

Strategies for development of high-yielding climate resilient cultivars

Diversification of maize germplasm

Maize has tremendous genetic diversity;significant yield gain achieved in maize as compared to other cereal crops during the last six decades across the globe signifies the fact that maize is the crop with highest yield potential. However, the hidden potential existed in the form of genetic diversityavailable in different landraces and its wild relatives has not yet explored largely. The growing demand for maize by entirely different kinds of industries like bio-fuel, paper and bio-degradable plastic and changing climate especially the vagaries of monsoon has necessitated the need to explore the possibility to use genetic diversity existed in landraces and wild-relatives . In addition, the heterosis between temperate into tropical germplasm has not yet been exploited largely in developing countries and particularly in India.Development of novel germplasm through temperate into tropical crosses and also introgression of exotic germplasm into active breeding material would create genetic variability to further enhance the yield potential.

Development of climate resilient cultivars

The intra-seasonal fluctuations in rainfall and temperature in different agro-ecological zones demand for cultivars with climate resilience trait. Identification of cultivars with tolerance to various kinds of moisture stress like drought and waterlogging at critical crop growth stages would help to reduce the yield losses due to different kinds of moisture stresses. Development of phenotyping network in different agro-climatic zones by creating managed stress conditions would assist in selection of right kind of cultivars. Thus the focused research on development of climate resilient hybrids and deployment of such climate resilient hybrids in targeted areas would certainly increase the productivity of rainfed areas. The large-scale demonstration of climate resilient hybrids on farmers' field across multiple locationswould increase the rate and percentage of adoption of such hybrids by farmers.

Applications of novel methods to accelerate the rate of cultivar development

The maize genome sequence information is out in public domain, several thousands of gene(s) and quantitative trait locus (QTL) determining key traits like resistance to different biotic stresses, tolerance to abiotic stresses; different yield contributing traits, quality traits etc. have been identified. The novel precise targeted gene editing technique like CRISPR-Cas9 is also available. In addition, other advanced technique like doubled haploid techniques (DH), marker assisted selection (MAS) and of late speed breeding technology would facilitate accelerated breeding.. Application of such novel tools and techniques in maize improvement would help in breeding by design. The techniques have also increased the rate of cultivar development by substantially reducing the breeding cycles. The simultaneous development in high-throughput field-phenotyping facilities, statistical algorithms for analysis of complicated data etc. together can help in increasing the genetic gain thus help in developing new, high yielding, climate resilient cultivars.

Development of genetically modified (GM) maize

The area under genetically modified maize across the globe has been continuously increasing and the number of countries adopting GM maize is also increasing. In India also several transgenic events against insect resistance, herbicide tolerance have been tested under contained conditions under supervision of the Genetic Engineering Appraisal Committee (GEAC). In fact transgenic events with tolerance to abiotic stress like drought have been developed;DroughtGard™, the first commercial genetically modified maize hybrid released for drought tolerance. Similarly for other traits where the sources of resistance are not available or available in low frequency could be considered to improve through transgenic approach..

Expansion of area under hybrid cultivars

Presently around 60% of the total maize area of the country is under hybrid maize, whereas the national average productivity of maize is around 3 t/ha. There is scope to bring additional 40% of maize area under hybrid cultivars to further increase the productivity by at least by 50%. In order to expand the maize area under hybrids, the promotion of hybrid seed production in different parts of the country would bring awareness among farmers about hybrids.. Several sites have already been identified in different states like Rajasthan, West Bengal, Bihar, Jharkhand etc. to enhance the hybrid seed production capacity involving National Seed Corporation (NSC) and other state seed corporations like Rajasthan Gujarat etc. The government policy push to bring more area under hybrid maize would certainly help to increase the maize productivity.

Production and Protection Technologies

Adoption of improved agronomic practices and also undertaking timely plant protection measures depending on the need would help in reducing the yield gaps substantially and reduces the losses due to various insect pests respectively. The plant production practices like crop diversification, crop rotation, intercropping, and adoption of conservation agriculture practices help in enhancing the soil health in long-run. The application conservation agriculture (CA) practices like residue retention would serve as moisture conservation technique. Retention of soil residue would modulate soil temperature, soil pH, organic carbon, soil micro-biome etc. The CA practices also reduce the cost of cultivation which in turn helps in enhancing the farmers' income. In order to augment and enhance farmers' income, the specialty corn cultivation like sweet corn and baby corn can be promoted in selected areas around urban areas. Contract farming approaches can provide market stability to farmers and also continuous supply to traders. The government's policies can also focus consider to promote specialty corn cultivation due to huge export market for specialty corn.

Development of backward and forward linkages

The maize production in India is increasing gradually.During the last one decade (2007-2017), the area, production and productivity of maize have increased by 15, 51 and 31 per cent respectively. In order to avoid post-production losses and also maintain the farmer's interest in maize cultivation, there is need to create adequate large-scale storage facilities and also provide the farmers the market stability respectively. The diversified uses of maize coupled with increased maize production have directly or indirectly helped several industries to expand their consumption capacity. The policy support in this direction to promote further industrial growth is needed. The policy should consider all the stakeholders like farmers, industrialist and consumers. One of the current developments in this direction is the initiative taken by Haryana Government with respect to crop diversification. The Haryana government has announced the comprehensive package to farmers cultivating maize. The government has giving assurance to farmers that the government will buy-back all their maize produce at MSP; such kind of policy support would not only increase the maize productionbut also help in conserving the precious natural resources like water. Further, promotion of maize as food crop is also required by highlighting the nutritional importance of quality protein maize (QPM). The advantages of QPM over other cereals like rice and wheat would increase maize consumption as food. The number of persons with diabetic is increasing in India; initiative like promotion QPM would certainly reduce the burden on spending on health. However, the strategy should be developed to link, QPM producing farmers, food processing industries and the consumer. Considering the existing infrastructure and business models in India like omni-presence of super markets, the health awareness the task is easy to accomplish. Similarly linking maize producers, starch industry, poultry industry and consumers could create enabling environment to further enhance the maize production and productivity.

Policy intervention to further enhance the maize production in India

- Establishment of centralized state-of-the-art research facilities or centre of excellence to carryout advanced research on DH, MAS, gene editing techniques etc. to further enhance maize productivity.
- Mission mode approach to bring 100% maize area under hybrids through National Seed Corporation (NSC), State Seed Corporations (SSC) and private companies by linking with State Agriculture Departments to supply hybrid seeds at the door steps in subsidized rate.
- Large-scale campaign to promote mechanization in maize cultivation from land preparation to sowing to harvesting and facilitating either subsidy or through PPP to establish custom-hire centres to rent big and small machineries.
- Linking food, feed and starch industries with farmers to purchase the maize produce from the farmers door-steps along withestablishing community based large scale dryers to produce, market and procure quality maize.

Challenges and future outlook of maize research and development in India

The challenges in maize production are dynamic. The major challenge is the low productivity in rainfed areas of kharif season. The major reason for low yield is the vagaries of monsoon as 70% of maize area is under rainfed condition which largely depends on the monsoon rains. The 70% of maize area often experience moisture stress either in the form of low moisture (drought) or high moisture (waterlogging) at different growth stages. About 80% of maize area is being cultivated during kharif season. The kharif season and dependencies on monsoon rains are the two major factors which is responsible for low productivity. Heavy incidence of weeds and losses due to weed infestation during kharif season is the other major challenge. However, in recent years one or two post-emergence herbicides are available to control weeds but use of herbicides increases the cost of production. On the contrary we are aiming to double the farmers' income which is possible either by increasing the yield or by reducing the cost of cultivation. The third most important challenges is scarcity of labor and lack of customized small to medium to big machineries for complete mechanized cultivation of maize by small to marginal to large farmers.The labor wages are increasing across all states and percentage of agriculture laborers is decreasing. On the contrary, in order to reduce the cost of cultivation and also to overcome the labor scarcity, mechanized maize cultivation is not happening mainly due to lack of desired machines in sufficient number. The fourth most important challenge is lack availability of quality seed in sufficient quantity at affordable price at the farmer's door step. The hybrid maize seed production has concentrated largely in coastal Andhra Pradesh and some parts of Telangana and most of the hybrid seed produced is get sold-out in peninsula part of India. Recently an invasive pest fall armyworm has created an alarming situation in most parts of India. The losses may go up to 100% if proper measures not taken at right stage of infestation. Finally, the application of modern tools and techniques in India to develop new and improved maize cultivars is not comparable with other parts of World.

The domestic demand and international demand for maize is increasing continuously. Presently India is self sufficient to meet the domestic demand. However, it is estimated that the future demand for maize in India would increase at increasing rate. In order to meet the future demand India has to increase the rate of genetic gain in increasing rate in coming years which is not easy under decreasing natural resource base and changing climate. However, by application of advanced tools and techniques like DH, coupled with germplasm diversification, genomic selection, the future demand can be met, provided 100% adoption of hybrid technology. The application advanced tools and techniques, would help in identification of gene(s) determining tolerance to different kinds of stress like biotic and abiotic stresses. Integration and use of genotypes carrying such gene(s) in active germpalsm would help in developing climate resilient cultivars. Further, integration of DH, MAS and genomic selection (GS) would further accelerate the rate of cultivar development.

The policy intervention towards ensuring 100% adoption of hybrid technology, availability of quality seeds at affordable price at the door step of farmers would not only increase the productivity but also enhance the farmers' income.

Conclusion

India has to achieve the maize production target of 50-60 million MT by 2025. Presently India is producing around 28.75 million MT of maize (2017-18). During last ten years (2007-2017), India has increased its maize production from 18.96 to 28.75 million MT. The challenge looks daunting; but, it is achievable through strong policy support. Because, presently large number of single cross hybrids are already available with yield potential of 6-7 tons/ha during kharif season and 9-10 t/ha during rabi season. However, the only major challenge is to adoption of already available technologies like single cross hybrids on 100% area and ensuring availability of quality seeds at the door steps of farmers. In addition, focused research on germplasm diversification, development of climate resilient hybrids, accelerated development of hybrid cultivar through application of advanced tools and techniques, promotion and popularization of new and improved hybrids, adoption of improved production and protection practices would ensure sustainable increase in maize production and productivity.

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Maize Biology

Yathish, K.R, Lakshmi Soujanya P, Sunil N, AK Das and J C Sekhar
Winter Nursery Centre, ICAR-IIMR, Hyderabad

Maize, third most important cereal crop in India after wheat and rice; with its wide adaptability is cultivated throughout the country during all the three seasons. *Kharif* maize represents around 80% of maize area while *Rabi* maize represents 19% of area. Summer maize occupies 1-2% of total maize area in India. It is also called queen of cereals because of its highest genetic yield potential among the cereals and is a C_4 plant. The demand for maize is increasing not only as grain but for specialty purposes as well. Among specialty corns, sweet corn, baby corn and pop corn are very popular have an immense market potential. Other than food purpose, maize is also used as livestock feed, poultry feed, various other industrial uses etc.

Taxonomy

Maize belongs to the tribe Maydeae of the grass family Poaceae. "*Zea"* (zela) was derived from an old Greek name for a food grass. The genus *Zea* consists of four species of which *Zea mays* L. is economically important. The number of chromosomes in *Z. mays* is 2n = 20.

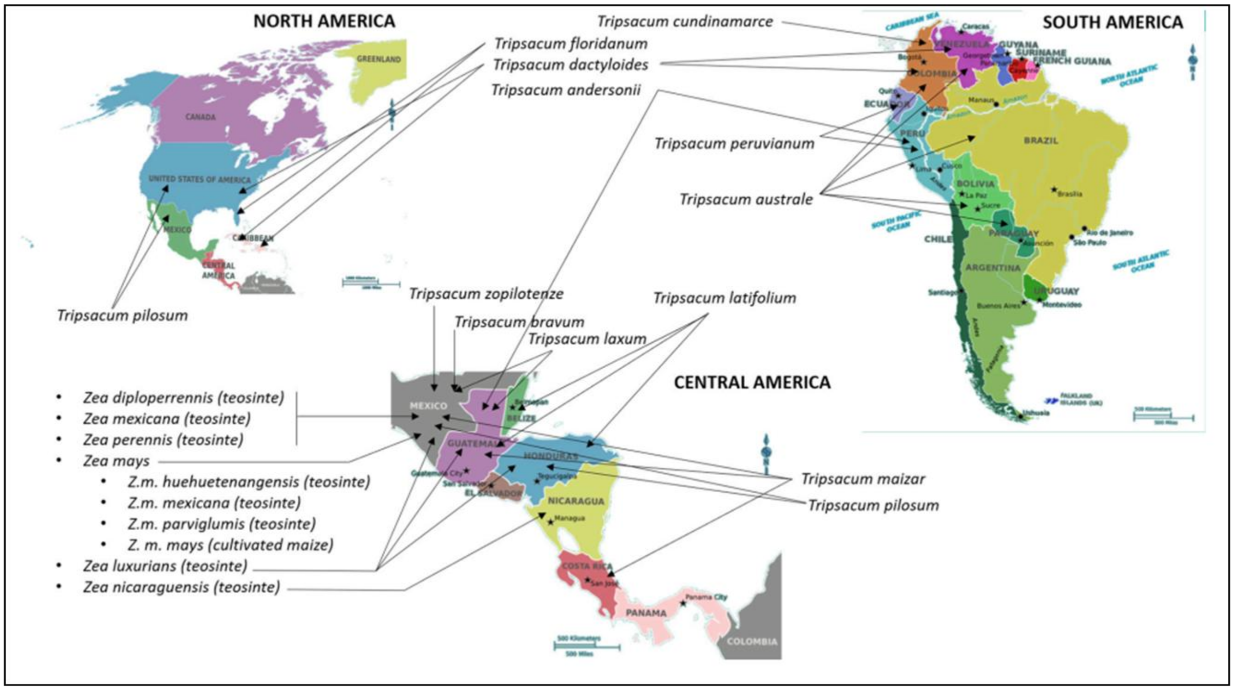
Name	**Maize**
Kingdom	Plantae
Division	Magnoliophyta
Class	Liliopsida
Order	Poales
Family	Poaceae
Genus	*Zea*
Species	*mays*

Tribe Maydeae comprises seven genera which are recognized, namely Old and New World groups. Old World comprises Coix (2n = 10/20), Chionachne (2n = 20), Sclerachne (2n = 20), Trilobachne (2n = 20) and Polytoca (2n = 20), and New World group has Zea and Tripsacum. The genus Zea consists of four species of which only Z. *mays* L. (2n = 20) is economically important. The other Zea sp., referred to as teosintes, is largely wild grasses native to Mexico and Central America (Doebley, 1990b). It is generally accepted that maize phylogeny was largely determined by genera Zea and Tripsacum, however it is also accepted that the genus Coix also contributed significantly to the phylogenetic development of Z. *mays* (Radu et al., 1997).

Geographic Origin and Distribution

The center of origin for Z. *mays* has been established as the Mesoamerican region, now Mexico and Central America (Watson & Dallwitz, 1992). Figure clearly shows the centers of origin and primary geographical distribution of cultivated maize and its relatives.

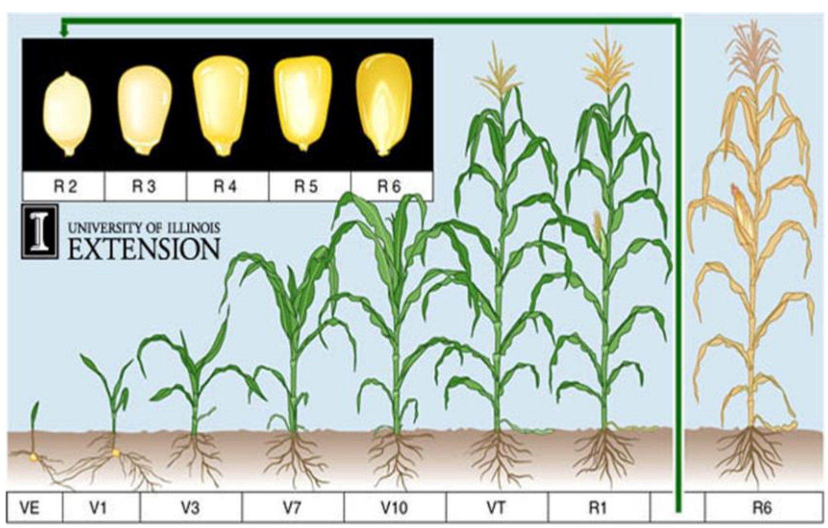
Archaeological records suggest that domestication of maize began at least 6000 years ago, occurring independently in regions of the southwestern United States, Mexico, and Central America (Mangelsdorf, 1974). The Portuguese introduced maize to Southeast-Asia from the America in the 16th century. In India, Portuguese introduced maize during the 17th century. From India, it went to China and later it was introduced in Philippines and the East Indies.



Mammadov et al. 2018

Phenology (Life Cycle)

Typical Maize plants develop 18 to 22 total leaves, silk appears about 55 days after emergence, and mature in around 125 days after emergence (Ritchie et al., 1993). The specific time interval, however, can vary among hybrids, environments, plantings date, and location. The length of time between each growth stage, therefore, is dependent upon these circumstances. For example, early maturing hybrids may produce fewer leaves or progress through the different growth stages at a faster rate In contrast, a late – maturity hybrids may develop more



Different developmental stages in plants [Ritchie et al., 1993].

leaves and progress through each growth stage at a slower pace.

Almost all pest management decisions for corn are based on the vegetative stage. These are identified by the number of collars present on the corn plant. The leaf collar is the light – colored collar – like “band” located at the base of an exposed leaf blade, near the spot where the leaf blade comes in contact with the stem of the plant. Leaves within the whorl, not fully expanded and with no visible leaf collar are not included. For example, a plant with 3 collars would be called a V3 plant, however, there may be 6 leaves showing on the plant.

VE - Emergence

Coleoptile reaches the soil surface and exposure to sunlight causes elongation of the coleoptile and mesocotyl to stop. The growing point, located just above the mesocotyl, is about 0.75 inches below the soil surface. Embryonic leaves rapidly develop and grow through the coleoptilar tip. Seminal root growth begins to slow and nodal roots are initiated at the crown. Weed control at this stage will result in little yield loss, but late-emerging weeds may produce substantial seed, increasing the soil seed bank.

V1 - First leaf collar

Lowermost leaf (short with rounded tip) has a visible leaf collar. Nodal roots begin elongation. Again, weed control at this growth stage will result in little yield loss, but seed from weeds that emerge later in the growing season may contribute to the soil seed bank if a residual herbicide has not been applied.

V3 - Third leaf collar

The growing point remains below the soil surface as little stalk elongation has occurred. Lateral roots begin to grow from the nodal roots and growth of the seminal root system has ceased. All leaves and ear shoots that the plant will produce are initiated at this stage. Since the growing point remains below the soil surface, cold soil temperatures may increase the time between leaf stages, increase the total number of leaves formed, delay tassel formation, and reduce nutrient uptake.

V7 – Seven leaf collar

During the V7 and V8 growth stages the rapid growth phase and kernel row determination begins. Senescence of lower leaves may occur if plant is stressed, but must still be counted when staging plants.

V10 – Ten leaf collar

At the V9 and V10 growth stages the stalk is in a rapid growth phase a accumulating dry matter as well as nutrients. The tassel has begun growing rapidly as the stalk continues to elongate. Many ear shoots are easily visible when the stalk is dissected.

VT – Tasseling

Initiation of the VT stage begins the last branch of the tassel is visible and silks have not emerged. This stage begins about 2-3 days before emergence. The plant is almost at its full height and pollen shed (anthesis) begins. Pollen shed typically occurs in the morning or evening. Plants at the VT/R1 are most vulnerable to moisture stress and leaf loss (hail).

R1 – Silking

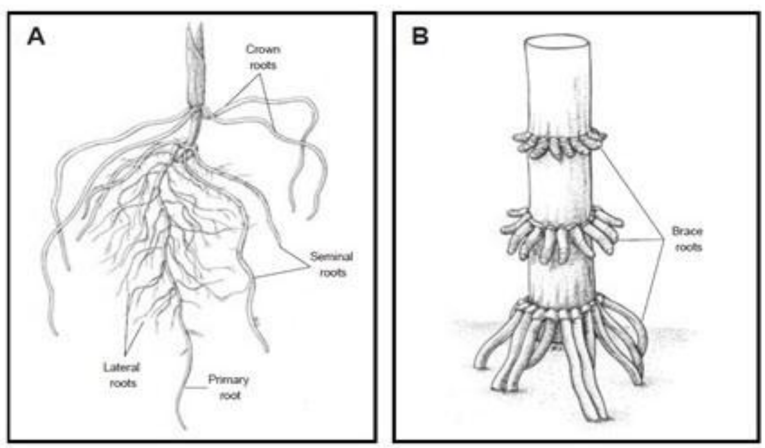
This stage begins when any silk is visible outside the husk. Falling pollen grains are captured by the silk and grow down the silk over a 24 hour period ultimately fertilizing the ovule. The ovule becomes a kernel. It takes upwards of three days for all silks on a single ear to be exposed and pollinated. The number of fertilized ovules is determined at this stage. If an ovule is not fertilized, it will not produce a kernel and it eventually degenerates. Environmental stress at this time is detrimental to pollination and seed set, with moisture stress causing desiccation of silks and pollen grains. Nutrient concentrations in the plant are highly correlated with final grain yield as nitrogen and phosphorous uptake are rapid.

R6 - Physiological Maturity

Occurring approximately 45-50 days after silking, all kernels on the ear have attained maximum dry weight. A black or brown layer has formed where the kernel attaches to the cob, indicating physiological maturity has been attained. The stalk of the plant may remain green, but leaf and husk tissue has lost its green colour at this stage. Kernel moisture content ranges from 30-35% at this stage, with much variation among hybrids and environmental conditions.

Botanical Features

Maize is a tall, determinate annual C4 plant with varying in height producing large, narrow, opposing leaves, borne alternately along the length of a solid stem. The botanical features of various plant parts are as follows:

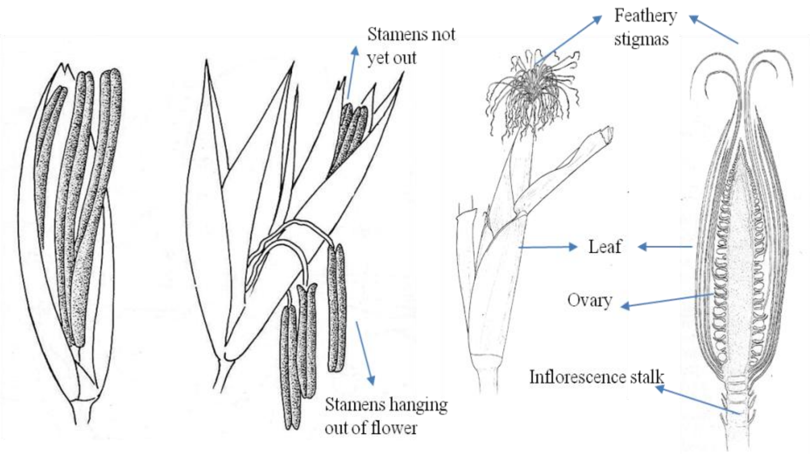


Root: Normally maize plants have three types of roots, i) seminal roots - which develop from radical and persist for long period, ii) adventitious roots, fibrous roots developing from the lower nodes of stem below ground level which are the effective and active roots of plant and iii) brace or prop roots, produced by lower two nodes. The roots grow very rapidly and almost equally outwards and downwards. Suitable soils may allow corn root growth up to 60 cm laterally and in depth.

Stem: The stem generally attains a thickness of three to four centimeters. The internodes are short and fairly thick at the base of the plant; become longer and thicker higher up the stem, and then taper again. The ear bearing internode is longitudinally grooved, to allow proper positioning of the ear head. The upper leaves in corn are more responsible for light interception and are major contributors of photosynthate to grain.

Floral Biology

Maize is a monoecious plant, i.e. the sexes are partitioned into separate pistillate (ear), the female flower and staminate (tassel), the male flower (Fig.). It has determinate growth habit and the main shoot terminates in a staminate tassel. Maize is generally protandrous, i.e. the male flower matures earlier than the female flower. Within each male flower spikelet, there are usually two functional florets, although development of the lower floret may be delayed slightly in comparison to the upper floret. Each floret contains a pair of thin scales i.e. lemma and palea, three anthers, two lodicules and rudimentary pistil. Pollen grains per anther have been reported to range from 2000 to 7500 (Kiesselbach, 1949). The pollen grains are very small, barely visible to the naked eye, light in weight, and easily carried by wind. The wind borne nature of the pollen and protandry lead to cross-pollination, but there may be about 5% self-pollination.



Maize: Male and Female flowers

The female (pistillate) inflorescence, a spike, produces pairs of spikelets on the surface of a highly condensed rachis (central axis, or "cob"). The female flower is tightly covered over by several layers of leaves, and so closed in by them to the stem that they don't show themselves easily until emergence of silks from the leaf whorl at the end of the ear. The silks are the elongated stigmas that look like tufts of hair initially and later turn green or purple in color. Each of the female spikelets encloses two fertile florets, one of whose ovaries will mature into a maize kernel once sexually fertilized by wind-blown pollen. Silks are covered with numerous hairs, trichomes which form an angle with the silk where pollen grains are harboured. The base of the silk is unique, as it elongates continuously until fertilization occurs. The cobs bear many rows of ovules that are always even in number. The female inflorescence or ear develops from one or more lateral branches (shanks) usually borne about half-way up the main stalk from auxillary shoot buds. As the internodes of the shanks are condensed, the ear remains permanently enclosed in a mantle of many husk leaves. Thus the plant is unable to disperse its seeds in the manner of a wild plant and instead it depends upon human intervention for seed shelling and propagation.

Pollination and Fertilization

In maize, the pollen shed is not a continuous process and usually begins two to three days prior to silk emergence and continues for five to eight days. The silks are covered with fine, sticky hairs which serve to catch and anchor the pollen grains. Pollen shed stops when the tassel is too wet or too dry and begins again when temperature conditions are favourable. Under favourable conditions, pollen grain remains viable for only 18 to 24 hours. Cool temperatures and high humidity favour pollen longevity. Under optimal conditions the interval between anthesis and silking is one to two days. Under any stress situation this interval increases. Fertilization occurs after the pollen grain is caught by the silk and germinates by growth of the pollen tube down the silk channel. Within minutes of coming in contact with a silk, pollen tube grows and enters the embryo sac in 12 to 28 hours. Pollen is light and is often carried considerable distances by the wind. However, most of it settles within 20 to 50 feet. Pollen of a given plant rarely fertilizes the silks of the same plant. Under field conditions, 97% or more of the kernels produced by each plant are pollinated by other plants in the field. Fertilization of ovules begins about one third of the way up from the base of the ear.

Seed Dispersal

Seed dispersal of individual kernels naturally does not occur because of the structure of the ears of maize. Maize, as a thoroughly domesticated plant, has lost all ability to disseminate its seeds and relies entirely on the aid of man for its distribution (Stoskopf, 1985). The kernels are tightly held on the cobs. In case ears fall to the ground, so many competing seedlings emerge that the likelihood that any will grow to maturity is extremely low.

Grain: The individual maize grain is botanically a caryopsis, a dry fruit containing a single seed fused to the inner tissues of the fruit case. The seed contains two sister structures, a germ which includes the plumule and radical from which a new plant will develop, and an endosperm which will provide nutrients for that germinating seedling until the seedling establishes sufficient leaf area to become autotrophy. The germ is the source of maize “vegetable oil” (total oil content of maize grain is 4% by weight). The endosperm occupies about two thirds of a maize kernel’s volume and accounts for approximately 86% of its dry weight . The endosperm of maize kernels can be yellow or white. The primary component of endosperm is starch, together with 10% bound protein (gluten), and this stored starch is the basis of the maize kernel’s nutritional uses.

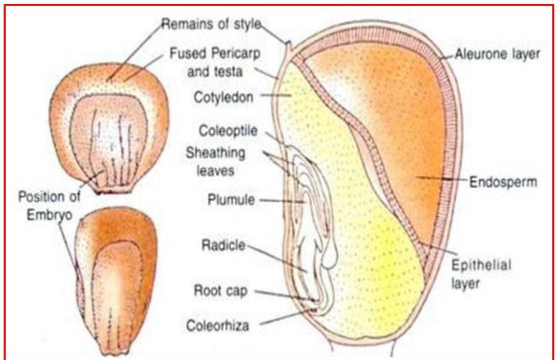


Image taken from http://cdn.biologydiscussion.com

Relatives of Maize

Teosinte and Tripsacum are two CWRs that have been extensively characterized as donors for economically important traits that could be used for improvement of maize. It took nearly a century to confirm that Balsas teosinte (Z. *mays* ssp. *parviglumis* Iltis & Doebley) is a progenitor of maize (Matsuoka et al., 2002). Teosinte is a wild grass natively grown in Mexico and some Central American countries.

Among teosintes, the nearest teosinte relative to Zea *mays* is Zea *mays* ssp. *mexicana* (Schrader) Iltis, which grows in central highlands of Mexico. It possesses the same diploid chromosome number as maize (2n = 20). The other teosintes include perennial teosintes, viz. Zea *diploperennis* (2n= 20) and Zea *perennis* (2n= 40), distributed in Jalisco, Mexico. The annual teosintes include Zea *luxurians* from southeastern Guatemala, Zea *mays* spp. *parviglumis* of southern and western Mexico and Zea *mays* spp. *huehuetenangensis* from the western highlands of Guatemala. The main morphological differences between teosinte and maize are their branches and inflorescences. Teosinte plants contain more branches and smaller female inflorescences than maize.

Zea *mays* spp. *parviglumis* A - Tillering ; B - Infloresence; C - seeds

Tripsacum has been considered closely related to Zea due to morphological similarities including the highly specialized cupulate fruitcase, and the ability to cross with Zea and produce viable but generally infertile hybrids (Galinat, 1961). The genus Tripsacum comprises nine species of warm-season, perennial grasses that are native to the area starting in southern Canada (North America) and extending as far south as Chile (South America) (Eubanks, 2006); One species of Tripsacum that has been broadly used to generate intergeneric hybrids with maize is T. *dactyloides*, or Eastern gamagrass (De Wet et al., 1981).

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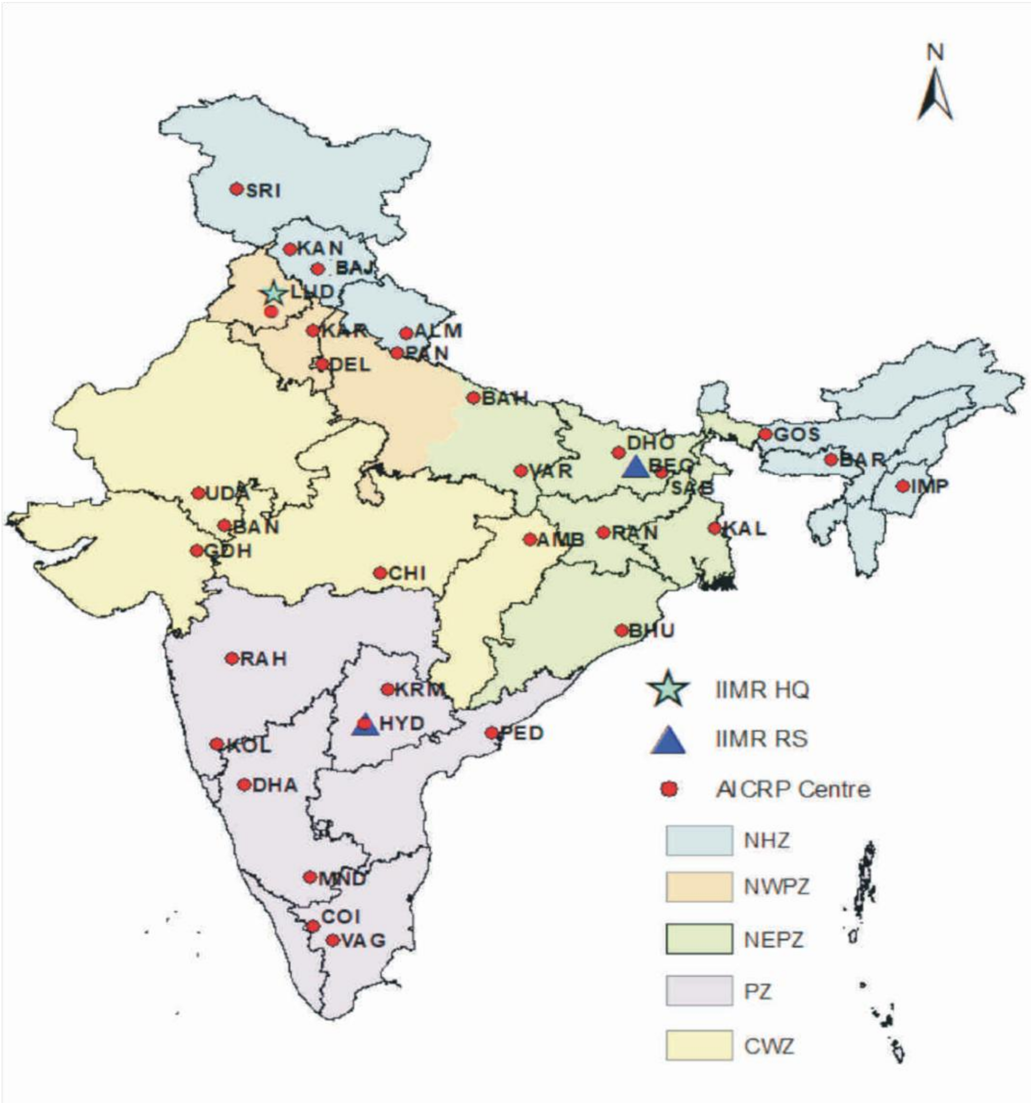
Maize hybrid release- process and procedure

N. Sunil[*], Bhupender Kumar[©], P. Ramesh Kumar[®], Sujay Rakshit[®]
[*]Winter Nursery Centre, ICAR-IIMR, Hyderabad, [©] ICAR-IIMR, Delhi Unit
[®] ICAR-IIMR, Ludhiana

Maize is an emerging potential crop for meeting the food, feed and industrial requirements of the country. Maize consumption in India increased with CAGR of 11% in last 5 years. In India, 65-70 percent of the area of the 9.0 million ha under maize, is under hybrid varieties, which record higher yields as compared to traditional varieties. Planting high yielding single-cross hybrids played a major role in raising Maize production in India. Also, the Feed Industry growing with a CAGR of 6 – 7% globally and 9% in India, presents huge opportunity for maize growers. There is immense scope for expansion in the area of the maize crop and spread of the area under hybrid varieties for increasing productivity. This can be achieved through state-wise meticulous planning towards identification of potential areas, regions and zones to put Indian maize on global map.

To meet the increasing demand, annually, new hybrids are released by both public and private sectors with higher productivity. The testing of these hybrids is done by ICAR-Indian Institute of Maize Research through All India Coordinated Research Project (AICRP) on Maize. The entire process involves planned experiments in the form of trial constitution involving breeding, plant protection and agronomy trials followed by physical monitoring of the trials by the experts, analysis and reporting of the data.

Project (AICRP) on Maize by the Indian Council of Agricultural Research (ICAR). It was the first in a series of by the ICAR. The Project released >360 cultivars having different genetic makeup including double cross hybrids, synthetics, composites and recently highly productive single cross hybrids for various regions and end-uses. The major mandate of the AICRP centres is to develop region specific hybrids and production technologies. The main objective of the project is to conduct and coordinate multidisciplinary and multi-location research to identify appropriate technologies for varied agro-climatic conditions in different parts of India. The project also becomes mainstream for dissemination of technologies to the farmers field through FLDs and other activities in the respective states. Today, AICRP-Maize is a unique network of 34 centres spread across 23 states of the country. This network also served farmers since its inception and as an impact of its productivity enhancement by 1800 kg/ha during T.E. 2016 compared to T.E. 1959. Not only yield but also the area increased by 5 million ha and production by 20 million tonnes during this period.



All India Coordinated Research Project on Maize Network

Zone-wise distribution of centres in AICRP

Zone	**Centres**
Zone I	Srinagar, Almora, Bajaura, Barapani, Kangra, Gossaigaon
Zone II	Karnal, Ludhiana Panthnagar, Delhi
Zone III	Bahraich, Varanasi , Bhubneshwar, Kalyani, Ranchi ,Sabour, Dholi
Zone IV	Rahuri, Dharwad, Mandya, Coimbatore, Vagarai, , Kolhapur, Karimnagar, Hyderabad, Peddapuram,
Zone V	Udaipur, Banswara , Godhara, Chhindwara, Ambikapur

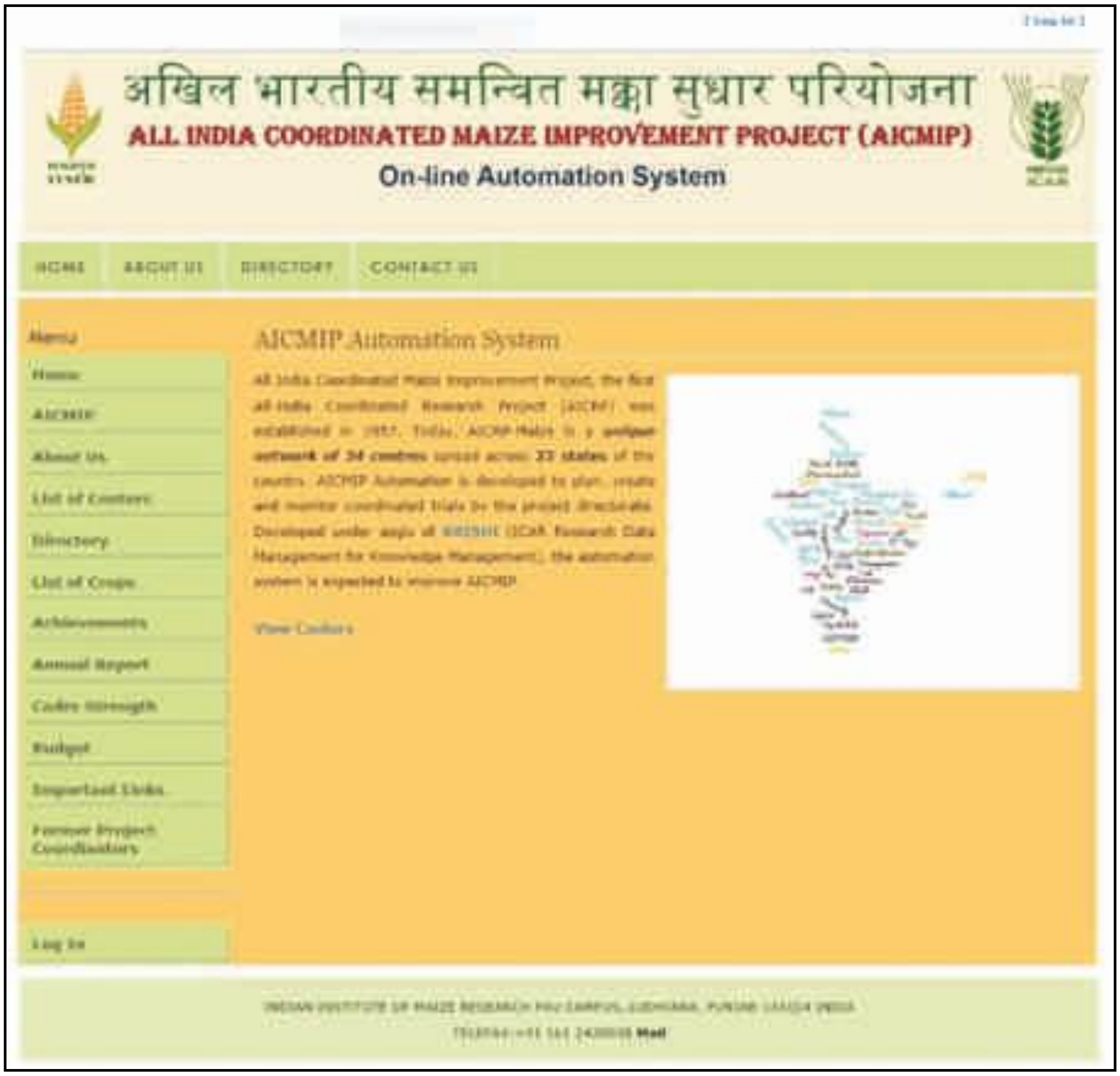
The hybrid testing is a three-year process and begins with the submission of the seed samples, both by the public and private companies to the Coordinator. The quantity of the seed to be submitted is given below for each of the trials

Trial-wise seed requirement for AICRP trials

S. No	Trial	Year of testing	Seed Quantity	Mode of Conduct
1	National Initial Varietal Trail (NIVT)	First	3.5 Kg/Entry	Across the zones
2	Advance Varietal Trial-I (AVT-I)	Second	6 Kg/Entry/Zone	Zone specific
3	Advance Varietal Trial-II (AVT-II)	Third	10Kg/Entry/Zone	Zone specific
4	Baby corn	1st 2nd 3rd	8 Kg/Entry	Across the zones
5	QPM	1st 2nd 3rd	7Kg/Entry	Across the zones
6	Sweet corn	1st 2nd 3rd	3.5Kg/Entry for 1st and 2nd ,6.0 Kg/entry for 3rd year	Across the zones
7	Popcorn	1st,2nd,3rd	3.5Kg/Entry for 1st and 2nd,6.0 kg/Entry for 3rd year	During kharif in Zone-1(NHZ) and during *rabi* in rest of the zones

The public sector is required to submit the data regarding the % superiority of the entry against the check hybrid over two years. Whereas, the private sector have to submit a DSIR certificate along with the testing fees of Rs. 75000/- + 18% GST

The submitted seed samples are processed for trials. All the seed pertaining to breeding and agronomy trials are subjected to seed treatment, whereas for the pathology and entomology trials, untreated seed is sent. The trials are created using the automation system available at aicmip.naarm.org.in



On-line Automation System for constitution, reporting and analysis of the data

Experimental Layout recommendations for breeding trials:

A. National Initial Varietal trials (NIVT-I) (Across the zones) :
No. of rows – 2 (net)
Row length – 4m (net)
Spacing – 60cm x 20cm in Irrigated
Replications – 3
Fertilizer – As per recommendations
Locations- Regular Centres

B. Advance Varietal Trials-I (AVT-I) (Zone Specific):
No. of rows – 4(net)
Row length – 4m (net)
Spacing – 60cm × 20cm in Irrigated
Replications-3

Fertilizer- As per recommendations
Locations: Regular and Voluntary centers

C. Advance Varietal Trials-II (AVT-II) or (AVT I+II) (Zone Specific) :
No. of rows -6(net)
Row length – 4m (net)
Spacing – 60 cm × 20 cm in Irrigated
Repications – 3
Fertilizer – As per recommendations
Locations – Regular and Voluntary centers

D. Specialty corn (QPM/SC/ PC/BC-I-II-III (Across the zone) :
No. of rows – 4(net)
Row length – 4 m (net)
Spacing – 60cm × 20cm in Irrigated,
BC: 60cm × 15cm
Replications – 3
Fertilizer – As per recommendations
No. of rows in Baby corn trial= 2(net)
Locations: Regular Centers
Rainfed/OPV: 70 × 25cm; Rep: 3; Rows length: 4m; RowNo.4/Rep
Locations: Regular Centres

Recommendations for Pathology and entomology trials:

No. of rows – 1 (net)
Row length – 2.5m (net)
Spacing – 60cm ×20cm in Irrigated
Replications – 2
Fertilizer – As per recommendations
Locations- Select locations

Recommendations for Agronomy trials

300-350g seed of the each entry in the AVT-II trials is sent to selected centers for Agronomy experiments and they conduct the trials as per the recommendation of PI, Maize agronomy

Data Recorded by the centres for breeding trials

Field Corn:

1. Initial Plant Stand(No./Plot)
2. Days to 50% Anthesis – Rounded to 0 decimals
3. Days to 50% silking – Rounded to 0 decimals
4. Plant Height (cm) – Rounded to 0 decimal
5. Ear Height Placement (cm) – Rounded to 0 decimal
6. Days to Maturity – 75% dry husk/apperance of black layer
7. Plant population at harvest (No./Plot)

8. Cobs count at harvest (No./Plot)
9. Fresh cobs weight at harvest (Kg/plot)
10. Grain Moisture at the time of shelling (%)- should be recorded in minimum two replications
11. Shelling percentage (%)- should be recorded in two replications (for this purpose 10 cobs from first 10 plants of 2^{nd} row are to be considered and grain moisture also to be recorded from shelled grains of these cobs). Shelling % should be recorded by taking ratio of grains weight of selected 10 cobs with their total cobs weight multiply with 100. Observations from Sr. No.9 to 11 are to be taken simultaneously.

Quality Protein Maize (QPM)

1. Initial Plant Stand(No./Plot)
2. Days to 50% Anthesis – Rounded to 0 decimals
3. Days to 50% silking – Rounded to 0 decimals
4. Plant Height (cm) – Rounded to 0 decimal
5. Ear Height Placement (cm) – Rounded to 0 decimal
6. Days to Maturity – 75% dry husk/apperance of black layer
7. Plant population at harvest (No./Plot)
8. Cobs count at harvest (No./Plot)
9. Fresh cobs weight at harvest (Kg/plot)
10. Grain Moisture at the time of shelling (%)- should be recorded in two replications
11. Shelling percentage (%)- should be recorded in two replications (for this purpose 10 cobs from first 10 plants of 2^{nd} row are to be considered and grain moisture also to be recorded from shelled grains of these cobs). Shelling % should be recorded by taking ratio of grains weight of selected 10 cobs with their total cobs weight multiply with 100. Observations from Sr. No.9 to 11 are to be taken simultaneously. Lysine and Tryptophan (%) – should be recorded in selfed cobs of two replications (Only at specified centers).

Popcorn

1. Initial Plant Stand(No./Plot)
2. Days to 50% Anthesis – Rounded to 0 decimals
3. Days to 50% silking – Rounded to 0 decimals
4. Plant Height (cm) – Rounded to 0 decimal
5. Ear Height Placement (cm) – Rounded to 0 decimal
6. Days to Maturity – 75% dry husk/apperance of black layer
7. Plant population at harvest (No./Plot)
8. Cobs count at harvest (No./Plot)
9. Fresh cobs weight at harvest (Kg/plot)
10. Grain Moisture at the time of shelling (%)- in two replications
11. Shelling percentage (%)- should be recorded in two replications (for this purpose 10 cobs from first 10 plants of 2^{nd} row are to be considered and grain moisture also to be recorded from shelled grains of these cobs). Shelling % should be recorded by taking ratio of grains weight of selected 10 cobs with their total cobs weight multiply with 100. Observations from Sr. No.9 to 11 are to be taken simultaneously.
12. Popping volume and percentage – should be recorded from selfed cobs at all centres.

Pathology Data recorded in all the trials

1. Turcicum Leaf Blight (TLB)Score(1-9)
2. Sorghum Downy Mildew (SDM) Incidence (%)
3. Rajasthan Downy Mildew (RDM) Incidence (%)
4. Maydis Leaf Blight(MLB)Score(1-9)
5. Fusarium Stalk Rot(FSR)/PFSRScore(1-9)
6. Cyst Nematode Range(Cystperplant)
7. Curvularia leaf spot(CLS)Score(1-9)
8. Charcoal Rot(ChR)Score(1-9)
9. Bacterial Stalk Rot (BSR)Incidence(%)
10. Banded leaf and SheathBlight(BLSB)Score (1-9)

Entomology data recorded in AVT trials

FAW: 1-9 at 45DAG
FAW Eardamage1-9scale at harvest
Chilo partelus Score (1-9)
Sesamia (1-9)
Shoot fly % dead heart

Agronomy data recorded in AVT II trials

300-350g seed of the each entry in the AVT-II trials is sent to selected centers for Agronomy experiments and they conduct the trials as per the recommendation of PI, Maize agronomy

General instructions:

- Last date for receiving seed at WNC, ICAR-IIMR, Rajendranagar, Hyderabad- Kharif season-**May 10, 2019** and For Rabi- **10 Oct, 2019**. • For Zone: NHZ (Z-1): Dr S. K. Guleria, Maize Breeder, Bajaura-H. P. ; 10th April.
- Testing Fee (Private/Non-ICAR organizations) – 75, 000 + 18% GST/entry/trial. This will be applicable after acceptance of proceeding by ICAR, which will be communicated in due course of time.
- DD should be in favour of Director, ICAR-Indian Institute of Maize Research, Ludhiana, Punjab141004 • Seed of all entries must be Untreated and graded properly.
- Seed and all correspondence must be dispatch to: Dr. N. Sunil, Principal Scientist & Incharge Trials & Nursery (AICRP on Maize) Winter Nursery Center, Maize, ICAR-IIMR, Rajendranagar, Hyderabad, Telangana-500030.
- Breeder who submit the entry must mentioned their contact no. and email ID in covering letter for further communication
- Detailed information of entry in attached format must be provided; the superiority (10%) over the zone specific check in one year data, the female productivity should be given

The data from all the centres is submitted online and analysed online. The reports of both *Rabi* and *Kharif* evaluation are published soon after data evaluation process is completed.

The entries are promoted to next level based on the following promotion criteria

The test entries will be promoted from first year (NIVT) to second year (AVT-I), second year (AVT-I) to third year (AVT-II) on the basis of the following criteria:

Entries must be numerically superior over the best check in a zone for yield and should have nonsignificant differences in yield from the best entry (rank 1st) of the trial at CD (P=0.05).

- In early and medium trials, besides yield, the test entry should not exceed the relevant best check by 2.0 days in days to 50% Anthesis.
- The disease reaction of test entries to the disease of national average will be considered for promotion.
- In speciality corn, viz., sweet corn and popcorn, besides yield, the quality parameters were also be considered while promotion. e. g. (SC: TSS ≥15%; PC: Popping% age ≥ 85% and expansion in the ratio of 1:15).
- In QPM, all entries will be compared with best check except for NHZ (Zone I) where the test entries found to be early based on days to 50% anthesis criteria will be compared with Vivek QPM 9
- In addition to the above, the entry should have resistance to moderately resistance response on scale 1-9 for major diseases on national level.

Entries which are promoted in AVT II are required to prepare a proposal for Varietal Identification Committee (VIC). The Committee which is chaired by ADG (CC& FFC) includes director of ICAR –IIMR and members from both public and private sector, which identifies and recommends the hybrid for release

In addition to existing promotion criteria, the following points are to be taken into consideration at the time of identification in VIC:

- The entries with negative superiority over best check in final year of testing will not be considered for identification.

- In case of hybrids to be compared with hybrid check the yield superiority must be ≥ 5% for identification (in late maturity) and ≥ 10% for all others however in case of comparison of hybrid with composite as check yield superiority in hybrid over composite should be ≥ 20%.

Introduction on Hybrids Maize Technology

Bhupender Kumar, Sonu Kumar & Sujay Rakshit
ICAR-Indian Institute of Maize Research, Ludhiana-141004

Maize Scenario

Maize (*Zea mays* L.) is the most versatile food crop being grown on 188 million ha area in more than 170 countries across the globe with 1060 million ton of production and 5.6 tonnes/ha productivity (FAOSTAT, 2018). In India, the maize area has reached to around 9.2 million ha with production and productivity of 27.20 million tones and 2.9 t/ha, respectively (4^{th} advance estimate of 2018-19: Source: Agricultural Statistics Division, Directorate of Economics & Statistics). It can be grown around the years in one or another part of the country with elevation ranging from sea level to up to 3000 m amsl.
Maize is also known as queen of cereal as it has highest yield potential amongst the major cereal crops. The consumption pattern of maize (feed-64%, food-16%, industry-19%, seed and other miscellaneous 1%) in India largely matches with the global pattern (feed-61%, food-17% and industry-22%). Further, it is an important industrial raw material where more than 3000 products are being made from it providing wide opportunity for value addition.

The USA and China together contributes about more than 38% of area and 58% of the production of the world's maize. Major factors favouring for better performance of USA and China primarily includes adoption of single cross hybrids/ plus transgenic technology with long crop duration, assured irrigation and high inputs in maize production. In India, ~80% of maize is grown as rainfed crop and provides low cost nutritious and risk free green fodder to the livestock. Adoption of single cross hybrid technology by replacing the composites, multiple parent crosses and synthetics cultivars after 2000 onward paved the way to enhanced maize production and productivity in India. The SCHs of maize may have the yield potential of more than 12.0 t/ha, which is significantly very higher from composites and synthetic cultivars. Apart from normal maize, it has many other types' *viz*. Quality Protein Maize (QPM), sweet corn (SC), baby corn (BC), pop corn (PC), waxy corn (WC), high oil (HO) etc. The cultivation of maize as baby corn, popcorn and sweet corn has increased the income of the farmers many fold, which has given livelihood security to *peri*-urban farmers thus checking the rural urban migration.

Ecologies for maize cultivation in India

Based on the agro-ecological conditions, the entire India has been divided in five major zones –Northern Hill Zone (Zone I), North West Plains Zone (Zone II), North East Plains Zone (Zone III), Peninsular Zone (Zone IV) and Central Western Zone (Zone V) for effective evaluation and identification of suitable hybrids as well as breeding materials of maize. The details of maize growing states included in these zones are given in Table 1.

Table 1. Different zones for maize cultivation in India

Zone	States
Northern Hill Zone (NHZ), Zone-I	Jammu and Kashmir, Himachal Pradesh, Uttarakhand (Hill region), North Eastern Hill Regions (Meghalaya, Sikkim,

	Assam, Tripura, Nagaland, Manipur, Arunachal Pradesh
North West Plains Zone (NWPZ), Zone-II	Punjab, Haryana, Delhi, Uttarakhand (Plain), Uttar Pradesh (Western UP)
North East Plains Zone (NEPZ), Zone-III	Bihar, Jharkhand, Odisha, Uttar Pradesh (Eastern UP), West Bengal
Peninsular Zone (PZ), Zone-IV	Maharashtra, Karnataka, Andhra Pradesh, Telangana State, Tamil Nadu
Central Western Zone (CWZ), Zone-V	Rajasthan, Madhya Pradesh, Chhattisgarh, Gujarat

Hybrids priority for different regions

In low to medium average rainfall sub-region viz., central part, part of northern India and western region of the country, moisture stress is the key constraint to maize production. Therefore aggressive breeding efforts to overcome the drought problem are needed thought to be more relevant for this region. Development of early and medium maturity hybrids can be the one of important component of breeding strategies for these regions. For more favorable production environments, breeding efforts needs mostly for development of full as well as medium maturity maize hybrids having tolerance to biotic stresses viz. Stem borer, turcicum leaf blight and post flowering stalk rot. Now winter maize is coming in a big way, therefore, long duration maize hybrids, tolerant to cold are more useful. In spring season early and medium duration hybrids, which need to be heat stress tolerant are more preferable compare to late maturity. The objectives of single cross hybrids development are therefore based on the zonal and season requirements. Generally, Northern Hill Zone (Z-I) requires early and medium duration drought tolerant hybrids, North West Plains Zone (Z-II) requires early, medium and late duration drought tolerant during *kharif*, heat tolerant in spring and cold tolerant single cross hybrids during *rabi* season. The North East Plains Zone (Z-III) requires water logging tolerant cultivars in *kharif* and long duration cold tolerant hybrids in *rabi* season, in Peninsular Zone (Z-IV), depending upon the cropping pattern, all type of maturity groups can be grown with more preference to long duration where the irrigation facility is available. In Central Western Zone (Z-V), early to medium duration drought tolerant during *kharif* and late cold tolerant hybrids during *rabi* season are more preferable for cultivation.

Maize hybrids technology

One of the major achievements in maize breeding has been the exploitation of heterosis through commercial cultivation of maize hybrids. Inbred found better combiner is crossed in specific combination to develop hybrids. Inbred development in maize hybrids breeding is one of the most important components. A pure inbred line is a homozygous and homogeneous population developed by continuous inbreeding, usually by self-pollination, followed by selection during subsequent segregating generations. Complete self-cob of the selected plant should be grown in long row of length 25 to 30 m in field for effective and efficient selection during the segregating generations. Preference should be given to select more progenies of a cross having less inbreeding depression than that of selecting more crosses carrying progenies having high inbreeding depression. The fixed selected inbred lines (selfed for 6-7 generation) are crossed in specific combination represents the types of hybrids. There are different types of hybrids viz., single cross ($I_1 \times I_2$, I denoting an inbred), modified single cross [$(I_1 \times I'_1) \times I_2$, I' denoting the sister lines], three way cross [$(I_1 \times I_2) \times I_3$], modified three way cross [$(I_1 \times I_2) \times (I_3 \times I'_3)$] and double cross [$(I_1 \times I_2) \times (I_3 \times I_4)$]. A cross between two varieties is a varietal hybrid and between variety and an inbred line is a top cross hybrid. Among all types of hybrids, the single cross hybrids, which are more uniform, productive and tolerant to major biotic and abiotic stresses, easy to maintain purity and multiply seed are mostly recommended for commercial cultivation.

Advantages of single cross hybrids technology

Area, production and productivity remain stagnant for many years in India due to the cultivation of less productive OPVs and multi parent hybrids. The impact of single cross hybrids (SCHs) technology adoption has already been witnessed in USA, China and many other countries of world. Even in India by hardly covering 25-30% area under single cross hybrids, the crop growth rate with respect to area, production and productivity of maize has increased significantly. The total maize produced during 1950-51 in India was around 1.73 mt, which has increased to around 27.2 (16 times higher than the base). Details advantages of SCHs technology are given below:

1. Uniform, high yield potential & farmers acceptable
2. Tolerant to biotic and abiotic stresses
3. Wider adaptability in the era of climate change
4. Quick and higher germination %
5. Fair dealing to all farmers, industries, dealer etc
6. Employment generation
7. Provide food, feed and nutritional security
8. Export potential & foreign exchange

DMRH1308

Specialty Corn – for Livelihood Security

With the increase of urbanization, change in food habit and economic status, the specialty corn has gained significant importance in *peri*-urban areas of the country. The demand of baby corn, sweet corn and pop corn is increasing every year. To check the migration from rural to urban, to enhancing the profitability and livelihood security of the farmer s, the suitable hybrids and production technology for baby corn and sweet corn have been developed. The farmers can earn 50-60 thousand rupees per annum per acre with the cultivation of 2-3 crops of baby corn and sweet corn. Besides, they can harvest green and nutritious fodder for livestock. Specialty corn cultivation may provide livelihood security to the farmers through following ways:

- Employment generation
- Check the migration of peoples from rural to urban
- Solve the green fodder scarcity
- Promote livestock industry
- Increase the milk production by availing green fodder
- QPM maize for nutritional security

Table 2. Details of public sector single cross hybrids/varieties of maize released for cultivation since 2010.

S.No	Name	Nature of Hybrids	Organization/Centre	Year of Release/Notification	Maturity	Area of Adaptation	Cropping season
Normal Corn Hybrids							
1.	Gujarat Anand Yellow Maize Hybrid - (GAYMH - 3) (GYH - 0363	SCH	Anand Agriculture University, Anand.	2019	Medium	Middle Gujarat	Rabi
2.	JMC-3 (PMSY 3)	Composite	S. K. University of Agri. Sciences & Technology, Jammu.	2019	Medium	Jammu	Kharif
3.	SHIATS Makka-2 (IVT DMR 262)	Composite	SHUATS, Allahabad.	2019	Medium	Uttar Pradesh	Kharif
4.	Maize VGIH-1 (VaMH-12014)	SCH	TNAU, Coimbatore.	2019	Medium	Bihar, Jharkhand, Odisha, Uttar Pradesh (Eastern Region) and West Bengal	Kharif
5.	PMH 12 (JH 13347)	SCH	PAU, Ludhiana.	2019	Medium	Bihar, West Bengal, Jharkhand, parts of Uttar Pradesh and Odisha	Kharif
6.	VL Maize Hybrid - 57 (FH 3754)	SCH	VPKAS, Almora	2019	Early	Jammu and Kashmir, Himachal Pradesh, Uttarakhand (hilts), Assam, Arunachal Pradesh, Meghalaya, Nagaland, Tripura. Manipur, Mizoram, Sikkim and Tripura.	Kharif
7.	Shaktiman-5 (MHQPM 09-08)	SCH	Rajendra Prasad Central Agriculture University	2018	Medium (100Days)	Uttar Pradesh, Bihar, Jharkhand, West Bengal, Orissa and Chhattisgarh.	Kharif and Rabi
8.	Gujarat Anand White	SCH	Anand Agriculture	2018	Early	Middle Gujarat	Kharif

	Maize Hybrid-2 (GAWMH-2)		University, Anand				
9.	DMRH 1305	SCH	ICAR-IIMR, Ludhiana	2018	Early	Jammu & Kashmir, Himachal Pradesh, Uttarakhand (Hill region),Meghalaya, Sikkim, Assam, Tripura, Nagaland, Manipur and Arunachal Pradesh	Kharif
10	Jawahar Makka 218	OPV	Jawahar Lal Nehru Krishi Vishva Vidhalya, Jabalpur (MP)	2018		Madhya Pradesh	Kharif
11.	Pusa Jawahar Hybrid Maize-1	SCH	Jawahar Lal Nehru Krishi Vishva Vidhalya, Jabalpur (MP) and IARI, New Delhi.	2018	Medium	Madhya Pradesh	Kharif
12.	DMRH1301	SCH	ICAR-IIMR, Ludhiana	2017	Medium	Eastern Uttar Pradesh, Bihar, Jharkhand, Odisha, West Bengal, Rajasthan, Gujarat, Madhya Pradesh & Chhattisgarh	Rabi
13.	DMRH1308	SCH	ICAR-IIMR, Ludhiana	2017	Medium	Bihar,Rajasthan, Gujarat, Chhattisgarh & Madhya Pradesh	Rabi
14.	KNMH-4010141	SCH	PJTSAU, Telangana State	2017	Medium	MH, Karnataka, AP, Telengana & TN	Kharif
15.	Central Maize VL 55 (FH3605	SCH	ICAR-VPKAS Almora	2017	Medium	Jammu & Kashmir, Himachal Pradesh, Uttarakhand, NE Hills, Maharashtra, Karnataka, Tamil Nadu, Telangana and Andhra Pradesh	Kharif
16.	Pant Sankar Makka- 4 (PSM -4)	SCH	GB Pant University of Agriculture and Tech. Pantnagar	2017	Early	Uttarakhand	Kharif
17.	GAYMH-1	SCH	AAU, Godhra, Gujarat	2016	Early	Gujarat	Kharif

	(1H0461/GYH0461						
18.	NAH-1137	SCH	UAS ,Bangalore	2016	Late	Karnataka	Kharif+ Rabi
19.	CoH (M) 10 (CMH 08-433)	TWC	TNAU, Coimbatore	2015	Medium	Andhra Pradesh, Tamil Nadu, Karnataka, Maharashtra, Rajasthan, Gujarat, Madhya Pradesh and Chhattisgarh	Kharif
20.	HM-13 (HKH317)	SCH	HAU, Hissar	2015	Early	Jammu and Kashmir, Himachal Pradesh and Uttarakhand	Kharif
21.	PMH 10	SCH	PAU Ludhiana	2015	Medium	Punjab State	Spring
22.	PMH 6 (JH 31292)	SCH	PAU Ludhiana	2015	Medium	Bihar, West Bengal, Jharkhand, Odisha and Uttar Pradesh	Kharif
23.	CoH (M)7 (CMH 08-287)	SCH	TNAU, Coimbatore	2014	Late	Uttar Pradesh, Bihar, Jharkhand, Odisha, Andhra Pradesh, Telangana, Tamil Nadu, Maharashtra and Karnataka	Kharif
24.	CoH (M)8 (CMH 08-292)	SCH	TNAU, Coimbatore	2014	Medium	Uttar Pradesh, Bihar, Jharkhand, Odisha, Andhra Pradesh, Telangana, Tamil Nadu, Karnataka, Rajasthan, Gujarat, Madhya Pradesh, Chhattisgarh, Punjab, Haryana, Delhi and Maharashtra	Kharif
25.	CoH (M) 9 (CMH 08-350)	SCH	TNAU, Coimbatore	2014	Medium	Uttar Pradesh, Bihar, Jharkhand, Odisha, Rajasthan, Gujarat, Madhya Pradesh and Chhattisgarh	Kharif
26.	DHM 121 (BH 41009)	SCH	PJTSAU, Telangana State	2014	Medium	Odisha, Bihar, Jharkhand, West Bengal , Gujarat, Rajasthan, Chhattisgarh and Madhya Pradesh	Kharif
27.	GH 0727 (Shrushti)	SCH	ARS, Arbhavi	2014	Late	Karnataka	Kharif
28.	Vivek Maize Hybrid 47 (FH 3513)	SCH	VPKAS, Almora	2014	Early	Uttrakhand, Himachal Pradesh, Jammu & Kashmir, Arunachal Pradesh, Assam, Manipur,	Kharif

						Meghalaya, Mizoram, Nagaland, Tripura and Sikkim	
29.	Vivek Maize Hybrid 53 (FH 3556)	SCH	VPKAS, Almora	2014	Extra-Early	Uttrakhand, Himachal Pradesh, Jammu & Kashmir, Uttar Pradesh, Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Tripura and Sikkim	Kharif
30.	Vivek Maize Hybrid 51 (FH 3554)	SCH	VPKAS, Almora	2014	Extra-Early	Gujarat, Rajasthan Chhattisgarh and Madhya Pradesh	Kharif
31.	CMH 08-282	SCH	TNAU, Coimbatore	2013	Late	Rajasthan, Gujarat, Madhya Pradesh and Chhattisgarh	Kharif
32.	Pant Shankar Makka-1	SCH	GBPUA&T, Pantnagar	2013	Early	Uttarakhand	Kharif
33.	PMH7(JH 3956)	SCH	PAU Ludhiana	2013	Medium	Punjab State	Spring
34.	Vivek Maize Hybrid 45 (FH 3483)	SCH	VPKAS, Almora	2013	Extra-early	Uttarakhand, Himachal Pradesh and Jammu & Kashmir	Kharif
35.	HM-12 (HKH 313)	SCH	HAU, Hissar	2012	Medium	Uttar Pradesh, Bihar, Jharkhand and Orissa	Kharif
36.	CO 6	SCH	TNAU, Coimbatore	2012	Late	Tamil Nadu	Kharif
37.	Vivek Maize Hybrid 43 (FH 3358)	SCH	VPKAS, Almora	2012	Late	Uttar Pradesh, Madhya Pradesh and Rajasthan	Kharif
38.	Vivek Maize Hybrid 39 (FH 3356)	SCH	VPKAS, Almora	2012	Extra-early	Uttarakhand and Himachal Pradesh	Kharif
39.	DHM 119 (BH 4062)	SCH	ANGRAU, Hyderabad	2011	Medium	Andhra Pradesh, Tamil Nadu, Maharashtra and Karnataka	Kharif
40.	PMH 4 (JH 31153)	SCH	PAU, Ludhiana	2011	Medium	Delhi, Punjab, Haryana and Uttar Pradesh	Kharif
41.	PMH 5 (JH 31110)	SCH	PAU, Ludhiana	2011	Early	Rajasthan, Gujarat, Madhya Pradesh and Chhattisgarh	Kharif
42.	KMH-22168	SCH	MPKV, Kolhapur	2010	Late	Maharashtra	Kharif & Rabi
43.	BH-40625 (DHM-117)	SCH	PJTSAU, Telangana State	2010	Medium	Andhra Pradesh, Maharashtra, Karnataka and Tamil Nadu	Kharif & Rabi

44.	BH-1620 (DHM113)	SCH	PJTSAU, Telangana State	2010	Late	Andhra Pradesh, Maharashtra, Karnataka and Tamil Nadu	Kharif & Rabi
45.	BH-1576 (DHM111)	SCH	PJTSAU, Telangana State	2010	Medium	Andhra Pradesh, Maharashtra, Karnataka and Tamil Nadu	Kharif & Rabi
Specialty Corns Hybrids							
1.	DMRHP1402 (Popcorn)	SCH (Popcorn)	ICAR-IIMR, Ludhiana	207	Early	Punjab, Haryana, Delhi NCR & Western Uttar Pradesh, Rajasthan, Madhya Pradesh, Chhattisgarh & Gujarat.	Kharif
2.	BPCH-6 (Popcorn)	SCH (Popcorn)	PJTSAU, Telangana State	2016	Medium	Across Country.	Kharif
3.	IMHB-1532	SCH (Baby corn)	ICAR-IIMR, Ludhiana	2018	Medium	Punjab, Haryana, Delhi, Uttarakhand, Uttar Pradesh (NWPZ) and Rajasthan, Gujarat, Madhya Pradesh and Chhattisgarh (CWZ).	Kharif
4.	IMHB-1539	SCH (Baby corn)	ICAR-IIMR, Ludhiana	2018	Early-Medium	Jammu and Kashmir, Himachal Pradesh, Uttarakhand (Hill region), Meghalaya, Sikkim, Assam, Tripura, Nagaland, Manipur and Arunachal Pradesh.	Kharif
5.	Vivek Hybrid 27 (Central Maize VL Baby Corn 2 (Babycorn)	SCH (Baby corn)	ICAR-VPKAS Almora	2017	Early	Jammu & Kashmir, Himachal Pradesh, Uttarakhand, Punjab, Haryana, Delhi, UP, Maharashtra, Karnataka, Tamil Nadu, Telangana, Andhra Pradesh, Gujarat, Rajasthan, Chhattisgarh and Madhya Pradesh.	Kharif
6.	VL Sweet Corn Hybrid-2 (FSCH 75)	SCH (Sweet Corn)	VPKAS, Almora	2019	Early	Jammu and Kashmir, Himachal Pradesh, Uttarakhand (Hills) and Assam, Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim and Tripura	Kharif

						(NEH Region)	
7.	Pusa Super Sweet Corn 1 (ASKH4)	SCH (Sweet Corn)	ICAR-Indian Agricultural Research Institute, New Delhi	2018	Medium	Jammu and Kashmir, Himachal Pradesh, Uttarakhand (Hill region), Meghalaya, Sikkim, Assam, Tripura, Nagaland, Manipur, Arunachal Pradesh (North Eastern Hill Region), Punjab, Haryana, Delhi, Uttarakhand (Plain), Uttar Pradesh (Western region), Bihar, Jharkhand, Odisha, Uttar Pradesh (Eastern region), West Bengal (NEPZ) and Maharashtra, Karnataka, Andhra Pradesh, Telangana and Tamil Nadu (PZ)	Kharif
8.	Shalimar Sweet Corn1 (KDM1263SC)	Sweet corn (Composite)	SKUAST, Kashmir	2018	Early	Jammu and Kashmir	
9	Central Maize VL Sweet corn 1 (FSCH18) (Sweet corn)	SCH (Sweet corn)	ICAR-VPKAS Almora	2016	Medium	Jammu & Kashmir, Himachal Pradesh, Uttarakhand, NE Hills, Punjab, Haryana, Delhi, Western UP, Karnataka, Tamil Nadu, Telangana, Andhra Pradesh, Gujarat, Rajasthan, Chhattisgarh and Madhya Pradesh	Kharif
10.	HSC 1 (Sweet Corn)	SCH (Sweet corn)	HAU, Hissar	2010	Medium	Himachal Pradesh and Uttarakhand	Kharif
QPM Maize hybrids							
1.	Shalimar QPMH-1 (KDQH-49)	SCH	SKUAST, Kashmir	2018	early	Jammu and Kashmir	Kharif
2.	Pusa Vivek QPM-9 (APQH9)	SCH	ICAR-IARI, New Delhi	2017	Extra early	J&K, HP, Uttarakhand (Hills) & NEH states , Maharashtra, Karnataka, AP, Telengana &TN	Kharif

3.	Pusa HM4 (AQH-4)	SCH	ICAR-IARI, New Delhi	2017	Medium	Punjab, Haryana, Delhi, Uttarakhand (Plain), UP (Western region)	Kharif
4.	Pusa HM8 (AQH-8)	SCH	ICAR-IARI, New Delhi	2017	Medium	MH, Karnataka, AP, Telengana &TN	Kharif
5.	Pusa HM9 (AQH-9)	SCH	ICAR-IARI, New Delhi	2017	Medium	Bihar, Jharkhand, Odisha, UP (Eastern region), West Bengal	Kharif
6.	Pratap QPM Hybrid-1 (EHQ16)	SCH	MPUA & T, Udaipur	2013	Medium	Rajasthan, Gujarat, Madhya Pradesh and Chhattisgarh	Kharif
7.	HQPM-4	SCH	HAU, Hissar	2010	Late	Across the country except Himalayan belt	Kharif

Hybrid seed production technologyof single cross hybrids of maize

S.B. Singh and Santosh Kumar
Regional Maize Research & Seed Production Centre (ICAR-IIMR), Vishnupur, Begusarai-851129

Introduction:

Maize (*Zea mays* L.) is the only billion-ton cereal crop of the world with total production of 1.13 billion tons (Singh *et al*., 2018). It is also known as queen of cereals because of its highest genetic yield potential among the cereals and in addition to being the staple food for human being and quality feed for animals. It also serves as a basic raw material as an ingredient to thousands of industrial products that includes starch, oil, protein, alcoholic beverages, food sweeteners, pharmaceutical, cosmetic, film, textile, gum, package and paper industries *etc*. Globally, it is cultivated on more than 197.19 mha area across 166 countries having wider diversity of soil, climate, biodiversity and management practices due to its vast adaptability in tropical, sub-tropical and temperate regions under irrigated to semi-arid conditions. China (42.39 million ha), USA (33.47 million ha) together account 38.48 per cent of total area of maize of the world and contribute 55.52% of the total global maize production. Globally India ranks 4th in maize area (9.2 milion ha) after China, USA and Brazil and 5th in production (28.72 million tons) after USA, China, Brazil and Argentina (Singh *et al.*, 2018). The demand for maize is ever increasing and estimated to touch around 50mt maize grain by 2025 which can be addressed only through complete adoption of single cross hybrid varieties because of its vigorous & high yielding nature (Kumar and Singh, 2019). Single cross maize hybrids has proved itself in the significant upliftment of productivity in comparison to the synthetics or composite varieties, three way or double cross hybrids (Dass *et al*., 2009). Maize is one of the most important crops that have been successfully utilized heterosis in the significant upliftment of the maize production. Heterosis is a phenomenon in which heterozygous hybrid progeny are superior to both homozygous parents. Hybrid seed is produced from the cross-pollination between two genetically distinct inbred parent lines. One inbred line is selected as the pollen donor (male parent) and the other as the pollen recipient (female parent) on which the hybrid seed will develop. To produce pure hybrid seeds, the female inbred parent line must be prevented from undergoing self-pollination and should be specifically crossed to the male inbred parent because of monoecious nature of maize plant. Manual or mechanical detasseling, the physical removal of the male floral structure, remains the predominant method in commercial hybrid seed production in maize. For commercial production of maize hybrid seed, male and female inbred parent lines are planted alternately, in adjacent rows, in isolated fields and allowed to open-pollinate.

As hybrid seeds are very pricey which is hard to be afforded by the farmers, so hybrid seed production at the local village level through seed village concept can enhance the farmers income as well as it can cut down the cost of the hybrid seed of the maize resulting in the reduction of cost of cultivation subsequently leading to the rise in farmers' income. Hybrid seed production technique in maize some additional important operations like planting the male and female parental line in specific planting ratio in adjacent alternate manner, roguing, detasseling and harvesting hybrid seed only from the female parent. It also requires the careful attention for all the operations to be done at proper time for getting the quality hybrid seed.

Floral biology of Maize:

The maize plant is of monoecious and protandrous in nature. Protandry deals the development or maturation of male flowers before the appearance of the corresponding female flower thus inhibiting self-fertilization and promoting cross fertilization. The staminate (male) flowers are borne in the tassel at the apex of the stalk while the pistillate flowers are located at the apex of condensed, lateral branches known as shanks protruding from leaf axils. The mature pistillate inflorescence is called cob. The male (staminate) inflorescence consists of many spikelets. The spikelets occur in pairs—the lower one is sessile and the upper one is stalked. Each spikelet is two-flowered. They have four glumes. The first and the second glumes located at the base, are sterile, and the third one, called flowering glume, and the last one, the two-nerved palea, enclose a flower. Flowers are obviously unisexual. Perianth is represented by a pair of fleshy scale-like bodies called lodicules. Androecium is composed of three free stamens with long prominent linear anthers. The female (pistillate) inflorescence, a spadix, produces pairs of spikelets on the surface of a highly condensed rachis (central axis, or "cob") arising from the axil of a lower leaf. A large number of spikelets are arranged closely on the fleshy axis, forming the cob. It remains surrounded by a few large hyaline bracts called spathes.

Each spikelet, like the male ones, is two-flowered and has protective glumes. Lodicules are absent. Gynoecium is monocarpellary. The ovary is one-chambered, superior, ovoid in shape with a single anatropous ovule. The styles are long and silky. Persistent styles hang out in tufts from the apex of the cob. Silks (elongated stigma) is long and feathery which look like tufts of hair initially and later turn green or purple in color. Due to being tightly covered over by several layers of leaves, and so closed in by them to the stem that they don't show themselves easily until emergence of the pale-yellow silks from the leaf whorl at the end of the ear. Each of the female spikelets encloses two fertile florets, one of whose ovaries will mature into a maize kernel once sexually fertilized by wind-blown pollen. As the internodes of the shanks are condensed, the ear remains permanently enclosed in a mantle of many husk leaves (Anonymous, 2012).

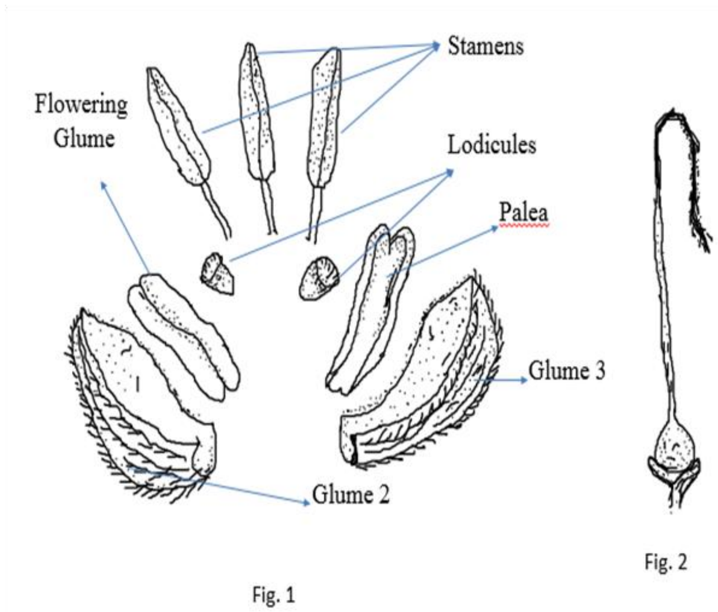


Fig.1. Dissected male flower Fig. 2. Carpel of female flower

Pollination and fertilization:

Maize is normally cross pollinated. The pollination is by wind. Cold wet weather retards the shedding of pollen while hot dry conditions tend to hasten it. The flowers near the middle of the ear develop the silks early and usually are pollinated first.

Formation of the female flowers or cobs is the first reproductive stage (emergence of silk) and occurs 2-3 days after tasseling stage. In maize, the pollens don't shed continuously and usually begins two to three days prior to silk emergence and continues for five to eight days. The silks are covered with fine, sticky hairs which serve to catch and anchor the pollen grains. Small dusty pollen grains are easily caught by the feathery stigma of the carpel where pollen germinates by growth of the pollen tube down the silk channel within few minutes of coming in contact with a silk and the pollen tube grows the length of the silk and enters the embryo sac in 12 to 28 hours. Pollen grain after falling on the silk remains viable for only 10 to 18 hours under favorable conditions. Pollen shed stops when the tassel is too wet or too dry and begins again when temperature conditions get favorable. Cool temperatures and high humidity favor pollen longevity. Under optimal conditions the interval between anthesis and silking is one to two days which may increase under any stress situation. Pollen of a given plant rarely fertilizes the silks of the same plant. Under field conditions 97% or more of the kernels produced by each plant are pollinated by other plants. Fruit is a caryopsis with a single closely fitted seed where fruit wall and seed-coat are inseparably united. A large number of fruits, called grains, remain densely crowded on the spongy axis. Seeds are albuminous. The single cotyledon, scutellum, serves as the absorbing organ. Germination is hypogeal. The plant itself is the most prominent generation, the sporophyte, with diploid (2N) chromosomes in the nuclei of the cells, and "the gametophytes with haploid (N) chromosomes are represented by embryo-sac and pollen tube. They are very small, reduced and dependent on the sporophyte. Gametophytic generation begins with reduction division in microspore-mother cell and megaspore-mother cells with subsequent formation of microspores and megaspores respectively. With fertilization '2n' number it restored and sporophyte begins (Anonymous, 2012).

Hybrid:

Hybrids are the first-generation crosses between genetically unrelated or dissimilar parents which may be purelines, inbreds, varieties or population. Pollen from male parent (Pollen parent) pollinate, fertilize and set seeds in female (seed parent) to produce F_1 hybrid seeds. For production of a hybrid, crossing between two parents is important; the crossing process will result in heterosis. In self-pollinated crops, it is difficult to cross but in cross pollinated crops, like maize, where, there is no need to do emasculation, it is easier.

Different types of hybrids in maize & their characteristics

Hybrid type	**Female parent**	**Male parent**	**Seed yield**	**Seed price**	**Hybrid characteristics**	**Hybrid grain yield**
Single cross	Inbred line	Inbred line	Lowest	High	Uniform	Highest
Three way cross	Single cross hybrid	Inbred line	High	Moderate	slightly variable	High
Double cross	Single cross hybrid	Single cross hybrid	Highest	Low	Highly variable	Moderate to high
Top cross	OPV	Inbred line	Moderate	Low	Highly variable	Moderate
Varietal cross	OPV	OPV	Moderate to high	Low	Highly variable	Moderate to high

Advantages of Hybrid corn:

Hybrid corn has high acceptability among the farmers because of its higher yield and highest yield potential among cereals as per day productivity is more due to heterosis utilization. It has quick and higher percentage of germination in addition to uniform and faster growth. Hybrid corn not only shows better adaptation under climate change but also shows tolerance to biotic and abiotic stresses *e.g.* tolerance to water stress due to better root system resulting in reduced need for irrigation water in comparison to the normal OPV/synthetic/composite varieties. It has less yield reduction under nutrient stress condition. It provides food, income and nutritional security for resource-poor farm families due to ease to marketing because of its uniformity and high productivity.

Prerequisites for hybrid seed production

- Good compatible, uniform, productive and diverse parents.
- Proper site selection, avoid the sites where preceding crop was maize.
- Fertile and quality land with good quality and assured irrigation.
- Proper isolation distance.
- Knowledge of recommended package of practices.
- Technically experienced manpower
- Stress free climatic condition.

Characteristic of good seed parent

Female parent	**Male parent**
• Productive • Strong • Long cobs with complete exertion • Low cob placement • Shorter anthesis silking interval • Nutrient responsive • Stay green traits • Erect leaves • Resistant/tolerant to biotic and abiotic stress • Strong root system	• Lax tassel, long main branch with few secondary branches • Long duration of pollen shedding • Taller than female parent • Attractive grain color • Strong resistant to lodging with better root system • High yield potential • Resistant/tolerant to biotic and abiotic stresses

Single Cross Hybrid Seed Production Technique:

Soils : Maize hybrid seed production can be done in soils ranging from loamy sand to clay loam. However, soils having good organic matter content and high water holding capacity with neutral pH are considered good for higher productivity. Being a sensitive crop to moisture stress especially excess soil moisture and salinity stresses; it is desirable to avoid low lying fields having poor drainage and also the field having higher salinity. Preferably, the selected field should be free of volunteer maize plants (unwanted plant growing from seeds that have fallen from the plants of previous maize crop) to maintain the genetic purity and avoid genetic contamination

Time of sowing : Maize can be grown in all seasons viz; *Kharif* (monsoon), post monsoon, *Rabi* (winter) and spring. The optimum time of sowing in kharif is Last week of June to first fortnight of July, in rabi last week of October for inter cropping and up to 15th of November for sole crop while in spring, it is first week of February. Generally, the raised bed planting is considered as best planting method for maize during monsoon and winter seasons both under excess moisture as well as limited water availability/rainfed conditions. For most part of India, First week of July is preferred in kharif to avoid flowering during heavy rains (washing off the pollens) and first week of November during Rabi to avoid low temperature during flowering (killing anthers). Generally, sowing during November – December is suitable for seed production, since seed maturity stage will not coincide with rainfall (Anonymous).

Seed Rate: Optimum plant stand is the key factor to achieve higher productivity. The seed rate varies depending on plant type, season, sowing methods *etc.* The following crop geometry and seed rate should be adopted. Generally, for grain (normal and QPM), optimum seed rate is 15kg for female and 10 kg for male parental inbred line. The spacing should be 60/75cm row to row & 20cm plant to plant. The minimum recommended germination percent is 80%.

Seed treatment: Seed treatment is the most important factor to provide protection from early infestations of pest and diseases, which is advisable/ recommended with fungicides and insecticides before sowing to protect the maize crop from seed and major soil borne diseases and insect-pests, as per the below given details.

Disease/insect-pest	**Fungicide/Pesticide**	**Rate of application (g kg-1 seed)**
Turcicum Leaf Blight, Banded Leaf and Sheath Blight, Maydis Leaf Blight	Bavistin + Captan in 1:1 ratio	2.0
BSMD	Apran 35 SD	4.0
Pythium Stalk Rot	Captan	2.5
Termite and shoot fly	Imidacloprid	4.0

Nutrient management

The rate of nutrient application depends mainly on soil nutrient status/balance and cropping system. For obtaining desirable yields, the doses of applied nutrients should be matched with the soil supplying capacity and plant demand (Site-specific nutrient management approach) by keeping in view of the preceding crop (cropping system). Response of maize to applied organic manures is notable and hence integrated nutrient management (INM) is very important nutrient management strategy in maize based production systems. Therefore, for higher economic yield of maize, application of 10ton FYM/ha, 10-15 days prior to sowing supplemented with 150-180 kg N, 70-80 kg P2O5, 70-80 kg K2O and 25 kg ZnSO4 ha-1 is recommended. Full doses of P, K and Zn should be applied as basal dose during field preparation. Nitrogen should be applied in 5-splits as detailed below for higher productivity and use efficiency. N application at grain filling results in better grain filling. Therefore, nitrogen should be applied in five splits as per below mentioned for higher N use efficiency.

S. No	Crop Stage	Nitrogen rate (%)
1	Basal (at sowing)	20
2	V4 (four leaf stage)	25
3	V8 (eight leaf stage)	30
4	VT (tasseling stage)	20
5	GF (grain filling stage)	5

Isolation distance: It is very important to maintain the proper isolation distance or time to avoid the pollen contamination from unknown sources for restricting gene flow and ensuring seed purity for maize seed production. It manages the pollen drift effectively. Isolation distance is accomplished in three ways including, distance, time and good synchronization. It also includes planting a barrier of foundation or certified seed of the same variety or the other crop like bazra or Napier grass on all sides about 50 m from the production block. It also depends upon wind velocity/ season. The recommended isolation distance for the hybrid seed production in maize is 400 mtr. and in terms of time, minimum time required for isolation must be 25 days.

Male female ratio: During hybrid seed production of maize, 3-4 female line is planted between one male line on each side (Fig. 3). Male female ratio must be maintained to get optimum pollen and achieve good seed set. It depends on the pollen shedding potential of male parent and male female synchrony in flowering. Different ratios are **1male:2female:1male:2female:1male** or **1male:3female:1male:3female:1male** or **1male:4female:1male:4female:1male.** Male female synchrony is also an important factor to get the good seed setting. Male female synchrony may be achieved through staggered planting of male and female parental lines, application of irrigation along with fertilizers and application of FYM in either male or female to induce earliness and vigor.

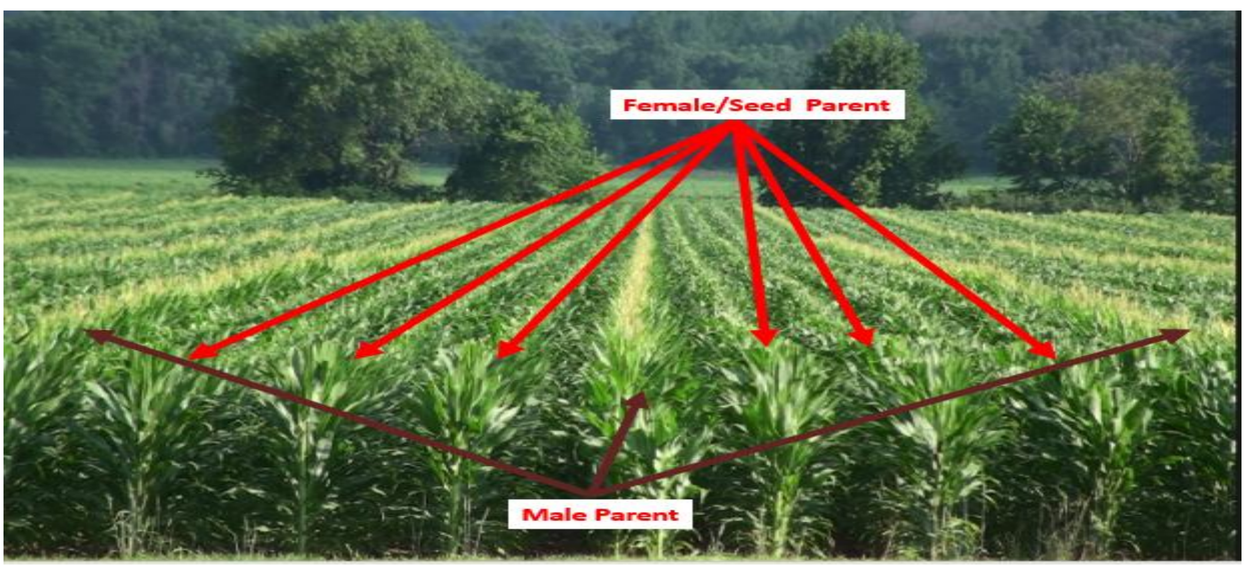


Fig. 3. Male female planting pattern

Roguing: It is the method of removing unwanted and off type plants which should be done periodically based on height of plant, position of cob, colour of silk, arrangements of seeds in cob, leaves *etc*. It should be conducted before genetic or physical contamination. Shedding tassels are to be removed in roguing. It refers to the tassels in female parent rows, shedding pollen or that has shed pollen in hybrid maize plots. During field inspection, a tassel whose main spike or any side branch or both have shed pollen or shedding pollen in more than 5 cm of branch length is counted as a shedding tassel. During inspection, the shedding tassels are taken into count for acceptance or rejection of production plot. Roguing on male plants must be complete before pollen shedding begins and female plants should be rogued completely soon after silk-emergence.

Detasseling : Detasseling the physical removal of the male-bearing floral structure at the top of the plant by hand or with mechanical cutters or pullers, remains the predominant method employed by industry to ensure that female parent plants in a commercial hybrid production field will only receive pollen from male parent plants (Fig. 4). Detasseling is done when the tassel emerges out of the boot leaf, but before anthesis *i.e.* anthers have shed pollen. Anthers take 2-4 days to dehisce after complete emergence. Only in few cases, the anthers start dehisces before its complete emergence. In such case, detasseling should be done earlier. Detasseling is done every day from the emergence of tassel up to 14 days. Detasseling is done by holding the stem below the boot leaf in left hand and the base of the basal in right hand and pulling it out in a single pull. Care should be taken to remove the complete pollen part and not to break or remove leaves as removal will reduce yields and will result in lower quality of seed. Removed tassels should not be left on the field they may also shed the pollen causing contamination.

Fig. 4. Detasseling and hybrid seed production

Crop inspection: Inspection of the hybrid seed production field by the scientific team must be done at the time of sowing, during pre-flowering/ vegetative stage, flowering stage, post flowering stage, pre harvest stage and also during the harvesting time to avoid the any type of genetic or physical contamination during any time of the production period.

Water management : The irrigation water management depends on season. However, in areas having assured irrigation facilities, depending upon the rains and moisture holding capacity of the soil, irrigation should be applied as and when required by the crop and first irrigation should be applied very carefully wherein water should not overflow on the ridges/beds. In general, the irrigation should be applied in furrows up to 2/3rd height of the ridges/beds. Young seedlings, knee high stage, flowering and grain filling (GF) are the most sensitive stages for water stress and hence irrigation should be ensured at these stages. In raised bed planting system and limited irrigation water availability conditions, the irrigation water can also be applied in alternate furrow to save more irrigation water. In rainfed areas, tied-ridges are helpful in conserving the rainwater for its availability in the root zone for longer period. For winter maize, it is advisable to keep soil wet (frequent & mild irrigation) during 15 December to 15 February to protect the crop from frost injury.

Weed Management: Weeds are the serious problem in maize, particularly during *kharif* /monsoon season they competes with maize for nutrient and causes yield loss up to 35%. Therefore, timely weed management is needed for achieving higher yield. **Atrazine** being a selective and broad-spectrum herbicide in maize checks the emergence of wide spectrum of weeds. Pre-emergence application of Atrazine (Atratraf 50 wp, Gesaprim 500 fw @ of 1.0-1.5 kg *a.i* ha^{-1} in 600 litre water, Alachlor (Lasso) @ 2-2.5 kg a.i ha^{-1}, Metolachlor (Dual) @ 1.5-2.0 kg a.i ha^{-1}, Pendamethalin (Stomp) @ 1-1.5 kg a.i. ha^{-1} are effective way for control of many annual and broad-leaved weeds. While spraying, following precautions should be taken care by the person during spray, he should move backward so that the Atrazine film on the soil surface may not be disturbed. One to two hoeing are recommended for aeration and uprooting of the remaining weeds, if any. While doing hoeing, the person should move backward to avoid compaction and better aeration. Under heavy weed infestation, post-emergence application of Paraquat & Loudis can also be done as protected spray.

Integrated pest and disease management should also be done carefully on incidence of specific pest and disease in consultation with agricultural expert.

Parental inbred line seed production:

The seed production of parental inbred line of the hybrid is done through planting the inbred lines either in time isolation or space isolation from each other as well as from any other maize crop field to avoid the any type of pollen contamination. The field is managed with proper management practices to get the good crop in addition to the application of more urea and irrigation as per the demand of the crop to provoke the silk and tassel emergence along with its synchronization helps in getting good seed set resulting in higher seed yield of the parental inbred line.

Harvesting

Male lines are harvested first before harvesting the female lines to avoid mixture. Harvest from the female line is taken as hybrid seed while from male line is taken as grain. Optimum moisture for grain harvesting should be 20%. Harvested crops should be spread evenly instead of pooling.

Recommended Field standard (%)

	Foundation seed	**Certified seed**
Off types	0.2	0.5
Shedding tassel	0.5	1.0
Inseparable other crop	Nil	Nil
Objectionable weed	Nil	Nil
Designated diseases	Nil	Nil

Seed standard:

Parameters	**Inbreds**	**Foundation seed**	**Certified seed**
Physical purity (%) (min)	**98**	**98**	**98**
Inert matter (%) (max)	**2**	**2**	**2**
Other crop seed (max)	**5**	**5**	**10**

ODV seeds (max)	**5**	**5**	**10**
Germination % (min)	**80**	**80**	**90**
Moisture content (%) (max) a. Moisture pervious b. Moisture vapour proof	 **12** **8**	 **12** **8**	 **12** **8**

Field Standards (certified seed)

Factor	**Maximum permitted (%)**
Off types plants that have shed or shedding pollen when 5% or more than 5% of the female flowers are in receptive stage.	**0.20**
Pure seed (minimum)	**98.0**
Inert matter (maximum)	**2.0**
Other crop seeds (maximum)	**5/kg**
Other distinguishable varieties based on kernel colour and texture (maximum)	**5/kg**
Weed seeds	**Nil**
Germination (minimum)-Inbreds	**80%**
Moisture content (maximum) Moisture pervious container	**12.0%**

Field standards for isolation:

Particulars	**Foundation stage (Meter)**	**Certified stage (Meter)**
Same kernel color	400	200
Different kernel colour	600	300
Field of single cross / inbreds not confirming to varietal purity	400	200
Single cross with same male parent confirming to varietal purity	5	2
Single cross with other male parent not confirming to varietal purity	400	200

Post-harvest management

Drying and sorting of seed parent cobs is needed after harvest in which Sun drying is the best. Cobs can be Spreaded on Tarpoline sheets to avoid seed injury. Final moisture of 13-14% should be retained. After drying, shelling should be done either manually or power operated maize sheller. Shelling should be avoided during high moisture to avoid embryonic damage.

After shelling, seed processing should be undertaken when seeds get dried completely. Seed processing is necessary to maintain the quality of the hybrid seed. It is done by removing all under sized, broken, damaged and malformed seeds. Seed drying should be done to bring moisture up to 8 % and should be kept in aerated jute bag for seed storage and marketing. Seed should be stored in dry and cool place to avoid germination and vigor loss during storage.

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Techniques for spurious seed detection in maize

Dr G. Anuradha
Principal Scientist and Head
Maize Research Centre, PJTSAU, Hyderabad

Maize known as the 'queen of cereals', ranks third as an important food crop of India after wheat and rice. It is an agro-versatile crop as it can be grown under a wide variety of geographical conditions and can be cultivated throughout the year. The area, production and productivity of maize in the world is around 197.18 million ha, 1134.74 million MT and 5.75t/ha, respectively (FAO, 2017) covering over170 countries. USA and China together account for nearly 61 per cent of total world maize production. In India it is grown in an area of 9.47 million ha with 28.72 million MT production and with the productivity of 3.03t/ha (2016-17). The major maize producing states in India are Karnataka, Andhra Pradesh, Bihar, Maharashtra, Uttar Pradesh and Rajasthan. Yhe productivity of maize in US is three times higher than that of India. The higher productivity of maize in USA is due to adoption of single cross hybrids, favourable climatic conditions, long duration and high input. The rising demand for corn as animal feed and food is the key contributor for maize hybrid penetration. Since India's maize yields are very low compared to global standards, farmers are depending on hybrid seeds to get more productivity gains. It is a fact that out of the total output, 49% is used as poultry feed, 12% is put into use as animal feed, 25% as food, 13% as corns starch and **1% as seed**.

Seed is the basic and most critical input for sustainable agriculture. The response of all other inputs depends on quality of seeds to a large extent. It is estimated that the direct contribution of quality seed alone to the total production is about 15 – 20% depending upon the crop and it can be further raised up to 45% with efficient management of other inputs(Liu *et al*,2000).

F1 hybrid maize varieties have become commercially dominant over open-pollinated maize varieties. As a result of the hybridization of maize, varieties with markedly improved performance and yields, more uniform characteristics, and improved resistance to insect and disease pests have been developed. F1 hybrid varieties are produced by the hybridization of two inbred lines as parents, where the parents are homozygous. The increased use of F1 hybrids is also due to the inherent protection of the intellectual property. With introduction of high yielding hybrid varieties in crops, the developments in the seed industry in India, particularly in the last 30 years, are very significant.

The National seed policy stimulated appreciable investments by private individuals, Indian Corporate and MNCs in the Indian seed sector with strong R&D base for product development in each of the seed companies with more emphasis on high value hybrids of cereals and vegetables and hi-tech products such as Bt. Cotton. As a result, farmer has a wide product choice and seed industry today is set to work with a 'farmer centric' approach and is market driven. The Indian seed industry comprises some 14 state seed corporations and two national-level corporations, 20 large players including multinationals and around 500 small regional players. The Indian hybrid seed sector is now pegged at around Rs 12,000 crore with hybrid maize accounting for little over Rs 1,500 crore.

The critical issue is the genetic purity of F1 hybrids. It is an essential characteristic of seed lots before it is sold to farmers. Because both parents used for producing hybrids, are so homogeneous by process of self-pollination, the seed to be finally harvested also will be very homogenous of genetic composition. The final crop growing from the hybrid seed is particularly uniform as to properties like morphology, yield, harvest time, manner of culture etc. Besides uniformity, hybrid varieties also give higher yield in comparison to open pollinated varieties. These advantages of the F1 hybrid varieties for the buyer of the hybrid seeds are of great importance (for example mechanical harvesting is made possible by the uniformity of the crop). The quality of the hybrid crop in terms of morphological uniformity is also very important.

When the mother line of the hybrid by whatever cause is self-pollinated, this leads to mother seeds instead of F1 hybrid seeds. Sometimes the seed of the father line may occur in the seed lot. Self-pollination of the mother line leads to inbred seeds in the hybrid seeds. This is not acceptable for the buyer as it reflects in final yield reduction. Therefore, the hybrid quality of seeds in practice is determined by samples taken at random. Maize seed purity is one of the fundamental question that affect maize yield. It is estimated that the yield per hectare will decrease about 135 kg if the maize hybrid seed purity drop by 1% (Liu et al.,2000)
The other crucial situation arises when huge demand supply gap exists for seed, **the sales of spurious seeds** by **fly by night sellers** to farmers shoot up. In general currently, about 30% of seeds are what the farmer himself saves from his crop.This can not be practiced in the crop like maize as the seed material is mostly single cross hybrids. Hence, the seeds bought and sold commercially is dominated by the private seed industry. The seed sold by private companies, are not certified, but rather what we call 'truthful label seeds'. That is, they are simply self-certified by the company. Here comes the risk for both seed companies and the farmers with the entry of spurious seed.

Regulatory measures for quality seed production have to be tightened so as to regulate such spurious seed sales. There are different methods to identify contaminated seed either arised due to some negligence during seed production or wishful mixture of spurious seeds for short term advantage.

Methods for assessing seed quality
1. Morphological/ Conventional grow out test
2. Chemical tests
3. Electrophoresis

1. Morphological/ Conventional grow out test

- Examination of seeds in the laboratory. (seed coat colour, seed weight, seed texture etc.,)
- Examination of the seedlings grown in growth chamber or green house.(anthocyanin pigmentation of stem, leaf sheath)
- Conducting field plot test or grow out test

Grow out test: Here the characters are studied at proper stage of the crop growth. The seeds are sown in the main field in a prevailing environment after proper land preparation. The check and authenticated samples are also grown along with the test samples. The crop is grown upto the peak flowering and fruiting stage. Based on distinguishable characters, the varieties are identified (leaf angle, blade attitude, anthocyani pigmentation at base of glume, glumes excluding base, anthers, silk and number of rows of grain, type of grain, grain shape etc.,).

This serves as the standard test for genetic purity examination under seed certification programme.

True plant types=total number of plants in plot - selfed plants/off types.

$$\%\text{Genetic purity} = \frac{\text{True plant types}}{\text{Total plant population}} \times 100$$

Disadvantages

- Time required for test will be long, (some months)
- The seeds cannot be sold directly after harvesting. This means that the seeds in many cases have to be stored for a long time, with all the accompanying costs.
- This not only causes extra costs by storing per se, but also quality loss, missing sales possibilities and a more difficult planning of next productions.

2. Chemical tests

A) Flourescense test:

- The seedlings are exposed to the flourescent light in a dark room.
- Some varieties coleoptile region will illuminate. Based on this seeds are identified. (eg:oats)

B) Disease resistance test:

- Based on the resistance and the susceptibility of seeds to pathogen test, the varieties can be identified.

C) Tetrazolium (TZ) Test Duration: 2 days

The tetrazolium test gives a rapid estimation of the percentage of live seeds in a sample that have the potential to produce normal seedlings under favourable germination conditions. It can also be used for small-seeded species in determining the viability of ungerminated seed at the end of the germination period. Two reps of 100 seeds (typically) are placed between moist brown paper towels or blotter paper overnight. The next day the seeds are pierced, cut in half, or left whole (depending on species) and placed in tetrazolium solution. After a short period of time, the seeds are examined for staining patterns. The tetrazolium test can also be used to detect frost damage, estimate vigor, or diagnose seed lot problems.

Advantages:

- The problem with germination testing is that it is ineffective when seeds are dormant (as they won't germinate even when viable). This test is useful as it measures the percent live seeds in a sample regardless of the seeds' dormancy status (Fig 1a & Fig 1b) as it evaluates seed viability based on seed respiration
- The tetrazolium (TZ) test is a quick biochemical test that. The test can be performed in 24 to 48 hours.

Fig 1a: Dead Seed

Fig 1b: Viable seed

Disadvantage

This test requires trained analysts and more labor than traditional germination tests, but it leads to faster results.

Seed damage can be assessed in 24 hours using the tetrazolium test rather than waiting 7 to 8 days for the results of a germination test. (DeVries, M and Susana, AG. 2006).

ii. GMO Rapid Test kits:

- Lateral flow strips also known as immunostrips are designed to quickly determine the presence or absence of genetically modified traits expressed in transgenic crops including corn.
- Lateral flow tests, also known as lateral flow immunochromatographic assays, are simple cellulose-based devices intended to detect the presence (or absence) of a target analyte in liquid sample (matrix) without the need for specialized and costly equipment, though many lab-based applications exist that are supported by reading equipment. Typically, these tests are used for medical diagnostics either for home testing, point of care testing, or laboratory use. A widely spread and well known application is the home pregnancy test (Fig 2).
- Results in 10 minutes or less. (Envirologics, Indiana Crop Improvement Association).

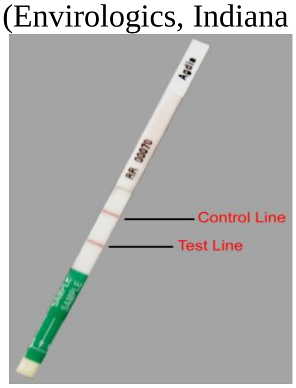

Fig 2 ImmunoStrip

Bt-Cry2A and Bt-Cry1Ab/1Ac ImmunoStrip® Test Strip test for the detection of Bt-Cry2A and Bt-Cry1Ab/1Ac transgenic protein Catalog no. STX 06801
Bt-Cry2A and Bt-Cry1Ab/1Ac ImmunoStrip® Test Strip test for the detection of Bt-Cry2A and Bt-Cry1Ab/1Ac transgenic protein Catalog no. STX 06801

3. Electrophoresis:

- It is the method of cultivar identification based on protein banding and isoenzyme activity.
- Here single seeds are defatted and extracted for proteins and esterases.
- The extracted proteins or esterases are separated by PAGE.

The current application relates to a more economical and superior method of determining the genetic purity of F1 hybrid varieties of maize. The method is based on preparation of a seed extract containing particular seed isoenzymes in a suitable extraction fluid and separation of the so extracted seed isoenzymes using isoelectric focusing at a suitable pH gradient formed by ampholytes, where after the so separated isoenzymes are conventionally colored and visually detected. The so obtained electrophoretic pattern is used to assess the genetic purity of maize hybrid varieties.Based on the banding pattern of protein and esterases the varieties can be differentiated and identified (Dou et al., 2012) (Fig 3).

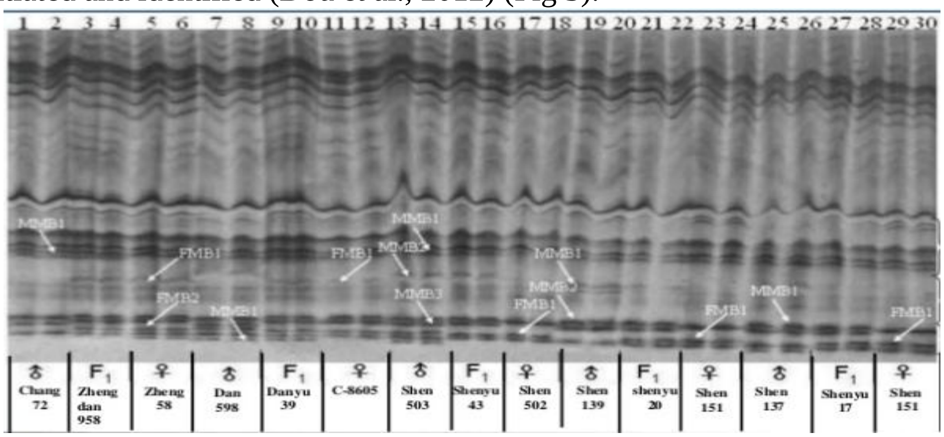

Fig 3: Isoelectic banding pattern of hybrids along with respective parents

4. Hybrid seed purity assessment using DNA test:

Traditional Grow Out Test (GOT) being used for genetic purity testing requires a complete season. Also, it is labour-intensive as well as sensitive to environmental changes and therefore is not totally a true-to-type method to assess genetic purity. Due to the above reason, there is unavailability of hybrid seeds for immediate cultivation which leads to the extra cost of storage, and hence an overall increase in the hybrid seed cost.

Molecular marker assisted identification with high power of genetic resolutions has emerged as a robust technique for cultivar fingerprinting, identify profiling, estimating and comparing genetic similarity and variety protection. Choice of marker varies with the specific objective. Among various DNA-based markers available for genetic purity testing, PCR based co-dominant SSRs (also known commonly as microsatellites) are preferred for genotyping because of their reproducibility, abundance and amenability to high throughput screening. (Fig 4). The SSR markers are of great importance for rapid assessment of hybrid and parental line seed purity.

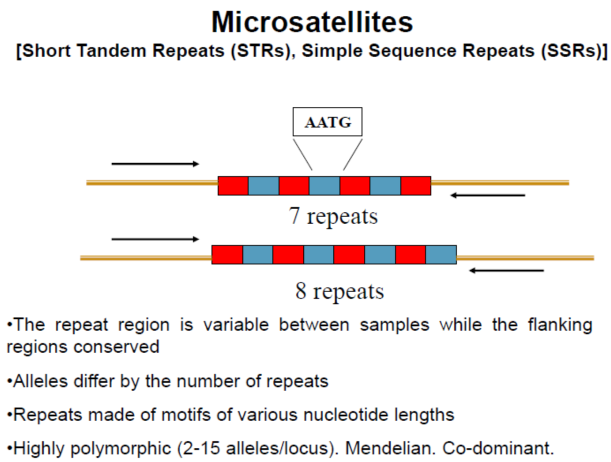

Fig 4: Microsatellites

These markers were used for hybrid purity testing in number of crops like rice (Sundaram et al. 2008), maize (Chaudhary et al. 2018.,Sanghamitra et al. 2017., Bhat et al.2017 and Sudharani *et al.* 2012,) sunflower(Pallavi *et al.* 2011), safflower (Naresh *et al.* 2009) cotton (Selvakumar *et al.* 2010)

Chaudhary *et al.* 2018 used SSR primer pumc1013 which amplified an allele size 180 bp in female parent (Hki193-2) which was absent in pollen parent (Hki 161). While, the pollen parent had an amplicon at 200 bp which was absent in female parent. However, the hybrid HQPM-4 exhibited both the alleles of the parents confirming the heterozygosity condition of the hybrid by having bands at 180 and 200 bp (Fig 5).

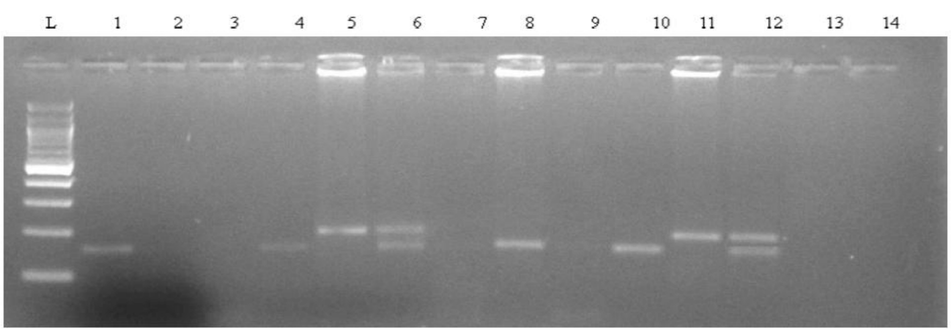

Fig 5: Polymorphic SSR marker profile confirm hybridity of HQPM 4 and HQPM 7 obtained with pumc 1013; 100b ladder, lane 4: HKI 193-2, lane 5: HKI 161, lane 6: HQPM 4, lane 10: HKI 193-1, lane 11: HKI 161, lane 12: HQPM 7

Sudha Rani *et al.* 2012. reported that the SSR markers Phi053 and umc 1600 could clearly distinguish the hybrid from its parental lines and can safely be used in hybrid purity testing of maze hybrid DHM117. (Fig. 6).

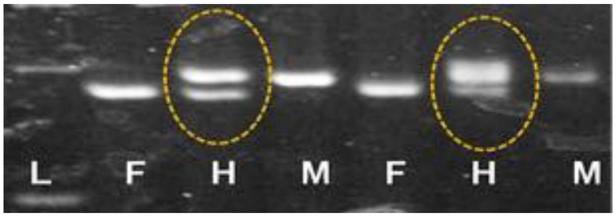

Fig 6: DNA Polymorphism Observed in Maize Hybrid (DHM-117) And Parental Lines Using

SSR Markers Phi053 And Umc1600.

The only wayout to check **spurious seed** is to roll out a software to barcode seeds in order to ensure transparency and traceability. The software system will be able to track seeds through the testing, certification and manufacturing process. By connecting to a dealer licensing system, seeds will be tracked through the distribution process. If we can use this to weed out poor quality seeds sold by some **fly-by-night operators**, it could increase productivity by 20 to 25%.

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Fodder maize and silage production

D. P. Chaudhary
ICAR-India Institute of Maize Research, Ludhiana
E-mail: chaudharydp@gmail.com

Abstract

Green fodder is an important component of dairy as its growth primarily depends upon the availability of nutritious fodder. Maize is one of the most nutritious non-legume green forage as it is palatable, nutritious and free from any anti-nutritional components. Maize is quick growing and yields high biomass. It contains sufficient quantities of protein and minerals and posses high digestibility as compared to other non-legume fodders. It contains high concentrations of soluble sugars at green stage which makes it fit to be preserved as silage. The increasing cultivation of baby corn and sweet corn in the peri-urban regions of the country may greatly help towards improving the prospects of dairy sector.

Introduction

Livestock production is backbone of Indian agriculture contributing 4% to national GDP and source of employment and ultimate livelihood for 70% population in rural areas. Contribution of livestock to agriculture sector GDP has been steadily increasing. The livestock are less affected by the climate change and its growth is also higher than agriculture. In 11^{th} plan, the average growth of livestock sector was 4.1 while it was 3.6 for agriculture as a whole. The growth in livestock sector is also demand-driven, inclusive and pro-poor. In India livestock production system is primarily characterized by low input as well as low output which is primarily attributed to low quality fodder. The livestock population is increasing and accordingly its feed requirements are also increasing. There is urgent need to meet the demand of increasing number of livestock and also enhance their productivity for which availability of good quality feed resources have to be increased. To compensate low productivity farmers generally maintain more number of animals which obviously increase the pressure on limited fodder resources. Fodder scarcity makes dairying uneconomical and unattractive as an income generation activity among the poor farmers of the country. Looking at the vast gap between the demand and supply position, it becomes necessary to put adequate efforts to transfer the potential technologies developed by various research organization in the country to farmer's field in order to increase the production and productivity of good quality fodder. To make dairying economically attractive, milk production and productivity has to be enhanced. This is possible only by making available good quality feed and fodder in adequate quantity as the economics of milk production is largely dependent upon the quality of nutritious fodder fed to milch animals. Feeding green forages as compared to concentrates lowers the cost of milk production substantially. For the optimum milk production around 40 kg of green fodder is required to feed per animal per day. Moreover, green forages are rich and cheapest source of carbohydrates, protein, vitamins and minerals for dairy animals. Therefore, by providing sufficient quantities of good quality fodder instead of costly concentrates to the milch animals, the cost of milk production can considerably be reduced. Maize is one of the most important non-legume green fodders. It is tall, leafy plant having biomass yields to the tune of 400-500 q/ha. It is highly nutritious, palatable fodder free from any unwanted anti-quality components. Green maize is rich in protein and possesses sufficient quantities of soluble sugars required for proper ensiling.

Green Fodders

Round the year availability of green fodder is the most challenging activity in the dairy sector. It not only reduces the feeding cost but also keeps the animals healthy, reduce micronutrient deficiencies and increase milk production. Forages usually contain relatively large concentrations of cellulose, hemicelluloses and lignin as well as variable amounts of non-fibrous carbohydrates and proteins. The dairy animals obtain nutrients viz: energy, protein, fiber, minerals, vitamins and water from the forages for the maintenance of their body and optimum performance. There are many legume and non-legume fodder varieties available for cultivation. Ideal characteristics of good fodder varieties are: short duration, high biomass potential, nutritious and tasty fodder, suitability for preservation and negligible concentrations of anti-nutritional components. Green fodders can be broadly divided into two categories viz: legumes and non-legumes. Some of the common green forages cultivated in India are listed in Table 1

Maize (*Zea mays*) is one of the most important crops having wider adaptability to varied agro-climatic conditions. In India, it is the third most important food crops after rice and wheat. It is the crop with the highest per day productivity. The production as well productivity of maize is growing in India at present the country is producing more than 26 MT of maize grains. It is an excellent crop in terms of biomass production also. Since, the production as well as productivity of maize is increasing, the availability of biomass from maize is also increasing by the same magnitude. The fodder quality of green maize is considered best among non-legume forage crops as it grows quickly, produces high yields, is palatable, rich in nutrients, and helps to increase body weight and milk quality in cattle (Sattar et al. 1994). As fodder for livestock, maize is excellent, highly nutritive and sustainable (Hukkeri et al. 1977, Iqbal et al. 2006).It is commonly grown as a *kharif* fodder in the North-Western regions of India. Its quality is much better than sorghum and pearl millet since both sorghum as well as pearl millet possesses anti-quality components such as hydrocyanic acid and oxalate, respectively.

Apart from grain, maize is also grown as baby corn and sweet corn (specialty maize). Specialty corn cultivation is gradually increasing in the peri-urban regions of the country. Baby corn is a very delicious and nutritious vegetable and has been considered to be a high value agriculture produce in national and international markets. The export potential of baby corn provides further boost to its cultivation. On the other hand sweet corn is highly valued by the Indian population due to its sweetness at the milking stage. A lot many value added products made from baby corn and sweet corn are being used for human consumption. A significant quantum of green biomass is available from specialty corn cultivation which can efficiently be used as animal fodder. Yield potential and nutritional quality of some promising genotypes including JH-3459, Parkash and PMH-2 grown for baby corn along with two most common fodder maize varieties viz. African Tall and J-1006 were evaluated for various parameters of fodder quality such as green fodder yield (GFY), dry matter (DM), crude protein (CP), fiber components viz. crude fiber (CF), neutral detergent fiber (NDF), acid detergent fiber (ADF), *in-vitro* dry matter digestibility (IVDMD) and total ash (TA) (Table 2 & 3). The data shows that the nutritional quality of baby corn stalks is almost at par to the maize grown for fodder purpose. Although, biomass from baby corn stalks was less compared to fodder maize J-1006 and African tall, but little difference is observed in terms of crude protein and in-vitro dry matter digestibility. The woodiness is also comparable. It means the baby corn is as good as fodder maize.

Forage Quality of Maize

Forage quality can be defined as the extent to which forage has the potential to produce a desired animal response. Adequate animal nutrition is essential for high rates of gain, ample milk production, efficient reproduction, and adequate profits. Many factors influence forage quality.

Some of these include palatability (whether the animals eat the forage), Intake (how much the animal will eat), digestibility (the extent to which forage is absorbed as it passes through an animal's digestive tract), nutrient content, anti-quality factors (tannins, nitrates, alkaloids, cyanoglycosides, oxalates, estrogens, and mycotoxins) and lastly animal performance which is the ultimate test of forage quality. Desirable forage characteristics include high dry matter yield, high protein concentration, high energy concentration (high digestibility), high intake potential (low fiber content), and optimum dry matter concentration at harvest for acceptable forage fermentation (Carter et al., 1991). Maize is an ideal forage crop as it is quick growing, high yielding, palatable and nutritious. Among the cultivated non-legume fodder, maize is the most important crop which can be grown round the year under irrigated conditions. It is free from any anti-nutritional components and is considered as a valuable fodder crop. It contains high concentrations of protein and minerals and posses high digestibility. Two fodder maize varieties, namely J-1006 and African tall, are developed and released for commercial cultivation in India. The nutritional quality of maize as compared with other non-legume fodders is expressed in Table 4

Ensiling (Silage Making)

Forage conservation is a key element for profitable, sustainable, productive and efficient ruminant livestock farms. It permits a regular supply of quality feed when forage production is low or dormant. It also provides farmers with a means of preserving forage when production is faster than its adequate utilization. This prevents lush green crop from becoming too mature. Consequently, forage conservation provides a more uniform level of high quality forage for ruminant. Silage is the material produced by controlled fermentation of nutrients under an anaerobic condition. The fermentation process is governed by microorganism present in fresh herbage to maintain anaerobic conditions and discourage clostridial growth with minimum loss of nutrients.

Maize is an excellent crop for ensiling. It posses high energy value. For proper fermentation, the crop might possess sufficient quantities of moisture as well as soluble carbohydrates which are converted to lactic acid during the process of fermentation. Maize cultivated for green fodder and baby corn purpose possesses the required moisture and soluble sugars, therefore, is utmost suitable for ensiling. Maize silage is becoming more important in dairy rations. Maize is valued because of its high yield, ability to make excellent silage, and it can be harvested in a single operation without significant leaf loss. Cows fed corn silage produced more milk and consumed more silage dry matter in both trials than those fed the sorghum silage. (Lance et al. 1964). Corn silage is used extensively for lactating dairy cows that require high energy feed for maximum milk production (Marsalis et al. 2010, Irlbeck 1993).

Methodology of Silage Making

The quality of silage depends on the stage at which the fodder is harvested. Maize is best suited to be ensiled when the grains are in the milking stage. In the tropics this is usually found in 60-70 days after sowing. The dry matter content of whole plant should be around 25-30 per cent. Maize is ready for ensiling if the dry matter in the grain has reached a value between 56 and 60 %. Harvesting at this recommended time will ensure optimum compaction properties, reduced tendency to heating up and mould formation. Silage making is a simple process which can be carried out manually in the farm area by employing a few laborers. The first and foremost thing in silage making is the digging of a pit. A rectangular pit is to be dug up near the cattle shed whose size depends upon the number of animals along with the availability of fodder. If the fodder is sufficiently available then the time duration of feeding could be considered in deciding the size of the pit. Usually one cubic meter pit can accommodate roughly 5-6 quintals of green fodder. Crop should be chaffed to 5-7 cm length before ensiling. For good silage the chop length should be kept shorter. Chaffed silage is more palatable to livestock and has little chance of secondary fermentation. The next step is filling the pit with chaffed fodder. For this purpose fodder is spread upto a height of 1 foot in the pit followed by compression. This process is repeated till the pit is filled with fodder. The major precaution during this process is to exclude as much air as possible from the chaffed fodder by compressing it properly. This is executed by pressing the material through manual labor or mechanically by using a tractor. Care should be taken that material on the sides and edges are properly compressed. Raise the fodder heap above the ground level upto a height of around one meter. Finally add some more fodder in the central portion of the heap and then trample it. Packing is important to create anaerobic conditions. It should be thoroughly pressed so that no air pocket is left in the silo otherwise chances of mould formation will be there which will spoil the silage. After filling, silo should be covered with polythene sheet followed by a layer of soil, etc. Some cracks may develop in the covered soil over time. These are to be plugged immediately.

After 45 days of ensilage, the silage will be ready to use, therefore, can be removed for feeding to animals. Care should be taken in removing the silage from pit. It should not be opened from one side only. Cover should be kept firmly in place as long as possible and the minimum face should be exposed at one time. The sugars, proteins and lactic acid present in the silage are subject to attack by mould growth and oxidation as some air is allowed to fermentation and causes loss of feeding value and intake by the animals.

Silage quality

Silage quality is determined mainly by the physical state i.e. colour and odor. Good quality silage should be the light brown in colour and have the smell of vinegar. Poorly fermented silage will be dark in colour and foul smelling due the production of butyric acid. Chemically it should be having the following characteristics: (i) pH 4.5-5.0, (ii) ammonical nitrogen of total N – less than 10% of total N, (iii) butyric acid- less than 0.2%, (iv) lactic acid 3 to 12%, etc. The end products of silage fermentation are often monitored to assess silage quality and the composition of "normal silages" is presented in Table 5

Thus it could be concluded that maize is an excellent crop which could effectively be utilized as a animal fodder. Specialty corn is going to play an important role in the socio economic perspective of the rural folk as the dual purposes of agriculture as well as livestock are fulfilled by its cultivation. Maize silage could greatly help towards reducing the green fodder scarcity and provide a much desired boost to the dairy sector.

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Table 1: Major legume and non-legume forages of India

S. No.	English name	Botanical name
Legume fodders		
1.	Egyptian	*Trifolium alexandrinum*
2.	Persian Clover	*Trifolium respinatum*
3.	Indian Clover	*Melilotus spp*
4.	Lucerne/Alfalfa	*Medicago sativa*
5.	Cowpea	*Vigna unguiculata*
6.	Cluster bean	*Cyamopsis tetragonoloba*
Non-legume fodders		
1.	Maize	*Zea mays*
2.	Sorghum	*Sorghum bicolor*
3.	Pearl millet	*Pennisetum glaucum*
4.	Teosinte	*Zea maxicana*
5.	Guinea grass	*Panicum maximum*
6.	Oat	*Avena sativa*
7.	Ryegrass	*Lolium spp*

Table 2: Comparative nutritional quality of non-legume fodders

Fodder crop	Physiological stage	Harvesting stage (DAS)	CP (%)	IVDMD (%)
Maize	Silk to milk stage	55-65	11-8	68-52
Bajra	Boot stage	45-55	10-7	62-55
Sorghum	Initiation of flowering	70-80	8-7	60-57
Teosinte	Pre-flowering	80-85	9-7	62-58
Sudax	Subsequent cutting after 30 days	65-70	11-7	60-55
Napier bajra hybrid	One meter height and Subsequent cutting after 30 days	55-60	11-7	60-55
Guinea grass	One meter height and Subsequent cutting after 25-30 days	55-60	10-8	60-57

Source: Gupta et al. (2004).

Table 3: Green fodder yield, dry matter, crude protein and crude fiber content of baby corn genotypes

Genotype	Use	GFY (t/ha)	DM (%) I harvest	DM (%) II harvest	CP (%) I harvest	CP (%) II harvest	CF (%) I harvest	CF (%) II harvest
JH-3459	Baby corn	38.12	21.19	21.13	8.72	7.43	24.77	28.67
Parkash		30.14	20.55	20.91	7.00	6.70	26.80	28.77

PMH-2		40.14	21.22	22.47	8.46	8.31	26.33	23.13
J-1006	Fodder	46.67	24.28	24.69	7.44	5.83	26.13	23.87
African tall		30.99	22.24	22.61	7.14	5.54	30.20	28.67

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Table 4: Neutral detergent fiber, acid detergent fiber, total ash and *in-vitro* dry matter digestibility of baby corn genotypes

Genotype	Use	NDF (%) I harvest	NDF (%) II harvest	ADF (%) I harvest	ADF (%) II harvest	Ash (%) I harvest	Ash (%) II harvest	IVDMD (%) I harvest	IVDMD (%) II harvest
JH-3459	Baby corn	64.13	66.63	40.80	43.13	8.00	6.23	58.23	55.90
Parkash		64.97	64.67	42.87	44.73	7.33	6.70	63.73	61.80
PMH-2		65.93	64.67	46.77	45.83	6.60	6.10	64.33	58.60
J-1006	Fodder	69.87	72.80	40.37	45.47	7.27	7.43	58.07	52.86
African tall		67.57	66.10	38.27	38.73	5.97	6.60	65.00	57.63

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Table 5: Common end products of silage fermentation

Item	Positive or Negative	Action(s)
pH	+	Low pH inhibits bacterial activity
Lactic acid	+	Inhibits bacterial activity by lowering pH.
Acetic acid	- +	Associated with undesirable fermentations. Inhibits yeasts responsible for aerobic spoilage.
Butyric acid	-	Associated with protein degradation, toxin formation, and large losses of DM and energy.
Ethanol	-	Indicator of undesirable yeast fermentation and high DM losses.
Ammonia	-	High levels indicate excessive protein breakdown
Acid detergent insoluble nitrogen (ADIN)	-	High levels indicate heat-damaged protein and low energy content.

Fig. 1: Filling of pit

Fig 2: Huge stock of silage

Fig. 3: Silage of baby corn

Scope of Specialty Corn Cultivation for Enhancing Farm Profitability in *peri*-urban Agriculture

Chikkappa G. Karjagi
ICAR-IIMR, Pusa campus, New Delhi

Maize (*Zea mays* L.), is a crop with diverse uses. However, if it is grown for 'other than grain' purposes, then it can be considered as specialtype ofmaize depending on its special trait like sweet, popping, waxy, high-oil, high-lysine and -tryptophan etc. and also stage of harvesting like green ear, baby corn etc.The special traits are governed by recessive genes (express their phenotype in recessive homozygous condition) while popping and high oil are altered due to *xenia* (alteration in trait expression during seed development due to fertilization with foreign pollen) effect. Further in baby corn care should be taken to avoid pollination and ensure unfertilized tender ears. Therefore, all the specialty corn should be grown in isolation to avoid pollen contamination from other type of maize. The cluster approach would be most appropriate to promote specialty corn cultivation in India considering the small land-holdings.Until recently, India largely dependent on imported sweet corn, baby corn and popcorn to meet the domestic demand mainly of urban areas. Since the demand for specialty corn mainly sweet corn, baby corn and popcorn is increasing continuously even in small towns and cities of India there is scope for Indian farmers to expand the area under specialty corn cultivation. However, the success of specialty corn cultivation largely depends on access to suitable market due to highly perishable nature of specialty corn. In this regard, a long-term contract agreement/tie-up between farmers and purchasers is very crucial for ensuring assured return/profitability to the farmers, maintaining the price stability and continuous supply. The Indian farmers, especially from *peri*-urban areas can increase their farm profitability by growing these specialty corns. The ideal times for specialty corn cultivation in different parts of India are as follows.

Particulars	**Sowing time**
Time of sowing (Kharif) North India	Last week of June to 20th July
Time of sowing (Rabi/winter) North India	Last week of October to 15th November
Time of sowing (Spring) North India	1st week of February to 15th February
Time sowing – South India	All round the year under assured irrigated conditions

Specialty corn and its production technology

Sweet corn production

Sweet corn (Fig. 1) cultivation requires mild climate which helps in increasing the sugar content in the ear. It is the delicious and rich source of energy, vitamin C and A. It is eaten as raw, boiled or steamed green ears/grain. It is also used in preparation of soup, salad and other recipes.

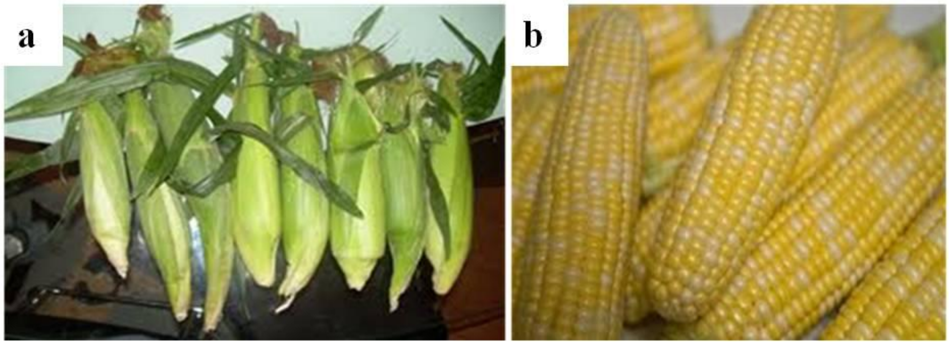

Figure 1. The sweet corn with husk (a) and without husk (b)

The commercial cultivation of sweet corn does not differ much with the field corn cultivation except in plant population and harvesting. As mentioned above, sweetness in sweet corn is determined by recessive genes thus maintaining isolation for commercial cultivation of sweet corn is very much necessary. Generally a distance of around 400 mts must be maintained or sowing dates of other maize types should be adjusted one month apart. Further, care should be taken to avoid either high temperature or heavy rains during flowering time to ensure proper pollination.Selecting suitable sweet corn hybrids which are released for the region depending on probable marketable area is most critical for successful cultivation of sweet corn.

<u>Soil Type: </u>Sweet corn can be grown on a wide range of soils with the intervention of suitable cultural practices in different soil types. However, highly fertile, deep, well drained soil with pH ranging from 6.0 to 7.0 is desirable.

<u>Plant Geometry:</u>The spacing and plant population varies depending on the cultivar, soil type, fertility status, and irrigation facility. The recommended plant population for optimum yield is 45000-60000 plants per hectare with spacing of 75 cm × 20-30 cm between rows and plants, respectively.

<u>Seed Rate:</u> Depending on the type of sweet corn the seed rate differs. The seed rate for *su*, *se* type of sweet corn, it is 7 to 9 kg/ha, whereas for *sh2* type of sweet corn it is around 5 to 6 kg/ha.

<u>Season:</u> The growing period should be sunny and mild with an average temperature ranging between 25ºC to 35 ºC. Maintaining good moisture level by keeping the soil moist during growth period is crucial to guarantee good grain filling.

Harvesting of sweet corn

Sweet corn is harvested at premature stage. Harvesting sweet corn at right stage is very crucial for getting good market price; even harvesting one to three days early or late will drastically reduce the quality which in-turn affects largely the market price. In general sweet corn will be ready for harvest about 17 to 24 days after pollination when it reaches milk stage. However, local temperature during that time also determine the harvesting time.

Sweet corn with *sh2* gene should not be grown where temperature goes below 16°C. The optimal harvest date is determined by the variety’s response to the environment and may differ from the reported maturity. Therefore, it is important to monitor crop development regularly, especially after tassels and silks emerge. The highest levels sugars in sweet corn kernels is observed at approximately twenty one days after silks emerge but, again it may be influenced by the local environment. Sweet corn should be harvested at milk stage which vary from 17 to 24 days after silk emergence; it attains milky stage more quickly in hot weather, more slowly in cool weather. To identify the right stage it is better to use thumbnail to puncture a kernel in regularly after about 15-16 days from the date of silk emergence to find the ideal stage for hervesting.If the liquid is clear, the corn is immature; if it is milky, it is ready; and if there is no sap, it is too late. Harvesting in early morning or late evening is generally recommended as during cool temperature loss of sugar by conversion will be slow.

Post-harvest handling of green ears

The eating quality of corn declines rapidly after harvest, so it is important to cool or hydro-cool sweet corn as soon as possible. The loss of sugar is more rapid at higher temperatures. At 32ºC, the rate of sugar loss is 20 times higher than that at 0ºC. Sweet corn must be moved quickly from the field to picking sheds, where it should be rapidly sorted, packed and cooled.

<u>Hydro-cooling:</u> It is most popular method of cooling, which involves immersing the corn in cold water.

<u>Packaging:</u> In this method 7-10 kg of crushed ice is distributed throughout the container during the packaging process. This is an excellent method for local direct shipment.

<u>Cold storage:</u> To maintain the best quality, sweet corn is placed in cold storage immediately after pre-cooling. Temperature is maintained as close as 0ºC at 95% or higher relative humidity without freezing the corn to keep the corn fresh.

<u>Cooling in transit:</u> It is very much necessary to maintain the freshness of the sweet corn and the best method is blowing fine ice into the corn crates.

Yields

If water requirements are met and other cultural practices optimized, sweet corn yields 66000 ears per ha.

Baby corn production

The term 'baby corn' refers to a young finger like unfertilized immature ears of maize /corn preferably harvested within 1-2 days of silk emergence with emerged silk of 1-3 cms depending upon the growing season (Fig. 2). Baby corn can be eaten raw as salad immediately after harvest. Generally baby corn is being harvested with green husk which prevents loss of water/desiccation, discoloration and damage of immature maize ears after harvest. However, the moment baby corn reaches the processing plant then the green husk will be removed and packed for marketing.

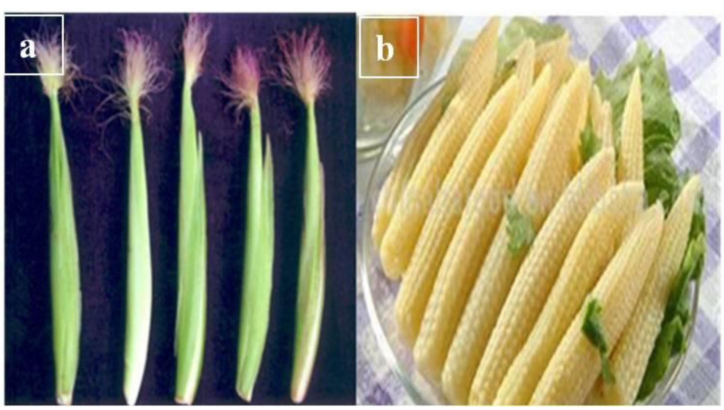

Figure 2. The baby corn with husk (a) and without husk (b)

The young baby corn looks very tender and is nutritious as well; its nutritional quality is at *par* or even superior to some of the seasonal vegetables. It is a good source of fibrous protein and easy to digest. Besides proteins, vitamins and iron, it is one of the good sources of phosphorus. The most desirable features of baby corn preferred by consumers/exporters are of 6 to 11 cm length and 1.0 to 1.5 cm diameter with regular row/ovule arrangement and the most preferred colour is generally creamish to very light yellow.

Baby corn production considerations

In general the baby corn cultivation is also similar to that of traditional maize cultivation, but it differs with respect to plant population, harvesting time and varietal preference. In addition baby corn cultivation needs detasseling to avoid pollination to maintain the good quality of baby corn as well as higher yield of baby corn per unit area. Although few varieties specially bred for baby corn production are available, baby corn can also be harvested from any common corn varieties *i.e.*, from field corn or sweet corn.

<u>Plant population and geometry:</u> The seed rate and hence plant population recommended for baby corn cultivation is relatively higher than the field corn to achieve relatively small and thin baby corn production due to interplant competition. Generally 25 kg/ha hybrid seed is recommended, which may vary depending upon the test weight of the cultivar. A spacing of 60 × 20 cm (83,333 plants/ha) or 60 × 15 cm (1, 11,111 plants/ha) depending upon the type of soil and cultivar has been recommended. For high yielding cultivar on black soil condition one can go for 60 × 15 cm spacing whereas under red soils it is better to go for 60 × 20 cm. The method of sowing is similar to field corn *i.e.* ridge and furrow method.Since baby corn can be cultivated round the year, a farmer can grow three to four crops of baby corn in a year which also helps to get green fodder round the year.

<u>Detasseling:</u> It is an operation of removal of tassel from the main plant before actual anthesis/pollen shedding. The timely detasseling operation will help to produce good quality baby corn. It is advised to move in every row for effective detasseling. The tassel should not be thrown out in the field; instead it has to be used as fodder for livestock for enhancing the profitability of baby corn production. Tassel is highly nutritious, feeding tassel to livestock reported to enhanced the milk production.

<u>Harvesting and post harvest management:</u> The harvesting should preferably be done either in morning or at evening when the baby corn moisture is highest and ambient temperature is low to avoid rapid moisture loss from husk and maintain the freshness of baby corn. To determine the appropriate time of harvest for a given variety in a particular area, harvest a few ears each day as soon as the ears appear on the stalk and also harvest individual ears by hand. Harvest baby corn every alternative or every 3^{rd} days depending upon the conditions. At this early stage of ear development, the ear can grow very quickly, becoming too large in just 4-5 days. Some field corn varieties may need to be harvested before the silks emerge. At least 9-12 pickings of baby corn over a period of 3-4 weeks are required.Each picking requires the same amount of time and labour that would be required to harvest hand-picked sweet corn. The close row spacing results in more high-quality primary ears per acre. Most varieties will produce 2-3 ears per plant; however, quality of the third ear may not be adequate. Immediately after harvest it should be transported to the processing unit at the earliest to facilitate subsequent up stream processing activities like de-husking, grading and packing etc. The effort should be made to peel the baby corn on the same day and stored in a cool and dry place to maintain its quality for long period. It should be carried out under shade and profuse ventilation/air circulation. De-husked baby corn should be put in containers like plastic baskets and should not be heaped.

Marketing and economics of baby corn production

For the purpose of assured marketing of baby corn, prior tie-up with the purchaser is desirable. Direct-marketing link up with restaurants and hotels may be good proposition to begin selling baby corn.Consider the market demand of baby corn with respect to quantity and quality before growing baby corn as market crop. Prior price analysis over a period of time is essential before entering into baby corn production venture and making it profitable venture. Baby corn cultivation in urban and *peri*-urban areas has edge over others because they can supply fresh, tasty product for consumers. Generally baby corns are sold with husk to maintain moisture and ear quality and they were sold either by number of ears or by weight. The economics of baby corn cultivation depends on various factors especially the yield of bay corn and cost of production. The yield of baby corn depends on the type of cultivar, production conditions and management efficiency. Further, the profitability of baby corn cultivation depends on market price, which in turn depends on supply and demand. However, a conservative estimation can be made based on the present price index, average yield of baby corn and the cost of production. On an average under well managed conditions, the baby corn hybrid yields around 15-20 quintals of de-husked baby corn and about 400 quintals of green fodder per hectares. Under normal conditions the average cost of baby corn production ranges from ` 45,000 to 50,000 per hectares The market price of baby corn ranges between ` 50-150 per kg whereas the green fodder price ranges from ` 50-60 per quintal. The calculated gross returns ranges between ` 95,000 – 1, 25,000 giving the net returns ranging between ` 50,000 - 75,000 per hectares during the span of 75-90 days.

Value addition and processing of baby corn

In general baby corn is perishable with relatively short shelf-life. However, it can be processed to improve its keeping quality. The major processing methods which can be used to improve the shelf-life are: canning, dehydration and freezing. The processing methods have evolved due to increased demand for baby corn from distant countries.

Augmenting farm income while baby corn cultivation through intercropping

Baby corn is very remunerative, if it is cultivated with intercrop. As many as 20 crops, *viz*., potato (Fig. 3a), green pea (Fig. 3b), cauliflower (Fig. 3c), cabbage (Fig. 3d),sugar beet (Fig. 3e), rajmash for green pods, palak, green onion, garlic, methi, coriander, knol-khol, broccoli, lettuce, turnip, radish, carrot, french bean, celery, gladiolus (Fig. 3f), etc. have been successfully intercropped in the winter season. Since, the season is long, farmers can utilize the lean period and get additional income through intercropping in baby corn.

Figure 3. Baby corn intercropping with (a) potato, (b) green pea, (c) cauliflower, (d) cabbage, (e) sugar beet, (f) gladiolus

There is no adverse affect of intercrops on baby corn and vice-versa, rather, some of the intercrops help in improving soil fertility and protect the baby corn crop from cold injury. Intercrops protect the baby corn from northern cold wind because baby corn is planted on southern side and intercrops in northern side of the ridge. In general, short duration varieties of crops are preferred for intercropping with baby corn. In *kharif* season, cowpea for green pods and fodder purposes, urd, mung, etc., can be intercropped with baby corn. Numbers of intercropping options are availbale for the farmers but for commercial purpose, pea and potato can be taken on large scale during winter season.

Popcorn production

Popcorn is a special type of flint corn/kernel with small hard endosperm and low-test weigh and has the highest popping ability when heated. It belongs to same plant species (*Zea mays ssp. mays*) as that of field corn (traditional maize). The kernels of popcorn are oval/round in shape. In general both field corn and popcorn pop but the ratio of expanded (after popping) to original volumes between popcorn and field corn differs significantly (5 to 15 times). It was found that the hard pericarp (hull) of popcorn and soft starch inside are important for popping. The pericarp (hull) of popcorn and starch packaging are important for popping. Popcorns are harvested for their grain and sold for human consumption, it can be sold un-popped for microwave or conventional use; or can be sold packed as a plain or flavour-added popped product. Popcorn is consumed fresh, as it has to be protected against moisture absorption from the air. It is liked by many because of its light, porous and crunchy texture. The popcorn flour can also be used for preparing many traditional dishes.

Economic Considerations for popcorn cultivation

Since popcorn is low yielder therefore its economics will be depends on the quality of popcorn and contract farming price. In India, the popcorn is not grown in large scale and, even today India is importing popcorn mainly from USA and Argentina. The economic consideration of popcorn differs slightly with traditional maize mainly because the cost of popcorn hybrid seed is quite higher than the traditional maize but the yield of popcorn hybrid is almost less than a half of an average field corn hybrid yield. Further, popcorn and field corn hybrids differ slightly with respect robustness of root system, initial vigour.

Commercial cultivation of popcorn

The commercial cultivation of popcorn will succeed if it is grown under contract farming. In general, there are two types of popping varieties reported *viz*., butterfly and mushroom. The better quality of pop corn variety is the one, which has maximum volume and minimum percentage of un-popped kernel. Even the growers are willing to become small-scale processors then they can also do packaging and sell popcorn in local market at small cities and towns as well. Its cultivation methodology is similar to that of traditional maize.The physical isolation of minimum 400 metre or a time isolation of minimum 20 days differences between the flowering periods of popcorn or any other field of maize other than the popcorn are ideal/necessary to produce quality popcorn.

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Quality Protein Maize (QPM): Importance and production requirements

Ramesh Kumar, DP Chaudhary, AK Das and Sujay Rakshit
ICAR-Indian Institute of Maize Research, Ludhiana

Introduction

The present scenario of increasing population puts pressure on agriculture not only to increase production and productivity but also the grain quality. It is imperative that increasing production of food crops to ensure food and nutritional security of the nation has become a necessity rather a matter of choice. However, the challenge to meet the growing demand for food seems to be a daunting task due to rapid reduction in agricultural land, reduced availability of water resources and climate change. Moreover, ensuring the nutritional security or improving the nutritional status of the poorer section on sustainable manner is an added challenge. The present food production scenario indicates that much of the future food production is expected to come from coarse cereals, particularly maize because of its highest yield potential as compared to any other food crop. Maize has already credited as queen of cereal and further due to its high content of carbohydrates, fats, proteins and some of the important vitamins and minerals, it has also acquired a well deserved reputation as 'poor man's nutri-cereal'(Kumar et al .,2012). In recent years the diversified uses of maize as food, feed and as an industrial raw material is also increasing. The food processing industries are coming up with new value added products of corn like flakes, chips, biscuits, *sooji* etc. Increased demand from consumers has led to higher per capita consumption and demand for maize. Improved growth in Indian economy has increased per capita income thereby improving the purchasing power of its people. The consequence of all these events has led to change in the food habits with an increased non-vegetarian population of the country. The increased non-vegetarian populations had its own cascaded of events on food/feed and meat industries. The increased demand of meat has increased the demand of maize from poultry and piggery feed industries. In this particular context, quality protein maize (QPM) can play a crucial and very important special role in ensuring the food and nutritional security of the country.

Nutritive Value of Quality Protein Maize

The maize grain on an average contains around 15 % moisture, 8-12 % protein, 2-4 % fat, 3 % fibre, 67-72 % starch and around 1.5% minerals. Hence it is a good source of carbohydrates, fats, proteins and some of the important vitamins and minerals and, therefore, termed as nutricereal. Majority of the population depend on cereals for their livelihood and maize is the staple cereal food for several million people, especially in the developing countries across Sub-saharan Africa who derive their >30% of the total dietary protein and >20% of the daily calories requirements from maize as it supplies many macro and micronutrients necessary for human metabolic needs.The kernel protein is made up of five different fractions, *viz*., albumin 7 %, globulin 5 %, non-protein nitrogen 6 %, prolamine 52 % and glutelin 25% and the left-over 5 % is residual nitrogen. The quality of maize protein is poor due to the presence of large concentration of an alcohol soluble protein fraction, prolamine also known as zein in the endosperm. Zein is very low in lysine and tryptophan content and since this fraction contributes more than 50 percent of the total protein, the maize protein is, therefore, deficient in lysine and tryptophan content. On the other hand, zein fraction contains very high amount of leucine and imbalanced proportion of isoleucine. The ill- proportion of four essential amino acids in normal maize kernels results in poor protein quality of traditional maize kernels affecting its biological value i.e. the availability of protein to the body. Thus the composition of maize protein has an in-built drawback of being deficient in two essential amino acids, *viz*., lysine and tryptophan.

However, high-quality protein sources, such as eggs, meat, dairy products, and legumes, provide total or complementary sources of these amino acids, but many rural poor have limited access to these foods. Therefore populations depending on maize as their staple food generally show the protein deficiency disorders like *Marasmus* and *Kwashiorkar*. In addition maize lacks vitamin B and also due to high concentrations of phytate some minerals in the maize grain have low bioavailability.

Therefore, a need was felt to improve the biological value of protein in maize varieties. In early 1960s the breeders at Purdue University obtained the natural mutants of maize which have soft and opaque grains. The biochemical and genetic analysis of mutant kernels revealed that they contain higher concentration of lysine and this nutritionally superior maize was named *opaque-2* maize, after discovering that "*opaque-2*" single gene mutation is responsible for the improved protein quality (Mertz et al 1964).

It was mentioned that the original mutants obtained were soft and opaque, but they have some draw- backs like higher susceptibility to storage and ear rot. Therefore to overcome this problem International Center for Maize and Wheat Improvement (CIMMYT) introduced endosperm modifier genes through continued recurrent selection breeding programme led by Dr. S. K. Vasal and team. As a result hard endosperm o_2 stocks were developed and were designated as quality protein maize (QPM) to distinguish it from soft o_2 strains. Quality protein maize (QPM) was created by selecting genetic modifiers that convert the starchy endosperm of an opaque2 (o_2) mutant to a hard, vitreous phenotype. However, not all of the hard endosperm o_2 lines retained high levels of the critical amino acids. Later the genetic studies on QPM have shown that there are multiple, unlinked o_2 modifiers (OPM), but their identity and mode of action are unknown. In QPM the concentration of zein is lowered by 30 percent, as a result the lysine and tryptophan content increases in comparison to maize. The lower contents of leucine in QPM further balance the ratios of leucine to isoleucine (Table1). The balanced proportion of all these essential amino acid in QPM enhances the biological value of protein (Table-2). The true protein digestibility of maize *vis-à-vis* QPM is almost same, but the biological value of QPM is just double as compared to maize varieties (Fig1), rather it is highest among all cereals and pulses (Fig1). The reason behind it is that all cereals except QPM are deficient in lysine, an essential amino acid and all pulses are deficient in another essential amino acid methionine.

Maize breeders have developed several QPM hybrids by incorporating *opaque*-2 mutant gene + modifiers in different parental lines. QPM looks and taste like normal maize, but it contains nearly twice the quality of lysine and tryptophan along with balanced amino acid profile.

QPM as Food and Nutritional Security

In India, tribal population constitutes approximately 10% of the total population and is found in most parts of the country especially in the states of Madhya Pradesh, Assam, Nagaland, Gujarat, Chhattisgarh, Jharkhand, etc. Thus a sizable tribal population exist which is economically deprived. Further, most of tribal population depends on maize as their basic diet. In these areas the scope for QPM to ensuring food and nutritional security is paramount. Substituting maize with QPM is a viable option for ensuring their nutritional requirements. Tribal peoples are acknowledged to have very close association with ecosystem and environment because of their dependence on nature directly for daily requirements. However, the problem of malnutrition arises due to inadequate intake of nutrients in the diet. The situations are almost same in some African countries. Several studies are conducted on human beings and animal and are continue to be conducted on positive health benefits of QPM consumption in their daily diet.

Gunaratna et al 2010 reported that consumption of QPM instead of maize leads to an increase in growth rate of height and weight by 12 and 9%, respectively in infants and young children coming from population with mild to moderate under nutrition where maize is the significant component of the diet. This happened due to the higher biological value of QPM as compared to the maize (Table 2). The results are encouraging and based on these results the Indian policy makers can think of providing QPM in the tribal belt or in the areas where there is a problem of malnutrition . Government of India can also think of introducing QPM in public distribution system and QPM based food in mid day meal in schools and Aanganwadis. Government of India has already started Tribal-Sub Plan (TSP) and under this programme the Directorate of Maize Research has provided QPM hybrid seeds for cultivation in the areas where tribal population is more. Some on-farm trainings have also being organized in these areas for creating awareness to use QPM as staple food.

QPM and Animal feed

Maize is an integral part of the animal feed used in India and outside. There are several studies where maize has been replaced by QPM as an ingredient of animal feed and encouraging results have been observed in case of broilers, chickens and pigs. Feed trials have repeatedly shown that pigs fed with QPM grow twice as fast as those fed with commercial maize (Krivanek et al., 2007). Some nutritional studies with pigs and chicken diets have shown that performance is improved when QPM is substituted for maize without any additional protein supplement. In broiler diet, the substitution of QPM for maize at a rate of 60% substantially reduces the need for soyabean meal and therefore the cost (Subsuban *et al*., 1990). Similarly, in an experiment with finisher pigs, less soybean meal was needed to maximize performance in diets based on QPM compared with diets diets having maize. Beef steers fed on high – lysine maize gained faster weight compared to those fed on normal maize.

Thus, QPM can reduce the cost of animal feed by decreasing the expenditure incurred on more expensive high protein sources. Linear programming models allow feed companies to indentify the cheapest way of providing the minimum dietary requirements for farm stock. Calculations for pig and poultry ration containing maize, QPM, sorghum, soybeans meal and synthetic lysine and tryptophan showed that the usage of QPM instead of maize resulted in saving of 2.8% on chickens feed and 3.4 % on pig feed (Lopez-Pereira, 1992). It is also evident that if QPM was to replace maize in broiler feed in Kenya, the 5% cost reduction would translate into a gain of US dollars 300,000 either as reduced costs for farmers or profit for feed manufactures. In India also it can happen if we use QPM as an ingredient in animal feed. It will help in reducing the cost of feed as well as in increase the growth of the animal either it is broiler, chicken, pig or cattle. The broilers and chickens fed with QPM matured in less time as compared to non QPM fed ones and the farmer benefitted by selling more number of animals in a short span of time. Additionally, QPM fed pigs experience rapid weight gain and are ready for market sooner or can provide an additional quality protein source for small farm families.

Impact of QPM

Babies and adults consuming QPM are healthier and at lower risk for malnutrition disorders such as *marasmus* and *kwashiorkor*. Data from Latin America and Africa showed the role of QPM in reversing the effects of malnutrition in those who are already affected. QPM offers 90% the nutritional value of skim milk, the standard for adequate nutrition value. At a time when UNICEF reports that 1,000,000 infants and small children are starving each month, the inclusion of QPM in daily rations improves health and saves lives. Additionally, QPM fed pigs experience rapid weight gain and are ready for market sooner or can provide an additional quality protein source for small farm families.

The commercial success of QPM can be achieved as several QPM hybrids have been developed and tested across varying climatic and growing conditions. At present QPM varieties are grown on roughly 9 million acres (36,000 km^2) worldwide. Meanwhile, QPM research and development have spread from Mexico to Latin America, Africa, Europe, and Asia. In Guizhou, the poorest province in China, where QPM hybrid yields are 10% higher than those of other hybrids, and the crop has enabled new pig production enterprises, bringing increased food security and disposable income. In total, the QPM germplasm is being grown worldwide and it is contributing over $1 billion annually to the economies of developing countries.

Production requirements

Isolation distance

The foremost requirement for QPM cultivation is isolation distance of minimum 400 meters. There should not be any other maize crop(non-QPM) in surrounding of 400 meters. The *opaque-2* gene is expressed when it present in homozygous conditions, if any other maize crop is there in surrounding area and pollen of other maize will fall on QPM silk and it will create heterozygous conditions resulting opaque 2 gene will not express that is why it is strongly recommended that we will have to grow QPM crop in isolation or we can grow this in a specified area where only QPM is grown.

Soil and climate

QPM can be grown successfully in a wide range of soil from loamy sand to clay. But it performs well in high organic matter content soil with high water holding capacity and neutral in pH. Soil should have high drainage capacity as maize is more susceptible to water logging condition. QPM can be successfully grown in varied climatic conditions though out the country in an altitude from mean sea level to 3000 m height.

Selection of cultivar

A no. of QPM hybrids have been released in India for cultivation namely, HQPM1, HQPM 4, HQPM 5, HQPM 7, Shaktiman 1, Shaktiman 2, Shaktiman 3, Shaktiman 4, Shaktiman 5, Pusa HM 8, Pusa HM 9, Vivek QPM 9 and Pusa Vivek QPM 9 improved. The farmers can select anyone among these hybrids in consultation with local maize breeder/agriculture expert.

Sowing time

QPM can be grown in all the seasons *viz.* kharif, rabi and spring.

Seed rate

Seed rate varied according to seed size, season, sowing method. But on an average 20 kg/ha is optimum for higher yield.

Seed treatment

To protect the seed from seed and soil borne diseases and pest seed should be treated before sowing with fungicide Bavistin + Captan in 1:1 ratio @ 2 g/kg seed.

Method of sowing

Line sowing in furrows at 60-70 x 20-25 cm (row x plant) spacing to obtain the optimum plant population of 70000 to 80000 per ha with sowing depth of 4-5 cm is the best method.

Nutrient management

The requirement of nutrient and fertilizers are as follows :

Nutrient	Dose	Form	Requirement (Kg/ha)
N	150-180	Urea	3255-3906
P2O5	70-80	SSP	438-500
K2O	70-80	MOP	116-133

Besides that ZnSO4 @ 25 kg/ha and FYM @ 10 t/ha is required for high productivity of QPM. FYM should be applied at 10-15 days before sowing. The whole amount of SSP, MOP, ZnSO4 and 10% of urea should apply as basal in furrows. The remaining urea should be applied in three split applications. 20% urea at 4 leaf stage, 40% at 8 leaf stage and remaining 30% at flowering stage. Fertilizers should be applied from both sides of rows. Three days before application of fertilizers light hoeing is needed for optimum use of nutrients by crops.

Water management

If irrigation facility is available then irrigation should be done in furrows upto 2/3rd height of the ridge at knee high stage, flowering and grain filling stage. **Weed management:** Weed is a serious problem of maize in Tirap district of Arunachal Pradesh which may causes yield loss upto 35%.Therefore, timely weed management is essential for good yield. Pre-emergence herbicide atrazine @ 1.0-1.5 kg *a.i.*/ha in 600 litre water is very effective for control of weed. Tembotrione @ 262 ml in 375 litre water is recommended for post-emergence application and it should be applied when the crop is 25-30 days old.

Earthing up

Earthing up is a very essential operation in QPM cultivation. Earthing up should be done when the crop is 35-40 days old.

INSECT PEST MANAGEMENT:

Maize stem borer (*Chilo partellus*)

The pest lays eggs on the lower suface of central whorl leaf h and the larvae enter the plant from the central whorl and eventually results in dead heat formation Foliar application of Chlorantraniliprole 18.5 SC @ 0.3 ml / litre water in 200 litre water per ha is quite effective The spray should be done at the appearance of symtoms on 2-3 weeks old crop. It can also control by release of 8 trico cards (*Trichogramma chilonis*) per ha at 10 & 17days after germination.

Pink stem borer (*Sesamia inferens*)

This insect is more serious in peninsular India during rabi season. Foliar application of Chlorantraniliprole 18.5 SC @ 0.3 ml / litre water in 200 litre water per ha is quite effective. The spray should be done at the appearance of symtoms on 2-3 weeks old crop.

Shoot fly (*Atherigona* spp.)

It is more serious during spring season in northern India. It lays eggs on emerging seedlings and maggets cuts the growing point resulting in dead heart formation. Seed treatment gaucho 600FS @ 6.0 ml/ kg seed is most effective.

Fall Armyworm (*Spodoptera frugiperda*)

It is new exotic pest in maize ecosystem. It feeds heavily on central whorl leaves and it is more serious on crop upto six weeks old. It lays eggs in clusters on upper and lower surface of the leaves. Young larvae cause papery windows on leaves while grown larvae feeds by making bigger irregular wholes , cut the leaf margins and may damage the central whorl leaves also. The infected plants are filled with its excreta. The seed treatment with Cyantraniliprole 19.8% +

Thiamethoxam 19.8% FS @ 6 ml/kg of seed offers protection for 15-20 days of crop growth against Fall Armyworm is quite effective up to 3 leaves/ 20 days old crop.
Release of egg parasitoids *viz.,Telenomus remus* (4000/ ac*)* or *Trichogramma pretiosum @* 50,000/acre at 7 and 14 days following first spray using neem formulation with the trap catch of one moth/day observed continuously. [Note: Parasitoid release may be alternated with neem spray at weekly intervals, but not to be applied simultaneously.

For management of early instar larvae with a damage level of 5-10%, whorl application of *Bacillus thuringiensis* v. *kurstaki formulations* 2% (400g/acre) applied @ 2g/l or *Metarhizium anisopliae* or *Beauveria bassiana* (1kg/acre) applied @ 5 g/liter is recommended.
If infestation is more than 10%, spray with anyone of the recommended insecticides with label claim , *viz.,*Chlorantraniliprole 18.5 SC (80 ml/acre) applied @ 0.4 ml/l or Thiamethoxam 12.6 % + Lambda cyhalothrin 9.5% ZC (50ml/acre) applied @ 0.25 ml/l or Spinetoram 11.7 % SC (100ml/acre)applied @ 0.5 ml/l is recommended

DISEASE MANAGEMENT

Turcicum leaf blight: Spray Zineb/ Meneb @ 2.5-4.0 g/l water 2-4times at 8-10 days intervals as a control measure.
Maydis leaf blight: It can be control by 2-4 times spraying of Diathane Z-75 or Zineb @ 2.4-4.0 g/l water at 8-10 days intervals after first appearance of the symptoms of disease.
Banded leaf and sheath blight: Seed treatment of peat based formulation (*Pseudomonas fluorescence*) @ 16 g/kg of seed or soil application @ 7 g/l water as soil drenching or foliar spray of Sheethmar (Validamycin) @ 2.7 ml/l water is effective against this disease.

Bird management

In some places mature cobs are damaged by birds. In such situations matured cob can be protected from bird damage by tying cobs with leaf of the same plant.

Harvesting

Harvesting should be done at optimum moisture content (20%) in grain to avoid post harvest loses due to store grain pest and diseases. Harvesting immediately after shower should be avoided. The harvested cobs should be sun dried before shelling and should be shelled at 13-14% grain moisture. During storage the moisture content of grain should be 8-10 %.

Table 1. Essential amino acid content of maize

Amino acid	**Normal (mg per g N)**	**QPM (mg per g N)**
Lysine	177	256
Isolcucine	206	193
Leucino	827	507
Sulphur amino acid	188	188
Aromatic amino acid	505	502
Theomine	213	199
Tryptophan	35	78
Valine	292	298

Table 2. Protein quality of maize

Quality measures	Normal	QPM
True protein digestibility	80	92
Biological value (%)	40-47	80
Amount needed for equilibrium	547	230

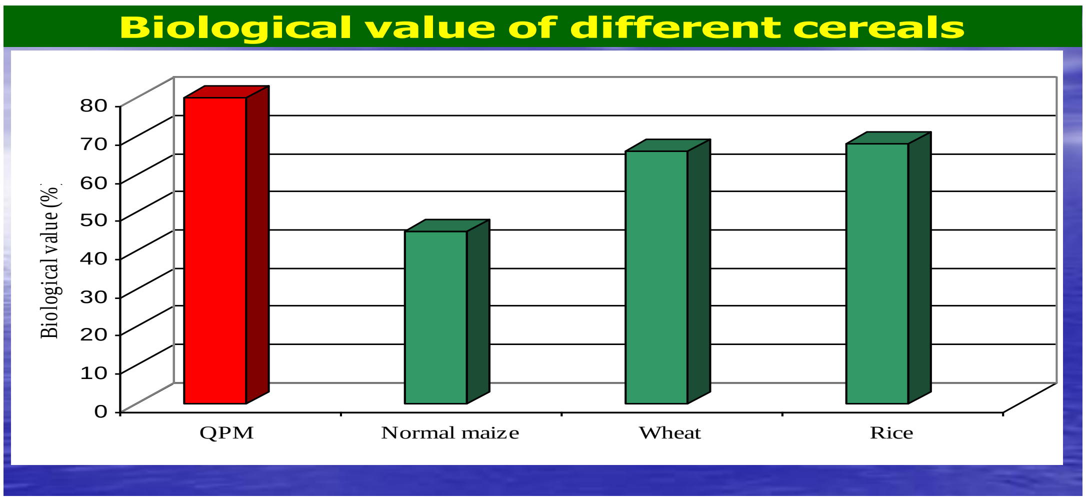

Fig.1: Biological value of Quality Protein Maize vis a vis' other cereals

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Conservation strategies and management of Maize germplasm

N. Sivaraj, S.R. Pandravada, Kamala Venkateswaran and B. Sarath Babu
ICAR-National Bureau of Plant Genetic Resources, Regional Station, Hyderabad 500 030

Introduction

Crop diversity is part of the biological diversity and includes the resources that contribute to people's livelihoods by providing food, feed, medicine, fiber, clothing, shelter and energy. Hence, it contributes towards achieving the global objectives of food security, poverty alleviation, environment protection, and sustainable development. Genetic variation must be conserved and effectively utilized to combat new pests and diseases, and to produce better adapted varieties for the changing environments. The genetic diversity is accumulated in the form of landrace, advanced cultivars, wild relatives of domesticated plants and wild species used by humankind. Conservation and utilization of these resources are important components of *ex situ* collections. The conserved germplasm accessions need to be characterized for important morpho-agronomic characters and these traits specific germplasm is to be distributed to bona fide researchers for utilization in crop improvement programs all over the world. Exiguous use of germplasm has been observed in breeding programs, mainly due to lack of information on economic traits.

The genetic diversity is a prerequisite for any crop improvement programme and form the basis for meaningful and effective conservation for their specific traits. Therefore, the selection of lines with rich potential valuable traits and significant morphological differences would help in quickly identifying the cultivars from diversity rich areas for effective conservation and also for future utilization. Genetic improvement and domestication of natural genetic resources variability that will help in selection and distribution of Germplasm/ selected superior clones to all stakeholders (co-operators) to promote cultivation and sustainable use. Availability of information on conservation strategies and the management of conserved germplasm would promote storage of seed material, cross fence and long-distance exchange of seed material among various stakeholders (co-operators) including farmers and evaluation for identification of superior types and sources of desired traits.

Germplasm Conservation

Conservation of plant diversity is of utmost importance in ensuring protection of healthy environment over the globe and also for meeting basic human needs of food, nutrition, health care, clothing and fuel. Although around 2,50,000 plant species have been described so far and a much larger number still remains to be duly recognized, yet only 3000 species are grown for their human use since the beginning of agriculture, considered to be nearly ten thousand years ago. Germplasm conservation is defined as the management of human use of the biosphere so that it may yield the sustainable benefit to present generations, while maintaining its potential to meet the needs and aspirations of future generations.

Conservation Strategies

The Convention on Biological Diversity (CBD) within its broader framework defines two conservation strategies *in situ* conservation and ex *situ* conservation. Both methods are highly complementary measures, which can be judiciously integrated so that the conservation efforts are effectively realized for sustainable release of useful variability. The genepool concept should be taken into consideration while planning the conservation of plant genetic resources. Following this approach, it is very likely that a range of conservation methods would be applicable to satisfy the needs for conserving a gene pool as a whole. This suggests the need for both *in situ* and *ex situ* conservation. This can be referred to as Complementary Conservation Strategy (CCS)

***In- situ* conservation**:

Conservation of genetic resources within their ecosystem and natural habitat ensures the maintenance and recovery of viable populations of species in their natural surroundings. The *in situ* conservation, which involves protection or keeping aside the ecosystems or habitat harboring biodiversity from human intervention is good for mainly forestry species, wild relatives of crop species, forage crop species, medicinal and aromatic plants and the species that are under various levels of threat or about to extinct, because they cannot be grown outside their habitat or they are the members of complex ecosystems, like tropical forest trees, have high dormancy or associated with highly specialized breeding system. To meet the set objectives following approaches are being followed:

i) Ecosystem approach: It involves conservation of ecosystems large enough to ensure self-perpetuation and evolution of organisms. Under this disturbance of habitat can cause degradation of vegetation that may disturb the stability of plant components. Thus, survival and conservation of genetic resources is greatly influenced by ecological imbalances and may result in change in species/population composition. Since there is only a limited variability available in India, this conservation approach may be suitable for wild species.

ii) Habitat approach: It helps manage the target species or group of species in its original habitat and can adopt any of the following methods-Managed forests (Sacred groves), Nature reserves with multiple uses, Preservation plots, Wildlife sanctuaries, Habitat or National parks, On-farm conservation and Agro-ecosystem through preservation of peasant cultivation as dynamic system. Since the cultivation system does not seem to change, genetic erosion may not be important concern at present. On-farm conservation, apart from allowing evolution to continue, contributes as well to the conservation of diversity at all levels (landscape, ecosystem, among and within species) and it is therefore highly strategic. It does contribute to empower the farmers to better exercise control over their crop genetic resources, major biological and livelihood assets. Another major advantages of on- farm conservation is related to its conduciveness in safeguarding the traditional knowledge associated to biodiversity which is an integral part of peoples' social and cultural identity, and which is fundamental for celebrating and appreciating crop diversity today and in the future. Lastly, on-farm conservation is a powerful instrument to allow the implementation of benefit sharing as recommended by the CBD which has in fact recognized the continued maintenance of traditional varieties on-farm as an essential component of sustainable agricultural development.

Ex-situ: Most of genetic resources for food and agriculture have been conserved following *ex situ* approaches. Based on genetic material that refers to "any material of plant origin of actual or potential value for food and agriculture, which include reproductive or vegetative propagating material containing functional units of heredity", suitable *ex-situ* approaches may be adopted for cost effective conservation to meet the desired objectives. This has been achieved by perpetuating sample population in genetic resources centres, botanical gardens, tissue culture repositories, genebanks for seed propagated species and conservation of pollen, embryo and other plant parts/organelle, etc. Conservation of seed propagated plants is relatively easy for seeds with orthodox type of storage behaviour, *i.e*., the viability can be maintained by drying the seeds and storing at low temperatures and *Jatropha* shows orthodox seed storage behavior. The *ex situ* preservation of orthodox seeds in genebank has been the most effective strategy for plant genetic resources conservation. Today, about 6 million accessions are conserved worldwide in more than 1000 genebanks as *ex-situ* germplasm collections including 5.27 lakh accessions maintained in field genebanks. Fifteen of the genebanks have long-term facilities. There is a basic advantage in following this approach that the availability of seed although in small quantities will be ensured even after 2-3 human generations. It is nevertheless scientifically accepted that the *ex-situ* mode of conservation does not provide a panacea for conserving crop genetic resources. It has been found to be associated with inadequate sampling procedures during field collecting, lack of representation in the genebanks of the whole range of diversity of a given crop and its close relatives, etc. Besides this, the storage of seeds involves the freezing of evolutionary processes, thus preventing new type or levels or resistance to evolve, because the plants are not allowed to respond to selective pressures of environment. The *ex-situ* conservation approaches can be classified into: a) **Plant conservation**: Botanical garden, herbal garden, arboreta etc.; b) **Seed conservation**: Storage of desiccation tolerant seeds at low temperatures; c) **In vitro conservation:** Maintenance of aseptic cultures of cell, tissue and organs; d)**Cryopreservation**: Preservation of desiccation sensitive seed, organ and cultures using cryogenics; e) **DNA conservation**: Genomic DNA, DNA libraries, Gene constructs

***In- situ* Conservation**

India has a land area of 329 million ha, of which more than 19 per cent is under forest cover. The country is distinguished into 16 phytogeographical zones classifying the major vegetation types of the country. Traditional, *in-situ* conservation of PGR through human intervention in India can be traced back to ancient times with the establishment of sacred groves and protection of plants around the temples of those species that are either part of religious practices or of medicinal value. During post-Independent period, since 1947, approximately, 4.2 per cent of the total geographical area has been put under the programmes of conservation of biodiversity, this has been achieved with the establishment of biosphere reserves, habitat-parks, and wild life parks and sanctuaries, protecting the diversity under natural habitat following ecosystem or habitat approach. The plant biodiversity of economically important or domesticated species is being conserved with the establishment of gene sanctuaries for certain species and their wild relatives and on-farm conservation of farmers/traditional varieties and landraces.

Clonal repositories/ Field gene banks

Plant genetic resources of different fruit plants/ tree species and many ornamentals are maintained by vegetative propagation in order to maintain their genetic make up true to the type. In case of fruit germplasm, usually conservation is done in field gene bank which were earlier known as varietal collection, clonal repositories or living collection. Field gene bank is a facility where clonal materials are conserved as living collections in field, orchard or in plantation. The reasons for retaining clonal lines relate to maintenance of heterozygosity and adapted complexes, inability to set seed early, long juvenile stages and production of recalcitrant and/or large seed. Many collections of tree species including their wild relatives are found in botanical gardens and arboreta, but no collection is complete. Almost all wild species of fruits/agroforestry species in India are being maintained in the forest, which face danger of extinction due to indiscriminate cutting of plant materials like wood, timber, bark and fruits etc. for various uses. *In-situ* conservation may involve many disciplines: ecology, agronomy and resource management, soil science, genetics, entomology and plant pathology.

In field gene banks the plant genetic resources are kept as live plants that undergo continuous growth and require continuous maintenance. They are often used when the germplasm is either difficult or impossible to conserve as seeds (i.e. when no seeds are formed, seeds are recalcitrant or seed production takes many years, as for many tree species) or the crop is reproduced vegetatively.

Village conservation areas

The decline of biodiversity in agricultural landscapes due to increasing demand for agricultural land and intensified farming is of increasing concern. Consequently, conservation of plant species within patches of marginal and degraded areas has been considered to be a step towards reversing this trend. Furthermore, these areas are excellent reserves for conservation of agro biodiversity of forestry species which is vital for maintaining a stable agro-ecosystem.

***Ex- situ* Conservation**

Seed conservation has vital role in preservation of genetic variability as it is simple to handle, cost-effective and capability of maintaining genetic stability over long time periods, Seed conservation is a popular tool for germplasm conservation at the global level. The most important components of managing *ex-situ* germplasm include well established procedures for collection/assembly, characterization, conservation and sound scientific approaches for effective utilization of conserved germplasm. The goals of *ex-situ* conservation in maize can be achieved in a variety of ways.

For short-term storage, any room can be converted into store with insulation and false ceiling and a domestic air conditioner to maintain it as cool as possible. For designing medium- and long-term stores, prefabricated modules with interlocking insulation panels are preferably used. These are made from painted galvanised steel sheets with sealed lap joints, containing polyurethane foam and Mefron-11 mixed with fire retardant. The floor is finished with heavy duly galvanised steel sheet suitable for heavy loads. The doors either hinged or sliding generally have a nominal clear opening of 100-120 cm x 200-250 cm. must have heat-sealed elements to prevent local icing. The modules are fitter with a heated ventilator port to equalize air pressure. On receipt of seed germplasm, accessions are checked for physical purity, pest freedom and seed viability to meet international standards. If on evaluation the accessions are found in sufficient quantity and show more than 85% Viability they are accepted for further processing. The qualified accessions are equilibrated at 15°C and 15% relative humidity (RH) to 3 to 7% moisture content, they are hermetically sealed in tri-layered aluminium foil pouches and labelled with al details required. These samples are placed in the cold storage modules maintained at -20°C. The National Genebank at NBPGR has facilities for long-term storage of over one million accessions and at present holds over 4,43,252 accessions of about 1762 species.

Based on the conservation objectives, collections can be of 2 types:

Active collections: Collections that are being regularly used for research and distribution to bona fide users.

Base collections: Maintained as safe deposit of germplasm, to be used only for regeneration of active collections and for replenishment of base collection.

Types of conservation

The following storage conditions are used in seed genebanks depending on their objectives:

Short-term: Seed can be shade dried and stored up to 2 years in sealed plastic containers, paper bags or muslin cloth bags at 18-20^0 C and 45% RH.

Medium term: Seed can be shade dried and stored up to 5 years in cloth bags, metal cans and plastic jars at 4-10^0 C and 35% RH. Active collections are kept at medium term storage which are immediately available for distribution, utilization and multiplication. The seeds which do not satisfy the quality and quantity and to be regenerated is also stored in medium term module. The seeds are equilibrated to 8-10% moisture content at these conditions. Medium term storage facilities are available at NBPGR Regional Stations and National Germplasm Active Sites.

Long-term (-18^0 C): Seeds can be dried and stored for long term in sealed aluminium foil pouches at -18 ^{0} C with 6-8% moisture content on fresh weight basis for long term. The base collections are stored in long term for posterity. This method is being practiced at NBPGR, New Delhi for storage of maize germplasm which is discussed in detail.

Conservation at National Gene Bank, New Delhi

The National Gene Bank (NGB) is responsible for the conservation of seeds on a long-term basis, as base collection for posterity. In addition, it provides technical support to the network in planning, development and operation of medium-term gene bank facilities, in human resource development and in provision of accessions for the regeneration of active collections. It is supported by a network of 11 Regional Stations in different agro-ecological zones of the country and 59 Crop based, National Active Germplasm Sites.

Processing and storage of maize seeds at NGB, New Delhi

Seed Conservation

The seeds are best stored at subzero temperature with 3-7 percent moisture content depending on species as the acceptable standards. Conservation of genetic resources is a high priority in the national context, as a global plan of action activity or a convention on biological diversity requirement. The National Plant Genetic Resources programme in India has already developed elaborate guide lines for sending germplasm for long term conservation in its Gene Bank, which maintains international standards and also ensures long term viability of the material conserved after due processing. The following points are check listed before sending the material for *ex- situ* conservation

i. Well developed and physiologically matured seeds.
ii. Free from insects, weeds and disease
iii. Clean and free from under sized, shrivelled, immature and discolour seeds.
iv. Properly labelled and packed to avoid damage during transit
v. Untreated with chemicals.
vi. Send to gene bank at the earliest possible (soon after harvest).
vii. Accompanied with the minimum passport data.

Processing of seed for long-term conservation

The cleaned seeds are dried to low moisture contents (6-7%) and stored hermetically sealed moisture impervious containers at sub-zero temperatures (-18^{o}C). Following steps are involved in processing the seed material for Genebank which have been depicted in the flow chart.

Flow chart for the processing of maize seed material in NGB

Receipt of seed material

↓

Verification of material for duplicates (Nat.ID/Collec. No.)

↓

Dup. rejected | Unique acc. Accepted

↓

Seed Accessioning (IC /EC)

↓

Cleaning of the seed

↓

Seed Quality/Quantity determination

↓

Seed Moisture and viability estimations

↓

Drying the seeds at 15 °C and 15%RH to 5% mc

↓

Packing in three layered aluminium foil packets

↓

Sealing with vacuum sealer and labelling

↓

Stacking in trays accession wise

↓

Store in module at -18℃

↓

Documentation of data with location

Genebank standards

To minimize the alterations in genetic structure and loss of viability in germplasm accessions during storage, the seed genebanks preferably follow the genebank Standards recommended by FAO/IPGRI (Anonymous, 1994).

- Acceptable —- These are minimal Standards that are considered adequate.
- Preferable — Higher and safer to maintain a high degree of viability and genetic stability

For germplasm conservation, healthy mature seeds must be processed in best conditions to maintain high viability. The seeds must be dried as soon possible to avoid deterioration. Since there is evidence that some chemicals used to treat seeds can reduce longevity under some storage conditions, and because the long-term effects of the majority are unknown, chemical treatment of seed for long-term storage should be avoided. Following standards should be followed while handling the material.

Storage containers: Should be temperature and moisture proof and sealable reusable glass or plastic containers with double screw caps are suitable for conservation of active collections where accessions are [o be retrieved from storage frequently.

Seed-moisture level

- for base collections: 3-7%
- for active collections: 8-10%

Sample size/accession: 4,000 seeds in out-crossing species, 2,000 in self- pollinated ones and 500-1,000 in crops with inherent problems of non-uniform physiological maturity, dormancy and multiplication.

Viability monitoring: A five-year interval in case of active collections and 10-year interval in base collections are recommended.

Regeneration: 100 or more plants for regeneration to avoid loss of alleles.

Information documentation: Passport, evaluation and management databases should be documented to provide full information to prospective users.

Germplasm distribution: Germplasm must be supplied with passport information to facilitate sustainable use in crop improvement and also protecting farmers' and breeders' privileges. Based on their objectives five types of genebank can be identified: 1. Institutional genebank, 2. National genebank, 3. Regional genebank, 4. International genebank, 5. Community genebank

There are around 1,500 genebanks in the world. In addition, there are 12 international genebanks at International Agricultural Research Centres holding around 600,000 accessions in trust for FAO and the international community. Over 3,27, 932 accessions of maize are being conserved worldwide and the biological status of maize accessions conserved are traditional cultivar/landrace, breeding/research material, inbred line, advanced cultivar, synthetic population, segregating population, wild, genetic stocks etc.

Germplasm Documentation

Data documentation is the most important and dynamic activity. Correct and reliable recording of data, its documentation and information transfer is as important as proper handling of germplasm itself. Proper documentation of plant genetic resources allows the best use of data, it's easy retrieval and usefulness. This way the documentation of plant genetic resources is very useful in disseminating information on germplasm holdings more effectively and for a specific purpose enabling one to a search information having desired traits so that the selected accessions could be used for breeding programmes for developing new traits. It also acts as a source of information to assist in planning and operation of any gene bank activity. For documentation of gene bank holdings in NGB, two types of information files are used: passport data descriptors and Gene bank management descriptors.

The passport data descriptors include Name of crop, Taxonomic code, Cultivar, National_Id, collector_no, other_Id, location in the Gene bank and Gene Bank management descriptors include seed quantity, seed viability, seed moisture content etc. Being the most important component of National Genebank, it is accomplished efficiently through a well managed computer network

Some other advanced methods for conservation

***In-vitro* conservation**

Although several techniques have been developed for micro-propagation of crop germplasm but initiatives in the direction of conservation are limited. Micro-propagation is advantageous in plants which facilitates the availability of planting materials irrespective of the seasonal fluctuation, Supply of high quality planting materials, based on the selection of explants from highly reliable good mother plants, Supply of disease-free plants, If the selected mother plant is disease resistant, progenies supplied are also disease-resistant plants, Production of large number of plants (seed stock) in relatively smaller area, Preservation and maintenance of germplasm in germplasm bank

Meristem cultures have assumed a significant place in the domain of plant tissue culture due to its role in clonal propagation as well as in the production of virus-free plants. Moreover, apical meristems are less differentiated and genetically more stable which makes this an ideal system for germplasm preservation. Two basic approaches are followed to maintain germplasm collections *in-vitro:* (i) minimal growth, and (ii) cryopreservation. Minimal growth conditions for short to medium term storage can be followed in several ways - reduced temperature and/or light; incorporation of sub-lethal levels of growth retardants, induction of osmotic stress with sucrose or mannitol, and maintenance of cultures at a reduced nutritional status particularly reduced carbon, reduction of gas pressure over the cultures, desiccation and mineral oil overlay. The advantage of this approach is that cultures can be readily brought back to normal culture conditions to produce plants on demand. However, the need for frequent sub culturing may pose a great disadvantage including contamination of cultures as well as imposition of selection pressure with subsequent change in genetic make-up due to soma clonal variation.

Preservation of embryos

The data available in literature regarding survival of embryos and their subsequent regeneration into plants, points that their most important use could be for conservation of: (a) difficult to store seed species (b) species in which less number of seeds are produced, (c) hybrid embryos produced out of incompatible crosses, and (d) haploid germplasm. For cryopreservation, different types of embryos have been used, i.e., zygotic, somatic, nucellar and the pollen embryos obtained from androgenic anthers which could be successfully cryopreserved.

Freeze preservation of pollen

Cryopreservation of pollen is easy and has been considered of great value in supplementing the usual germplasm preservation techniques by seed and clonal storage and for enriching haploid gene pools. Pollen banks are efficient, economical and space saving, compared to maintaining live field collections. Pollen storage was primarily developed as a tool for controlled pollination of asynchronous flowering genotypes, especially in fruit tree and agroforestry species. In addition pollen storage has also been considered as an emerging technology for genetic conservation. Conservation of pollen (eg., under organic desiccation freeze drying, low temperature) is primarily used for facilitating hybridization when flowering is asynchronous or for use in next season. Thus, it can help in better utilization of available genetic resources. Pollen can easily be collected and cryopreserved in large quantities in relatively small space. In addition exchange of germplasm through pollen poses less quarantine problems compared with seed or other plant propagule.

Cryopreservation of Seeds

Cryopreservation at the temperature of liquid nitrogen (LN) (- 196° C) offers the possibility for long-term storage with maximal phenotypic and genotypic stability. This method being relatively convenient and economical, large number of genotypes and variants could be conserved and thus maximize the potential for storage of genetically desirable material.

DNA banks may one day be a practical method of conserving germplasm, although at present technical difficulties in storing entire genomes and the inability to regenerate individuals from DNA alone mean that this technique is, as yet, only hypothetical.

These techniques can be further exploited to conserve and maintain the trait specific germplasm of maize and for easy exchange cross border.

Management of *Maize* Seeds in NGB

Presently LTS at National Gene bank holds 11,287 accessions of maize germplasm from different agro climatic zones of India were collected /assembled. A total of 2,13,671 maize accessions with exotic collection numbers have been facilitated under germplasm exchange and imports by the NBPGR headquarters and its regional station at Hyderabad.

Registration of Maize Germplasm

With the objective of giving credit to the scientist who developed or identified promising experimental material (including parents of inbreed lines) or promising germplasm and to facilitate flow of germplasm among the scientists working in crop improvement program, the ICAR initiated germplasm registration mechanism in 1996 to register such promising germplasm. The information regarding these germplasms is put for public domain, which has become a mandatory requirement to safe guard the national resources with respect to IPR. Under this mechanism 103 maize accessions have been registered between 2003 and 2017 by seven research institutes/Universities.

Future perspectives

The past two decades have witnessed the development of new techniques for plant germplasm conservation which offer new options and permit conservation of diversity in the form of seeds, pollen, embryos and *in-vitro* cultures. The rapid strides made in the past few years with regard to these novel approaches have enhanced the value of gene banks and clonal repositories. In *maize* several molecular tools can give an insight of the genetic distinctness of the crop in the centre of origin and other regions of its introduction which necessitates characterization of accessions with broader geographical background and comparison of genetic relationships with morphological characteristics in order to identify genetically divergent material to develop genetically superior stocks.

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Maize cultivation standard and novel methods

Aditya Kumar Singh, S.L. Jat, Deep Mohan Mahla and Shanti Bamboriya
ICAR-Indian Instiute of Maize Research, Ludhiana

Maize is a multi-faceted crop grown in varied agro-climatic conditions for food, fodder, feed and industrial purpose globally. Worldwide, maize is cultivated in nearly 185 mha area along with a production of above 1070 mt and average. Productivity of 5.6 t/ha. In India, this coarse grain is currently being cultivated on 9.6 mha with 28.26 mt production. In India, 7 different types of maize are grown, *viz*., normal maize for grain purpose, popcorn, sweet corn, baby corn, maize for green fodder, maize for green cob and maize for silage making.

Maize has wider adaptability, can be grown in almost any season and elevation of meansea level to high altitude. It is a day neutral tropical plant and can be grown round the year if, minimum temperature does not go below 10° C. Thus it is cultivated from Peninsular India to high ridges of Himalayan in the north. In India, maize is cultivated in two main seasons Kharif and Rabi with contribution of 72%and 16%, respectively. Spiral or summer maize in gaining popularity in the states of Punjab, Haryana and Western U P with around 2% area. The kharif maize is principally cultivated under rainfed condition (> 80% area) while rabi and spring maize is cultivated under assured irrigation. Due to chilled winters, the *rabi* maize cultivation is generally not popular and successful in north western regions of the country.

Brief Cultivation Facts

Climate:

The most suitable temperature for germination is 21^{0}C and for growth is 26-32 ^{0}C. Minimum mean temperature for growth of maize is 7-9 ^{0}C. Extremely high temperature and low humidity during flowering damage the foliage desiccate the pollen and interfere with proper pollination, resulting in poor grain formation. Well distributed rainfall of 500-750 mm is conducive to proper growth. The ideal LGP for maize crop is 105-135 days. If LGP is less than 75 days maize crop cannot be grown. Maize is most sensitive to moisture stress from the beginning of flowering until the end of grain formation (50-100 day from planting).

Wetness: Maize is very sensitive to stagnation of water, particularly during its early stage of growth. Maize is well adapted to well drained sandy loam to silt loam soils. Proper drainage is must for the success of the crop especially during kharif season. Maize will not thrive on heavy soils, especially in low lands. Maize cannot stand waterlogging in the first 5 weeks after sowing. From the 6th week onwards, waterlogging during 3 to 7 days may kill the crop. On soils with a low moisture retention capacity, or in areas of low rainfall, a low plant density should be used. Yield increases with planting density on irrigated plots, but the reverse may occur on rainfed plots.

Physical soil characteristics:

Maize grows on many types of soils. Well drained, well aerated, deep loam and silt loam soils with adequate organic matter are most suited for maize. For obtaining full potential yield of maize minimum 75 cm depth, fine loam, loam to clay soils with AWC of >100 mm is required because maize roots penetrate 65-70 cm soil. The water requirement of maize varies with the type of soil and the season and depending upon the rainfall received. In the northern India, the crop is normally sown after pre-sowing irrigation. During the monsoon, irrigation may be required whenever soil moisture falls below the desired level. The early vegetative considerably stage (20-40 days after sowing) and 'tasselling and silking stage (45-60 days after sawing) have been observed as critical stages in terms of demand for water by maize. Maize is very sensitive to excess water and hence it is advisable to plant it on ridges. Submergence of the soil for three to five days during seedling or flowering period reduces the yield. Under favourable conditions maize roots penetrates as deep as 60-65 cm soil, hence, for obtaining full potential yield, minimum 70-75 cm deep soil along with good drainage are required for maize crop.

Kharif maize

Irrigated kharif maize for grain purpose

Sowing time: Generally, the ideal sowing time is June 20 to end of July. However, in fields where water stagnation may occur, early sowing is desirables that plant reaches afirm stand to avoid lodging due to water logging.

Landpreparation: Maize needs well pulverized, fine and smooth field for seed emergence and root growth. Hence, deep tillage operation using mould board plough followed by two harrowing and one planking is needed for good field preparation and early season weed management. Maize can also be successfully produced under zero-till conditions.

Farm-equipments: Mould board plough, disc harrow/rotavator, land-leveler, bed planter etc.

Seed rate and seed treatment:8 kg of seed per acre should be used. The seed should be treated with fungicide such as Bavistin 50 WP or Derosal* 50WP or Agrozim* 50WP (carbendazim) @ 3g per kg seed.

Sowing method: In *kharif* season crop, it is always desirable to go for raised bed planting to protect the crop from water logging.In raised bed planting,70 cm wide ridges (40 cm ridge and 30 cm furrow) are prepared with the help of bed planter. Bed planter with incline plate seed metering system can precisely place the maize seed at required depth of 3.5-5.0 cm and does simultaneous operation of raised beds making and planting. One line of maize on each raised bed is desirable when sole crop of maize is planted keeping seed to seed spacing at 20 cm. Optimum plant density (30,000/acre) should be maintained to tap full potentials of hybrids. Southern side planting is advised on East-West oriented ridges. Happy seeder or zero-till bed planters with inclined plate to be used for crop establishment under zero tillage or for sowing under crop residue.

Sowing depth: For proper germination and early vigor, seed should be sown at 3.5-5 cm depth.

Inter cropping: One row of either (a) Cowpea for fodder; (b) Soybean/urdbean/mungbean for grain; (c) Groundnut for pods, in between two consecutive rows of maize is desirable. Do not use herbicides for weed control in intercropping system. The shade loving crops like turmeric and ginger can also be successfully cultivated as intercrop with maize. Slightly higher doses of fertilizers should be applied than sole crop.

Irrigation management: Water requirement of maize is 500–800 mm per growing season. Under *kharif* season, partially water requirement is met by rainfall. Hence, 1-4 irrigations are required, which may vary depending on frequency of rainfall. Adequate moisture at germination, pre-tasseling, silking and grain-filling stages should be ensured through irrigation, if rainfall is not there. If available, the sprinkler irrigation upto knee length stage is very good for maize crop. In ridge-sown crop, irrigation should be given in furrow upto 2/3 of height of the ridge.

Nutrient management

Hybrid maize is very responsive to nutrient application and has slightly high nutrient requirement as compare to other cereal due to high yield potential. It can be grown both organically or by integrated nutrient management involving organic and inorganic nutrient supplementation.

- Green manuring: Green manuring crops like dhaincha/sunhemp/cowpea at 12/20/20 kg seed rate/acre, respectively are very useful. Fifty days old crop is to be ploughed down and reserve the field for 10 days for decomposition before sowing of maize.
- Straw of summer mungbean/cowpea may be buried before sowing of maize or/with
- Farm yard manure/Compost @ 6 tonnes/acre or vermicompost @ 3 tonnes/acre
- Application of *Azatobacter*/*Azospirillum* with PSB and NPK consortia for seed treatment @ 200 g/acre or liquid formulation @ 100 ml/acre.
- Soil application of *Azatobacter*/*Azospirillum* with PSB, VAM and NPK consortia @ 5-6 kg/acre.

Organic nutrient management: Following options for nutrient management in organic maize production to be used based on availability in suitable combination:

Integrated nutrient management:

Application of 6 tonnes/ha well decomposed farm yard manure/compost mixed with *Azatobacter*/*Azospirillum* with PSB, VAM and NPK consortia @ 5-6 kg/acre or seed treatment with *Azatobacter*/*Azospirillum* with PSB and NPK consortia for seed treatment @ 200 each/acre or liquid formulation @ 200 g/acre or liquid formulation @ 100 ml/acre needed for better moisture retention and initial boost of the crop. Macro-and micronutrient requirements of the crop need to be accomplished through use of suitable fertilizers. The following schedule of fertilizer may be used:

Maize is sensitive to Zinc deficiency. Zinc deficient crop shows stunted growth and develop short inter-nodes. A white (or pale-yellowish) tissue with reddish veins appears on leaf blade. To mitigate it 10 kg/acre $ZnSO_4.7H_2O$ or 6.5 kg/acre $ZnSO_4.H_2O$ should be applied at sowing. Apply 10-15 kg S and 0.5 kg B/acre in deficient soils.

Weed management: Weeds damage significantly to maize production and the critical period for crop-weed completion is 15-45 days after sowing.

Cultural control: a) Two manual hoeing at 15 and30DAS; b) Inter-cropping of one or two rows of fodder cowpea in between maize rows reduces weed problem considerably.

Chemical control: Pre-emergence atrazine application followed by one hand weeding at 35-40 days gives good weed control. Recommended dose of atrazine at pre-emergence followed by either of the post-emergence herbicide for effective weed control (mentioned below) is also equally effective.

Herbicide	Formulations	Dose(g ai/acre)	Time of application (DAS)
Atrazine	50 % WP	300	0-2 (pre emergence)
Topramezone	33.6 % SC	12	20-30 (Post emergence)
Tembotrione	34.4% SC	50	20-30 (Post emergence)

Saving crop in case of excess water damage: If waterlogging occurs in the field and damage is moderate, 6kg/acre of urea in two sprays at weekly intervals may be applied. In case of moderate to severe damage, 25-50 kg urea/acre after the water flooding is over may be broadcasted.

Harvesting and drying options:

Maize can be harvested when the husk has dried and turned brown. Apart from hand-picking, combined harvester may also be used for quick harvesting. After manual harvesting, depending upon the cultivated area, manual shellers or maize dehusker-cum-sheller or maize thresher may be used for separating grains from cobs. The optimum moisture in grain for long-term storage should be below 14%.

Portable Maize Dryer can also be used for reducing the moisture content of the cobs. Sun drying of the cobs and seeds is required in absence of other drying options prior to marketing as moisture above optimum level reduces market prices and increases chance of aflatoxin contamination.

Rainfed kharif maize for grain purpose

For rainfed crops, soil moisture is the most limiting factor. Hence, moisture conservation practices are required to be followed to attain maximum yield.

Soil moisture conservation practices
• **Ploughthefieldagainstslopeafterpre-monsoonshowerstoenhancewaterabsorption/filtration** • Sowing and other operations should be carried out on contour/across the slope • Spread locally available mulching material in the last week of August • Application of the farm yard manure/compost@ 5-6 kg/acre.

Seed rate and spacing requirement in rainfed maize

Seed rate(kg/acre)	Spacing(cm)	Plant population(per acre)
7-8	70*20 -25	23,134 to 28,918

Rate of different fertilizers needed for rainfed maize crop

Organic nutrient supplementation to be given and inorganic N fertilizers is to be splitted into two doses, at basal and depending on moisture availability between knee high to teaseling stage.

Soil Type	Schedule	Fertilizer (kg/acre)		
		Urea	DAP	$ZnSO_4.7H_2O$
Sandy loam to clay loam soil with adequate moisture stored	Basal	46	35	10
	I[st]split	24	--	-
Loamy sand to sandy soils with low moisture stored	Basal	35	18	-
	I[st]split	--	--	-

Rest agronomic practices are same as discussed earlier.

Rabi maize for grain purpose

Sowing time:15[th] October to 15[th] November is the best time, however this may vary for region to region.

Sowing: Before sowing, seed should be soaked overnight in warm (45°C at the time of seed soaking) water. This treatment helps in obtaining better plant stand and healthy crop. Sowing should be done on the southern side of the east-west ridge so that the optimum amount of sunshine is received and the seedbed remains warm.

Seed rate and spacing requirement in rabi maize

Seed rate (kg/acre)	Spacing (cm)	Plant population (per acre)
20-22	60*20	33,333

Intercropping: During the rabi season potato, table pea, onion, garlic, coriander, spinach, coriander, beetroot cabbage etc. can be grown in between maize rows to ensure higher income of growers without harming the yield of winter maize.

Fertilizer scheduling for rabi maize

For higher yield, integrated nutrient management found beneficial for rabi maize and organic sources option mentioned in *kharif* maize to be used along with chemical fertilizer mentioned as below:

Crop stage	Schedule	Fertilizer (kg/acre)			
		Urea	DAP	MOP	$ZnSO_4.7H_2O$
Before/at sowing	Basal	26	70	53	10
4 leaf stage	I[st] split	26	-	-	-
8 leaf stage	2[nd] split	40	-	-	-
Tasseling stage	3[rd] split	26	-	-	-
Grain filling stage	4[th] split	6	-	-	-

Irrigation management: Four to six irrigations are needed during the rabi crop season. If six irrigations are given, they should be applied as two before flowering, one at the time of flowering, two after flowering and one at the early grain-filling stage. If only five irrigations are given, one irrigation at the vegetative stage may be avoided; and if only four irrigations are given, irrigation after the dough stage may be avoided. The irrigation should, however be changed suitably if adequate rains are received.

Spring maize for grain purpose

Sowing time: January 20-February 15

Seed treatment: Shoot fly incidence is higher in spring sown crop. Therefore, seeds should be treated with Imidacloprid600 FS @ 6ml/kg of seed or Thiomethoxam 30 FS @ 8ml/kg seed. The seed may also be treated with fungicide such as Bavistin 50 WP or Carbendazim 50WP @ 3 g per kg seed.

Sowing method:

Furrow planting: Evaporative losses of water during spring season from the soil under flat as well as raised bed planting is higher and hence crop suffers from moisture stress. Under such conditions, it is always advisable to grow maize in furrows for proper growth, seed setting and higher productivity. Zero-till planning is beneficial in spring maize after harvesting of potato, mustard etc.

Irrigation: Spring maize needs nearly 10-15 irrigations sometimes even higher as the evapo-transpiration demand is quite higher in summer season. Hence, a water use-efficient irrigation system i.e. drip method is desirable under spring sown maize. Apply first irrigation at 25-30 DAS. Under non-drip irrigation, apply irrigation at 2 weeks interval upto10th April and on per week basis after this, up to maturity. From water conservation point of view spring maize without drip irrigation is not recommended.

Rate of different fertilizers needed for spring maize

The organic input mentioned for the normal *kharif* maize can be used for organic sweet corn production. For higher yield, integrated nutrient management found beneficial for spring maize and organic sources option mentioned in *kharif* maize to be used along with chemical fertilizer mentioned as below:

Varieties	**Schedule**	**Fertilizer (Kg/acre)**			
		Urea	**DAP**	**MOP**	**$ZnSO_4.7H_2O$**
Medium duration hybrid	Basal	33	55	27	10
	Istsplit	33	--	--	
	2nd split	33	--	--	
Short duration hybrid	Basal	25	27	27	
	Istsplit	25	--	--	
	2nd split	25	--	--	

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Macro and Micro nutrient management in Maize

S.L. Jat, C.M. Parihar[1], A.K, Singh, S.D. Bamboriya, Bhupender Kumar and D.M. Mahala
ICAR-Indian Institute of Maize Research, Ludhiana
[1]ICAR-Indian Agricultural Research Institute, New Delhi

Nutrient requirements of the crops depends mainly soil fertility status and the farmers' targets yield. At each harvest, nutrients taken up from the soil by the growing crop are exported from the field in the form of grain or stover that further depletes the productive capacity of the soil. Thus, soils require external nutrient replenishment in the form of organic and inorganic fertilizers. Soils having low inherent fertility status would require more fertilizer nutrients compared to those with higher fertility to get same level of targeted yield. Nutrient mining, imbalanced nutrition and under/insufficient supply of plant nutrients are some of the major problems contributing to declining crop yields. Maize like most of the field crops, require a good amount of primary nutrients *i.e.* nitrogen (N), phosphorus (P) and potassium (K) with the addition of other essential elements *e.g.* zinc (Zn), sulfur (S) and boron (B) in smaller quantities wherever necessary. In several states of the country particularly hill ecologies (North Eastern Himalayas, Uttarakhand, Jammu and Kashmir and Himachal Pradesh) and rainfed tribal states (Madhya Pradesh, Chhattisgarh, Rajasthan, Gujarat and Odisha), large area under maize production still remained untreated with fertilizers. This extant of no fertilizer application goes up to 90 % especially in areas where farmers are not sure to harvest their crop due to frequent drought and floods during monsoon season. After adoption of hybrids at farmers field further emphasize the need of change in nutrient management in maize substantially due to higher plant stand and yield potential.

Besides, the current nutrient management practices in the high input maize systems indicates imbalance plant nutrition with very high use of N and less use of P and negligible use of K and micro nutrients. This has led to nutrient imbalances in soils and lower nutrient-use efficiency and farm profitability under the scenario of decontrolled fertilizer prices that increased the cost of this input in recent years. As the all three macronutrients i.e. NPK having synergistically increases the crop yield and hence needs to apply in balance amount to get higher efficiency of each other. Moreover, the crop performance depends on sufficient supply of each of the 17 essential nutrients required for crop growth and development while it is limited by the nutrient in shortest supply. Thus, it is required to have adequate and balanced use of plant nutrients to achieve better efficiency and increased farm productivity and profitability in our country. In this article, we summarized the identification of nutrient deficiency symptoms, factors affecting nutrient requirement, recommendation of nutrient for hybrids in different maize ecologies in India along with recent approaches like site-specific nutrient management and chlorophyll meter (SPAD meter) based nitrogen management.

Fertilizer use in maize systems aims at providing crop with balanced proportions of essential nutrients when required with all available organic and inorganic sources. To determine fertilizer needs for the crop, it is essential to know which nutrients are required for the desired target yield. In this chapter, we tried to enumerate answers for nutrient hunger assessment in crop, factors affecting nutrient requirement and best fertilizer management practices in maize towards increasing productivity and profitability.

How can we access nutrient hunger of our maize crop?

The nutrient hunger symptoms of maize showed as stunted growth in general appearance as well as the faded green colour of the plant. Typical symptoms are small (stunted) plants, pale green leaves, and spotting or striping on leaves. Deficiency symptoms for most important nutrient elements are identifiable normally (Figure 1); however, in some complex cases, where there is no clear distinction, a specialist needs to identify the problem. Some pest and disease damage symptoms are quite similar to those of nutrient deficiencies (e.g. striping or spotting), so it is important not to confuse the two.

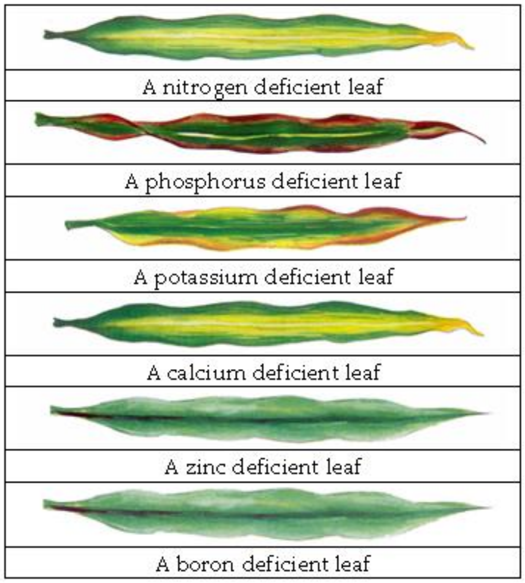

Figure 1. Nutrient deficiency symptoms in maize (Source: maizedoctor.cimmyt.org)

1. **Primary nutrients:** Nitrogen is the most important nutrient for plant involved in all major processes of plant development and yield formation. Loss of green color is the most typical hunger symptom of N which appears on lower older leaves as a v-shaped yellowing, starting at the tip and progressing down the midrib toward the leaf base resulted in premature death of lower leaves. In the early plant growth stages P is important in laying down foundation for its productivity required for good root system. The dark bluish-green and purple dicolouration of lower leaves caused marked reduction in plant growth under P deficiency. Symptoms of K deficiency include drying along the tips and edges of lower leaves. The K deficiency is accompanied with weakening of the stalk, resulting in lodging and crop loss as this nutrient provides strength to plant and helps in fighting with diseases. However, in most maize systems of northern India, K deficiency is rare because of its abundance in most of the soils whereas there is a need to apply it in peninsular India.
2. **Secondary nutrients:**Calcium deficiencies in maize, often called "buggy-whipping," are fairly common in a greenhouse or in crop gown under acidic soil conditions. The most common and troublesome calcium disorder occurs in the seedling stage where emerging leaves are damaged and don't unfurl. Distortion and twisting results in as newer leaves try to push through the damaged leaves. The plant recovers sometimes, if not the farmer must carefully unfurl the leaves manually to save the crop. Inadequate supply of magnesium appears as definite and sharply defined series of yellow/green streaks on all leaves due to a general loss of green color which starts with the bottom leaves and later

moves up the stalks. Sulfur deficiency symptoms in maize are similar to those of nitrogen in which plants show a pale green colour but it appears first on younger leaves.

3. **Micronutrients:** Micronutrient deficiencies are usually apparent on the new leaves of maize except molybdenum since these are immobile in plant. The zinc deficiency symptoms may appear within the first two weeks after crop emergence as a broad band of white to yellow bleached tissue on one or both sides of the leaf midrib. These deficiency symptoms called as white bud of maize, a physiological nutritional disorder.

   A stunted appearance and yellow stripes between green veins along the entire length of the leaf blade are distinct hunger symptoms of iron. Boron deficiency may easily be mistaken for iron deficiency where there is a general stunted growth and leaves fail to uncurl properly. Boron availability reduced under low rainfall/drought conditions or in soils with low in organic matter.

   The deficiency of molybdenum and manganese cause dwarfing of maize plants. Maize grown under soils low in molybdenum develops yellowing of older leaves and younger leaves usually fail to unroll, while with manganese deficiency, maize seeds may fail to germinate entirely. Copper deficiencies, typical symptoms include a general yellowing (chlorosis) of younger leaves while in older leaves, leaf tips curl like pig tails and dies.

What are the important factors affecting nutrient requirement in maize crop?

The recommended fertilizer application rates depend on a number of factors and the most important ones are discussed below:

1. **Cultivar and yield potential:** Varieties differ in their response to fertilizers depending on their yield potential. Improved hybrid cultivars in maize with high yield potential will require more nutrients in order to achieve their yield potential. Their yields will be significantly reduced if fertilizer rates are low in. Moreover, the nutrient use efficient cultivars may require less external inputs for same level of yields compared to inefficient genotypes. On the other hand application of higher nutrient doses in low yielder composites will decrease nutrient-use efficiency and farm profitability.
2. **Crop rotations:** The continuous cereal base rotation like maize-wheat requires higher amount of nutrients compared to legume in rotation with maize. The inclusion of legumes as intercrops (like soybean, mungbean, urdbean, pigeonpea, groundnut, *etc*) or in rotation considerably reduces N requirement in maize as carry over legume effect. Moreover, it recycles other macro and micronutrients from lower sub-soil layer to upper root zone in the form of leaf falls and thus helps in enhancing applied nutrient-use efficiency. The green manuring of legumes like dhaincha/sunhemp also reduces the nitrogen requirement in maize crop substantially. If the previous crop is cereal like wheat than full dose of recommended fertilizer is needed to get same yield.
3. **Crop management:** Efficient use of applied nutrients depends on soil and crop management practices and fertilizer application methods and timing affect nutrient availability. Timely weeding reduces competition for nutrients by weeds which otherwise removes large amount of nutrients. Availability of moisture/waterboth in terms of amount and timing also influences nutrient movement in the soil and the uptake by crop in synergistic manner.
4. **Soil type:** Soil fertility is determined by soil type, which in turn is based upon its depth, organic matter content and texture. N, P and S reserves are poor in soils with low organic matter content; coarse texture and a history of continuous cropping for many years are usually very low while there may be sufficient K for crop needs. Coarse texture soil with

higher sand proportions requires higher nutrients to produce same level of yields compared to those with fine textured clay soils.

5. **Soil reaction:** Maximum availability of essential nutrients occurs at pH 6.0-7.0 where maximum availability of fertilizer nutrients is also maintained. Thus, the differed pH may require higher amount of the nutrient to be supplied. A sufficient supply of all nutrients (including micronutrients) is important for a good, healthy crop and the efficient use of each applied nutrient. If the nutrient is present in soil, but insufficient in quantity, the plant growth and uptake of other nutrients is limited. Soil with higher organic matter requires less external input of the nutrients
6. **Climatic conditions:** Response of rainfed crops to fertilizer also depends on soil moisture and its availability during critical crop growth stages like seedling, knee high and reproductive. The erratic rainfall patterns make optimum yield and fertilizer requirements difficult to predict, so fertilizer use is a risky investment. When drought risk is high, split applications of nitrogen fertilizers may be advisable, with adjustments throughout the season based upon evolving weather conditions. Generally, P applied in the previous season retains some residual availability for the next crop since it is not easily leached, if drought occurs after fertilizer application resulted in crop failures.
7. **Residue management:**Maize with the grain yield potential of 6.3 t/ha removes178 kg/ha of NPK in its straw beside sizeable quantity of other nutrients. With the introduction of improved cultivars, the productivity has increased up to 5.0 t/ha in some of the states like Tamil Nadu and Andhra Pradesh in our country.Maintaining crop residues in the field contributes to natural cycle of nutrients and reduces the need for fertilizer nutrients specially K, Mg, Mn and Zn (Table 1). Thus the fertilizer requirement will be different in residue incorporated field compared to residue removal. The straw which is generally 4 to 5 times of the maize grain produced in the field, if not required for cattle feeding can be used for nutrient recycling in field itself under conservation agriculture based management practices. The straw retention in filed will be beneficial for potassium management.

Table1. Nutrient uptake by maizecrop.

Grain yield (t/ha)	**Part**	**Macronutrient uptake (kg/ha)**					
		N	**P_2O_5**	**K_2O**	**MgO**	**CaO**	**S**
6.3	Grain	100	40	29	9.3	1.5	7.8
	Stover	63	23	92	28	15	9
	Total	**163**	**63**	**121**	**37.3**	**16.5**	**16.8**

Micronutrient uptake (g/ha)				
	Part	**Mn**	**Cu**	**Zn**
6.3	Grain	70	40	110
	Stover	940	30	200
	Total	**1010**	**70**	**310**

(Source: Aldrich *et al*., 1986)

What are the nutrient management practices for higher productivity and profitability in maize systems?

Maize is grown in almost all states of the countries in various seasons. The crop is largely grown under rainfed conditions where soils are not only thirsty but also hungry for nutrient too. The less consumption of fertilizer in maize with traditional varieties was one of the major reasons for low maize productivity and profitability in such ecologies. The better nutrient management will synergistically act with water to improve the maize productivity in the country. Moreover, with the adoption of single cross hybrid technology there is need of proper nutrition of the maize crop for harnessing benefit of the hybrids at farmers' field. The application of organic and organic sources of nutrient in right amount, at right time and right place will further enhance the maize productivity in different soil types and agroecolgies.

1. **NPK recommendation:** Among all the cereals, maize in general and hybrids in particular are responsive to nutrients applied either through organic or inorganic sources. Blanket nutrient recommendation packages for different agro-ecological zones based on a 'normal' season's yield potential are available from most national agricultural research institutions. For raising good *kharif* season crop the application 150:75:50 kg/ha of $N:P_2O_5$: K_2O required for hybrids of medium and late duration while for early duration hybrids and composites can be grown with 100:40:25 kg/ha of $N:P_2O_5$: K_2O. During *rabi* season for cultivation of medium and late duration maize hybrid, it requires180:80:60 kg/ha of $N:P_2O_5$: K_2O. However, these recommendations vary in different agro-ecological situations as given in Table 2.

Table 2. Recommended dose of nutrients for maize cultivation in various states

S. No.	Season	RDF ($N: P_2O_5:K_2O$ kg/ha)	States
1.	*Kharif*	100:60:40	Odisha, Bihar and Madhya Pradesh
2.	*Kharif*	120:40:0	Rajasthan and Gujarat
3.	*Kharif*	120:60:40	Himachal Pradesh, Maharashtra, Punjab, Uttar Pradesh and Uttarakhand
4.	*Kharif*	150:80: 60	Chhattisgarh, Haryana, Karnataka, Jammu and Kashmir, West Bengal and Tamil Nadu
5.	*Rabi*	120:75:50	Bihar and Rajasthan
6.	*Rabi*	175:60:50	West Bengal
7.	*Rabi*	225:80:80	Andhra Pradesh and Tamil Nadu
8.	Spring	80:40:30	Bihar
9.	Spring	120:75:50	Punjab and Uttar Pradesh

For better response of the genotype to added nutrients, the innovation of the nutrient management helped in keeping synergies so that genotypic yield potential realized and management yield gaps could be minimal (Fig. 2).

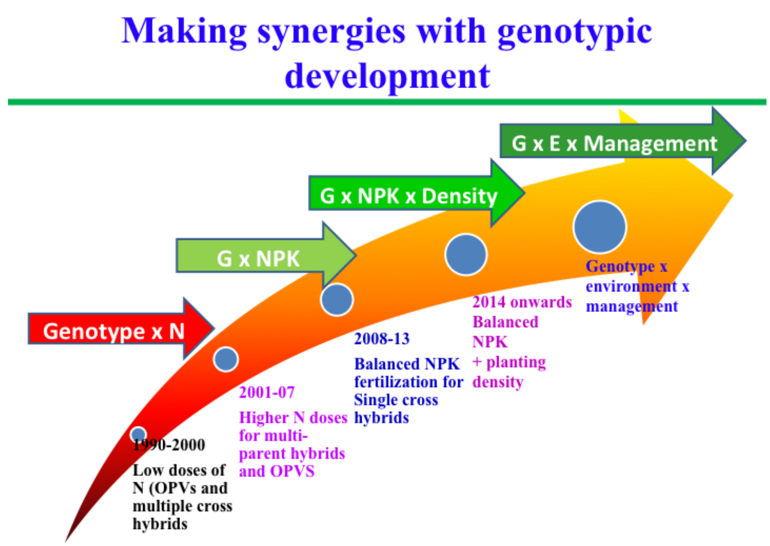

Fig. 2. Making synergies with genotypic development for enhancing resource use efficiency in maize.

Timing and method of fertilizer application: One of the most important aspects of fertilizer usage is to know when and how fertilizers should be applied to improve the efficiency of the nutrients applied. It primarily depends on the mobility of the particular nutrient applied to soil.With nutrients that are stored efficiently in soil (i.e. P, K, S), fertilizers can be applied before planting, or banded below/side of the seed. P is immobile in soil and it should therefore be applied into the root zone during sowing. N application should be timed to coincide with periods of peak demand and rates adjusted according to rainfall received during the season *via* split application to reduce leaching losses. The following points must be kept in mind for NPK management in maize cultivation:

- Apply NPK fertilizers as per soil test recommendation as far as possible. If soil test recommendation is not available adopt a blanket recommendation.
- The 20% N in irrigated and 34% N in rainfed conditions with full dose of P_2O_5 and K_2O should be applied as basal before sowing.
- Nitrogen is the most important in maize production but it faces losses of leaching, volatilization and fixation results in lower use efficiency. So, studies on N scheduling in maize were carried out at Delhi, Karnal, Pantnagar, Udaipur, Bahraich, Chhindwara and Srinagar Arbhavi. Results revealed that the application of N in 5-split (20% Basal, 25% V4, 30% V8, 20% VT and 5% GF) resulted significantly higher yield of QPM, sweet corn and pop corn over to 3-splits (33% at basal, 33% at V8 and 33% at VT) at Srinagar. However, the degree of yield increase varied across locations (2.5 to 22%) being lowest at Karnal and highest at Arbhavi. So, this can be used as strategy for enhancing N-use efficiency.
- We need to make synergies with the crop demand and in order to maximize maize crop yield, we should consider all 3 main factors and "create" the right fertilizer rates, mixture, timing that will optimize your fertilizer use specially for nitroegen split application (Fig. 3). As N uptake is continuous and almost half taken place after tasseling so application of N in split doses proved to be more remunerative at and after tasseling.

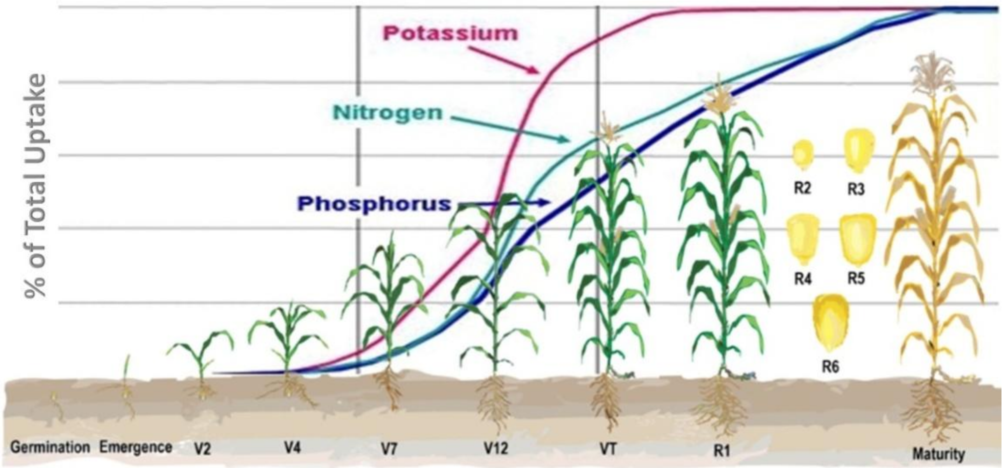

Figure 3. Plant growth stages and nutrient demand in maize (Source: https://www.smart-fertilizer.com/articles/corn_fertilizer).

- Apply rest 80% N in four splits as top dressing in following proportions:

S. No.	Crop Stage	Nitrogen rate (%)
1	V_4 (four leaf stage)	25
2	V_8 (eight leaf stage)	30
3	V_T (tasseling stage)	20
4	GF (grain filling stage)	5

- The top dressing may be done in two equal splits for rest 66% N under rainfed conditions at around knee high and tasseling stage of the crop according to the moisture availability in the field.
- The splitting of N found to increase yield in various agro-ecologies.

Treatment	Grain yield (kg/ha)				
	NHZ*	NWPZ	NEPZ	PZ	CWZ
T1	5263	5430	4542	2639	3888
T2	5748	5970	4111	3611	4032
T3	5992	6563	3819	4167	3795
T4	6309	6771	4653	3819	4145
LSD (p=0.05)	141	1071	606	450	510
Genotype	Early	Medium	Medium	Late	Early

**NHZ: Northern Hill Zone, NWPZ: North Western Plain Zone, NEPZ: North Eastern Plain Zone, PZ: Plain Zone, CWZ: Central Western Zone*

Treatment descriptions are as follows:

Treatment	N application (%)				
	Basal	Four leaf stage	Eight leaf stage	Tassel emergence	Early grain filling
T_1	33%	Nil	33%	33%	Nil
T_2	10%	30%	30%	20%	10%
T_3	5%	30%	40%	15%	10%
T_4	20%	25%	30%	20%	5%

2. **Integrated nutrient management (INM):** The application of the organic manure enhances soil fertility and improves water retention besides supplying vital macro and micronutrient for crop growth. All type of maize respond well to organic manuring and it is recommended to apply 10 to 15 tonnes/ha of organic manures before planting of crop will enhance maize productivity and profitability. This is very much necessary for seed production plots as inbred are lesser nutrient efficient with weak root system.

   INM is the best way of utilization of the farm waste and the enhancement in fertilizer nutrient-use efficiency apart from providing good soil health. Studies on INM in quality protein maize (QPM) and other specialty corn (Baby Corn and Sweet Corn) were conducted at various locations involving varying levels of organic and inorganic sources of nutrients. Integration of FYM and 100 to 125% recommended doses on nutrients through chemical fertilizers resulted in significantly higher yields of QPM, Baby Corn and Sweet Corn almost at all the locations. Application of FYM @ 6 ha resulted in 3 to 20% higher grain yield of QPM at different locations (Jat et al., 2013).

Treatment (N:P:K kg/ha)	**8 locations pooled yield (kg/ha)**	
	2007	**2008**
100:40:30 (N_1)	4226^{f}	4395^{f}
150:60:40 (N_2)	4735^{e}	4930^{de}
187:75:50 (N_3)	5136^{cd}	5173^{cd}
225:90:60 (N_4)	5482^{b}	5512^{bc}
N_1 + FYM @ 6 t/ha	4482^{ef}	4766^{ef}
N_2 +FYM @ 6 t/ha	5069^{d}	5333^{c}
N_3 +FYM @ 6 t/ha	5433^{bc}	5745^{ab}
N_4+FYM @ 6 t/ha	5839^{a}	6099^{a}
Yield gain by INM (%)	6.4	9.7

3. Biofertilizers: The seed treatment with *Azotobacter/Azospirillium* @ 600 g/ha found beneficial in maize production. When biofertilizer alone or cocktail is used for seed treatment in maize and soil application, 10 to 15% reduction in the total N is recommended.

4. **Micronutrient application:**Zinc is the major limiting factors for maize production in our country and 25 kg/ha zinc sulphate is recommended as basal application for higher maize productivity. Beside this maize crop also respond to sulphur application @ 30 kg/ha and boron application@ 1.5 kg/ha in deficient soils.
5. **Slow release fertilizers:**The one time or split application strategies of the fertilizers like neem/sulphur coated urea are having potential for decreasing the labour cost incurred in fertilizer application. Further these products will help greatly under zero-till maize cultivation as portion of the split applied urea remained on the surface of the residue which may volatilize or immobilised. An improvement of 18% in the agronomic nitrogen-use efficiency was found with application of sulphur coated urea over prilled urea application (Jat et al, 2019, 2019a).
6. **Precision nutrient management**: There is huge variation in Indian soil w.r.t the nutrient various nutrients content and the respond to varied fertilizer application. The 4R principles of applying right nutrient source, at right rate, at right time and at right place is expected to

increase nutrient use efficiency, productivity and farm profit from maize production and provides opportunity for better environmental soundness.

In-season N application adjustments of maize can be done using leaf colour charts (LCC), SPAD and Green-Seeker sensors. The N requirement of crops at initial growth stage (V3 in maize) is comparatively less. It has been well established thatmaize begins to rapidly take up N after V6, with the maximumrate of uptake occurring near silking and the diagnostic techniquesto monitor crop N status, such as the chlorophyll meter (SPAD-502), were found to be good for N management. As a in-season crop N management strategies, skipping basal application and application of nitrogen as per critical SPAD values was found beneficial for improving crop productivity.

The trails on site-specific nutrient management (SSNM) in two major maize systems i.e. maize-wheat at eight locations (Delhi, Bajaura, Udhampur, Dholi, Ludhiana, Pantnagar, Banswara and Ranchi) and rice-maize at three locations (Jorhat, Banswara, Hyderabad) were conducted in two consecutive kharif season. Significantly higher yield of maize was recorded under SSNM compared to state recommendations almost at all the locations. So, the SSNM can be adopted instead of blanket recommendation of nutrients for higher resource-use efficiency. In this connection a farmer and extension worker friendly tool ‘Nutrient Expert on Hybrid Maize™’ is being developed by International Plant Nutrition Institute which is going under validation through AICRP on Maize.SSNM also found effective in enhancing yield and water use efficiency in maize system (Parihar et al., 2017). It gives recommendation of the nutrient for field specific in absence or presence of the data on soil nutrient availability. This software of nutrient expert can be free access from http://seap.ipni.net.

Nutrient management	**System yield kg/ha (pooled values 3 yrs)**		
	NWPZ	**NEPZ**	**CWZ**
RDF	10160a	11593b	9711a
SSNM	10017a	12330a	8902b
FFP	8211b	11029b	8318c
p-value	<.0001	0.0474	<.0001
Change over Farmer fertilization practices			
RDF	1949	564	1393
SSNM	1806	1301	584

** NWPZ: North Western Plain Zone, NEPZ: North Eastern Plain Zone, CWZ: Central Western Zone, FFP: Farmer Fertilization Practices.*

Use of green seeker based N management in maize have resulted in enhanced yield and saving of the N in various agroecolgies which shows that the calibration curve developed by ICAR-IIMR in collaboration with CIMMYT and ICAR-IIFSR is working and can be used for in season precision N management.

Table 3. Effect of precision N management practices on the N use and the partial factor productivity in kharif maize during 2018 at various agro ecologies.

Treatments	N (kg/ha)						PFP (kg grain/kg N used)					
	BAJ	LDH	PNT	RAN	HYD	PED	BAJ	LDH	PNT	RAN	HYD	PED
RDF	120	125	120.0	150.0	200	200	25.8	24.9	18.9	20.8	29.7	15.6
STCR	277	126	224.0	177.0	228	118	24.8	41.2	19.0	39.5	37.2	47.9
NE-SSNM	150	184	120.0	144.0	141	120	60.9	32.3	35.7	52.4	61.3	44.7
33RDN+GS	91	112	119.9	115.5	253.7	114	87.3	52.4	34.2	63.7	3.1	47.2
60RN+GS_KH	128	142	87.1	130.1	171.8	140	59.6	41.0	47.3	50.8	47.4	38.7
70RDN+GS_KH	121	111	104.2	120.0	187.6	164	62.2	44.0	31.2	51.7	41.9	31.0
60RN+GS_TS	126	145	137.2	134.8	151.5	151	56.2	32.9	24.6	46.8	54.1	32.6
70RDN+GS_TS	132	158	140.8	149.8	140	167	55.7	28.8	24.1	39.8	59.9	28.0
30+30RDN+GS	123	145	121.3	110.0	174.8	137	59.1	30.5	27.6	55.5	47.5	33.2
35+35RDN+GS	127	158	133.8	119.1	194.8	167	57.6	33.5	31.0	54.3	42.3	35.8

**BAJ: Bajaura, LDH: Ludhiana, PNT: Pantnagar, RAN: Ranchi, HYD: Hyderabad, PED: Pedapuram*

7. Fertigation*:* Drip based fertigation also found beneficial in sweet corn at Hyderabad and for spring maize at Ludhiana.

Maize was traditionally grown as subsistence crop in rainfed ecologies till 2000 and hence there exist large management yield gaps in which large proportion was contributed by imbalance and inappropriate plant nutrition with multiple nutrient deficiencies. After 2005, maize grew at very faster rate in terms of area expansion in non-traditional assured ecologies replacing less remunerative crop due to higher productivity. In this context, for enhancing and sustaining higher maize productivity and profitability will be based on balanced adequate fertilization in maize systems using all available organic and inorganic sources with proper crop rotations and timing of application.

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Integrated Weed Management in Maize

Sreelatha, D., Lavakumar Reddy, M., Bhadru, D., Mallaiah, B and Anuradha, G.
Maize Research Centre, PJTSAU, ARI, Rajendranagar, Hyderabad-30

Maize (*Zea mays* L.) is the third most important cereal crop of India after rice and Wheat. It is grown for fodder as well as for grain purpose. It has the highest genetic yield potential, which is influenced by various biotic and abiotic factors viz., weeds, nutrients, pests and diseases. Amongst all, weed is the one important biotic factor that limiting crop yield in maize. The yield losses accounts for 25 to 80 % and the magnitude of losses largely depends upon the composition of weed flora, period of crop-weed competition and its intensity. The Weeds compete with crop plants for light, space, water and nutrients, especially during the early stages of crop growth (Sivamurugan *et al*., 2017). The wider row spacing, slow initial growth and high fertilizer requirement in maize allows abundant weed growth, resulting in poor grain yield .The critical stage of crop weed competition in maize crop is from 30 to 45 days from sowing. Weeds also exudates substances from roots and leaves which are toxic to crop plants. This causes severe interference with normal crop growth, leading to reduction in yield and quality.

The major weeds in maize field were *Cyperus rotundus* L. among the sedges, *Digitaria* spp, *Dactyloctenium aegyptium* L., *Dinebra arabica* L., *Cynodon dactylonL*., and *Eleusine indica* L. and *Rottoboellia spp* among grasses; *Parthenium hysterophorus* L., *Melilotus alba* L., *Trianthema portulacastrum* L., *Euphorbia geniculate* L., *Commelina spp*, *Tridax procumbens* L. and *Amaranthus viridis* L. among broad leaf weeds (Madhavi *et al*.,2014)

Digitaria sangunalis

Rottboellia spps

Dinebra arabica

Cynodon dactylon

Parthenium hysterophorus

Melilotus alba

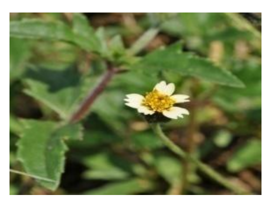
Trianthema portulacastrum

Amarathus viridis

Physalis minima

Cynotis cucullata

Corchorus aestuans



Tridax procumbens

Basic concepts in weed management

Field Scouting: Minimum of 20 weed counts taken in each field, each one in a 1 m^2 or 0.25 m^2 area. Weed patches, low spots and field margins should be considered separately, since they do not represent the entire field.

Assessing weed population: After field scout in the season note the species and numbers of weeds that have escaped control and produced seed in the previous season, as there is a strong potential that these species will be present the following season helps farmers to make good weed management decisions.

Critical period of weed control: The period of time in which weed control is necessary to avoid significant yield loss. The best time to control weeds and the length of the critical period depend on a number of variables including weed emergence timing, weed densities, the competitive ability of weeds compared to crops, and environmental factors.

Based on knowledge of the weed situation in a field: Farmers can reduce herbicide use by treating patches, using reduced herbicide rates or leaving fields unsprayed.

Herbicide Application Technology

Timing of herbicide applications is crucial for controlling weeds effectively and preventing excessive interference with the crop.

Herbicide performance can be affected by type, angle and spacing of nozzles, spray droplet size, travel speed, use of adjuvants, and electrostatic charging of herbicide sprays. Calibrate sprayer nozzles and set nozzle output and sprayer pressure to optimize herbicide performance and reduce the potential for spray drift.

 **Knapsack sprayer**	 **Flat fan nozzle**

Intensive agricultural production system with over dependence on herbicides, which have aggravated weed problem/shift and adversely affect biodiversity, animal health and environmental quality. Weed management, especially through herbicides have not much control on weeds however, sustainable intensification and integration of weed management strategies viz. cultural, mechanical, chemical and biological methods have been developed to limit the deleterious effects of weeds on crop plants.

Cultural weed control:

- Cultural practices play an important role for weed management in maize crop. The selection of a well-adapted crop variety or hybrid with good early-season vigor and appropriate disease and pest resistance provides considerable competition against weeds.
- Appropriate planting patterns, optimal planting time and density, placement, and amount of nutrient application minimizes the stresses on the crop from insect and disease damage and environmental stresses (frost, flooding, drought, etc.).
- Adoption of narrow row spacing will shade soil surface earlier than in wider rows, once the canopy has closed, very little light penetrates the soil surface or weeds beneath the canopy.
- Appropriate crop rotation, tillage practices, and cover crops have been one of the most common methods of managing weeds.
- The more diverse the crop in rotation in planting time, growth habit, and life cycle, the more effective the rotation will be in controlling weeds. Thus, the selection of a crop in rotation that includes small grains, forages, and legumes is significant. For ex; Maize followed by redgram, groundnut and safflower in rotation not only control weeds but improves productivity of maize. Maize preceded by green manure crops like Dhaincha and Sunhemp not only exterminate weeds due to rank vegetative growth but also improves the fertility of soil(Amit J. Jhala *et al*,2018)

Maize + Red gram intercropping

Maize + Soybean intercropping

Alternative methods of cultural weed control

- **Mulching**: Practice of covering the soil/ground to make more favorable conditions for plant growth, development by preventing germination of annual weeds from receiving light. Crop residue mulching can be opted for organic and sustainable weed management in maize.
- **Soil solarization: S**oil solarization (also called plasticulture) is an eco-friendly soil disinfestations method for managing soil-borne plant pathogens and annual weeds viz., *Ageratum* spp., *Amaranthus* spp.,barnyard grass, cogon grass, common purslane, *Digitaria* spp., *Portulaca* spp., redroot pigweed, *Setaria* spp.

Organic mulching for weed control

Inorganic mulching for weed control

Mechanical weed control:

Incessant rains and dry spells prevent weed control on time by traditional methods. Non-availability of manual labour due to competition from other crops or high wages of manual labour also come in the way of timely weed control in maize. In such situations, crop responds very well to mechanical weeding done by bullocks or tractor drawn implements between the rows and hand weeding within the rows.

- Tillage is the most common method of mechanical weed control and it can be divided into two categories: (1) pre plant tillage and (2) Intercultivation. The purpose of pre plant tillage is to kill all the weeds present before planting and to encourage better growth of the crop to compete with weeds during the initial stage. Cultivators and discs are commonly used by growers for preparatory tillage.
- The inter cultivation is used to remove weeds after the crop has been planted. The rotary hoe/ power weeders are widely accepted weeding tools for weeding and interculture in row crops. The cost of weeding by manual method, even though very effective, has gone up to Rs.1,750/ha. The average cost of weeding with power weeder is Rs.1,000/ha. The equipment saves 90% operating time and 30% in cost of weeding as compared to hand weeding. The tractor drawn intercultivators can also be operated at 30 DAS in between the rows followed by ridger for effective weed control and fertilizer use efficiency.

Preparatory tillage with plough

Preparatory tillage with cultivator

Inter cultivation with tractor drawn implement

Inter cultivation with power weeder

Biological weed control

The biological approach makes use of natural enemies of weeds (often referred to as biological control agents such as insects, mites, pathogens) help to reduce the weed's impact on agriculture and the environment under sustainable manner. Ensure that the release of biological control agents will not pose a threat to non target species, such as native and agricultural plants. Biological control method can reduce weeds but it is not possible to eradicate weeds. Currently, there are no commercial products for biological weed control in maize, though this area offers great potential for new weed control options in the future.

Biological control of Parthenium weed by *Xygogramma* beetle

Chemical weed control

- Weed control by mechanical means is possible only when crop grows upto certain stage and crop has to compete with weeds till such period. Chemical weedicides are boon in such a situation.
- Chemical weed control is a better alternative to manual weeding because it is cheaper, faster, and gives better control. Weed control in maize with herbicides significantly increased maize yield and decreased the weed density. However, continuous application of currently registered herbicides caused changing weed flora, poor controlling, and evolution of some herbicide resistant weed biotypes which necessitates the introduction of some other new herbicide options with different modes of action. The following pre and post emergence chemicals which controls weeds in maize grown as sole, intercropping and zero-tillage situations(Table1).

Chemical weed control by pre-emergence herbicide

Chemical weed control by post-emergence herbicide

An Integrated weed management proved to be a valuable concept in maize. However, it is to be reach to the small farmer's level. IWM approach aims at minimizing the residue problem in plant, soil, air and water without affecting the ecosystem. The nature and intensity of the species to be controlled, the sequence of crops that are raised in the rotation and the ready and timely availability of any method and the economics of different weed management practices are some of the potent considerations that determine the success for the exploitation of the IWM approach.

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Table: 1 Chemical weed control in maize

Crop	Weedicide	Dose/acre	Stage of application	Types of weeds control
Pre-emergence weeds				
Sole maize	Atrazine 50% W.P. or	800 -1200 g	24-48 hrs after sowing under well moist conditions	Broad leaved weeds
	Alachlor 50% EC	2.0 l		Broad leaved and grassy weeds
Intercropping Maize with pulses and oilseeds	Alachlor 50% EC	2.0 l		
Normal and zero-tillage maize	Atrazine 50% W.P. + Glyphosate 41% SL)or) Paraquat 24% SL	Atrazine 1.0 kg + Glyphosate 1.5 l) .or) Paraquat 1.0 l		Broad leaved weeds and re growth of rice stubbles
Post emergence weeds				
	2,4-D Sodium salt 80% WP	500 g	30 days age crop	Broad leaved weeds
Normal and zero-tillage maize	2,4-D, Dimethyl Amine salt 58% SL	0.35 l		
	2,4-D, Ethyl Ester 38 % EC	1.06 l		
	Tembotrione 34.4% SC + Atrazine 50% WP	Tembotrione 115 ml +Atrazine 400 g	Crop at 15-18 days age or 4 leaf stage of weed	Broad leaved and grassy weeds
	Halosufuron metyl 75 WG	36 g	Crop at15-20 days age or 4 leaf stage of weed	*Cyperus rotundus*
	Halosufuron metyl 75 WG +Atrazine 50% WP	Halosufuron methyl 36 g + Atrazine 400 g	Crop at15-20 days age or 4 leaf stage of weed	*Cyperus* rotundus and Broad leaved weeds
	Topramezone %33.6 SC + Atrazine 50% WP	Topramezone 30ml + Atrazine 400 g	Crop at 15-20 days age or 4 leaf stage of weed	Broad leaved and grassy weeds

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Integrated disease management in maize

K.S. Hooda, S.K. Aggarwal, P.K. Bagaria and DS Aulakh
ICAR-Indian Institute of Maize Research
PAU Campus, Ludhiana-141004

Maize (*Zea mays* L.) is the third most important cereal crop after rice and wheat. This crop is called as "queen of cereals" because of the highest yield potential and wider adaptability among cereals. It is cultivated in all types of climate such as tropical subtropical and temperate conditions. The food accessibility demands are directly proportional to increasing human population. This increased food accessibility must come through enhanced productivity as well as controlling losses due to pest and diseases. In India, maize occupies a prominent position with annual production of around 28.72 million tones over an area of approximately 10 million hectares (Indiastat.com 2017-18). In a systematic study conducted under All India Coordinated Maize Improvement Project about 60 diseases have been observed (Payak and Sharma, 1982). Most of them are of fungal and bacterial origin. Globally, about 9 per cent yield losses have been estimated in maize due to diseases (Oerke, 2005). In India maize diseases cause loss of 13.2 per cent (Payak and Sharma, 1985).

Turcicum leaf blight, maydis leaf blight, downy mildews, post-flowering stalk rots, ear rot and banded leaf and sheath blight are important diseases which affect maize yield. Bacterial stalk rot and brown spot are reported from northern India whereas downy mildews are more prominent in the peninsular India and Udaipur region of Rajasthan (Rathore *et al*., 2005). The extent of damages due to diseases depends on following factors:

a) Susceptibility level of maize genotypes to specific disease
b) Inoculum density of the pathogens present in the region/area
c) Environmental scenario during crop season.

Some economically important diseases of this crop along with their pathogen, diagnostic symptoms, and their distribution, disease cycle and management practices are being described to achieve potential yield of this crop. The major diseases causal agents, sources of inoculum, losses and epidemiological aspects are given in Table 1.

Table1. Major diseases of maize in India

Disease	**Causal Agents**	**Source of Inoculum**	**Losses (%)**	**Optimum conditions**
Turcicum leaf blight	*Setosphaeria turcica* Leon. &Sugs. (Anamorph: *Exserohilum turcicum* Pass. syn. *Helminthosporium turcicum* Pass)	Primary- Mycelia/Chlamydospores Secondary- Conidia	13–50 (AICRPM, 2013)	Cool and humid (18-27 ^{0}C)
Maydis leaf blight	*Cochliobolus heterostrophus Niskado& Miyake (*anamorph:*Bipolaris maydis syn. Drechslera maydis; Helminthosporium maydis Niskado& Miyake*)	Primary- mycelium Secondary- conidia	15–46 (AICRPM, 2013)	Hot and humid (20-28^{0}C)
Polysora Rust	*Puccinia polysora Underw*	Urediniospores	Up to100	77 to 80°C

Brown spot	*Physoderma Maydis* Shaw Teleomorph: *Cladochytrium maydis* Miyabe	Primary-sporangia Secondary-zoospores	6–20 (Payak and Sharma, 1985)	23 to 30°C and high rainfall
Banded leaf and sheath blight	*Thanatephorus sasakii*(Shirai) Tu and Kimbrough(anamorph: *Rhizoctonia solani* sp. *sasakii* Exner)	Sclerotia/ mycelium	Up to 60 (Tang *et al* 2004)	Warm weather
Common Rust	*Puccinia sorghi* Schw	Urediniospores	18–49 (Hagan, 2010)	High relative humidity and Temperature 16-25°C
Brown stripe downy mildew	*Sclerophthora rayssiae* var. *zeae*	Primary-oospore	Up to100	22 to 25°C
Rajasthan downy mildew	*Peronosclerospora heteropogoni* Siradhana *et al.*	Primary-oospore Secondary-conidia	10-60 (Siradhana, 1980)	23.5-30.1°C, RH of 87.3
Sorghum downy mildew	*Peronosclerospora sorghi* Weston & Uppal Shaw	Primary-oospore Secondary-conidia	Up to100 (AICRPM, 2012)	17-29° C
Bacterial stalk rot	*Dickeyazeae* Samson (Syn *Erwinia chrysanthemi* p.v. *zeae* (Sabet)Victoria, Arboleda & Munoz)	Soil and Seed borne	Up to 85 (Thind and Payak, 1985)	High temperature (30°C)
Fusarium stalk rot	*Fusarium verticillioides* Sacchardo	Soil borne	10-42 (Harlapur*et al* 2002)	Dry conditions and 28-30ºC
Charcoal rot	*Macrophomina phaseolina* (Tassi) Goid.(syn. *Macrophomina phaseoli*,*Botryodiplodia phaseoli* and *Sclerotium bataticola*)	Sclerotia	25-32 (Krishna *et al* 2013)	High soil temperature 30-42 ^{0}C and low soil moisture
Aspergillus ear rot	*Aspergillus flavus* Friedrich	Conidia	-	Hot and dry area

FOLIAR DISEASES

Turcicum leaf blight (TLB):

Distribution:
J&K, HP, Sikkim, WB, Meghalaya, Tripura, Assam, Rajasthan, UP, Bihar, MP, Gujarat, Maharashtra, AP, Telangana, Karnataka and Tamil Nadu

Diagnostic symptoms:

The disease starts at first as small elliptical spots on the leaves. Lesions appeared on leaves are greyish green in colour. The spots turn greenish with age and get bigger in size (1½" by 6"), finally attaining a spindle shape. Grayish black spores of the fungus develop abundantly on both sides of the spot in damp weather. Heavily infected field shows a scorched appearance. The disease is recognized by long elliptical grayish or tan lesions. The lesions appear first on the lower leaves and as the season progresses, the lesion number increases and all the leaves are covered. The plants look dead and grey resembling frost or drought injury.

Disease cycle:

The pathogen overwinters as mycelium and chlamydospores in diseased crop debris. It starts sporulating in cool/moderate humid conditions (18-27°C) and conidia are disseminated by wind and rain splash to freshly planted maize. Secondary cycles of disease occur through dissemination of conidia produced in the same season and to the adjoining fields by rain splash and wind.

Maydis leaf blight (MLB):

Distribution:

J&K, HP, Sikkim, Meghalaya, Punjab, Haryana, Rajasthan, Delhi, UP, Bihar, MP, Gujarat, Maharashtra, AP, Telangana ,Karnataka, Tamil Nadu. There are 3 physiological races of *C. maydis*: Race T, Race O and Race C. Race T and Race C are pathogenic only to maize germplasm with cytoplasm male-sterile T and cytoplasm male-sterile C respectively.

Diagnostic symptoms:

Symptoms of maydis leaf blight vary according to the causal race and host germplasm. Race O produces lesions that are initially small and diamond-shaped. These lesions elongate as they mature, although growth of lesions is restricted by leaf veins. Final lesions are rectangular (2-6 × 3 -22 mm), restricted by leaf veins, and tan in color. Lesions caused by isolates of Race O are restricted to leaves. In Race T, these are oval and slightly larger (6-12 × 6 -27 mm) than those caused by Race O. Lesion borders are usually characterized by dark, brown borders. Race T causes lesions on all above ground parts of the plant (including stems, sheaths and ears) and can also cause ear rots. Seedlings from seeds infected with Race T often wilt and die within 3 to 4 weeks after planting. Under severe disease pressure, usually when infection occurs prior to silking, lesions may coalesce, blighting the entire leaf.

Disease cycle:

The pathogen overwinters as mycelium in infected crop residue lying on the soil. Under favorable temperatures (20-30°C) and high humidity, mycelia within the crop debris produce conidia which are then disseminated to the crop through wind and rain splash.

Polysora Rust (PR):

Distribution: Coastal areas of Andhra Pradesh and Karnataka

Diagnostic symptoms:

The disease resembles common rust. The pustules appear on leaf are light cinnamon golden brown, circular to oval 0.2-2.0 mm long densely scattered on the upper surface of leaf.

The urediniospores are yellowish to golden. Development of pustules on lower surface is more as compared to upper surface. The telia are circular to elongate, covered by epidermis and longer than those of common rust.

Disease cycle:

Urediniospores of this fungus are windblown from previously infected corn leaves, and are blown progressively northward during the growing season. Although teliospores are roduced, they do not rupture the epidermis and have not been shown to germinate, and thus are unimportant in the disease cycle. Disease progress is most rapid when favorable temperatures of 77° to 80°F (25° to 28°C) and high humidity occur in fields of susceptible varieties.

Brown spot (BS):

Distribution:

J&K, HP, Sikkim, WB, Rajasthan, Punjab, MP and Karnataka

Diagnostic symptoms:

The pathogen attacks on leaves, leaf sheaths, stalks, and sometimes outer husk. The first noticeable symptoms develop on leaf blades and consist of small chlorotic spots, arranged as alternate bands of diseased and healthy tissue. Spots on the mid-ribs are circular and dark brown, while lesions on the laminae continue as chlorotic spots. Nodes and internodes also show brown lesions. In severe infections, these may coalesce and induce stalk rotting and lodging.

Disease cycle:

The fungus persists inside the host-tissue after harvest. During the next cropping season the sporangia spread as air-borne spores, releasing zoospores when sufficient moisture is present. The zoospores become attached to the young leaves and germinate to produce infection hyphae, which eat the host tissue to cause the characteristic spots.

Banded leaf and sheath blight (BLSB):

Distribution:

J&K, HP, Sikkim, Punjab, Haryana, Rajasthan, Delhi, UP, Bihar and MP

Diagnostic symptoms:

The disease appears on leaves and sheaths on 40-50 days old plants and later on spread to the ears. The characteristic lesions are first seen on lower leaves and sheaths (first and second) in the form of concentric bands and rings. The affected plant produces large, gray, tan or brown discoloured areas alternating with dark brown bands. Sclerotia later on appear in these diseased areas. The developing ear is completely damaged and dried up prematurely with cracking of the husk leaves. Brown rotting of the ears may develop which show conspicuous light brown cottony mold with small, round black sclerotia.

Disease cycle:

The fungus survives from one crop season to another through sclerotia and mycelia in plant debris, weed hosts and soil. Dormant mycelium in crop refuse may remain active in soil for almost a year. Survival of both sclerotia and mycelium depends on variable biotic and abiotic factors. The fungus is able to survive in soil during winters as sclerotia or as mycelium.

Common rust (CR):

Distribution: Bihar, Maharashtra, Karnataka, Tamil Nadu (Rabi), UP, Haryana, Assam, MP, AP and Telangana, Rajasthan, J&K, HP, Sikkim, WB, Tripura, Meghalaya, Punjab

Diagnostic symptoms:

Symptoms are oval to elongate cinnamon brown pustules scattered over upper and lower surfaces of the leaves. The pustules rupture and expose dusty red urediniospores, which are spread by wind and have the ability to infect other maize leaves directly. As the pustules mature, they turn brownish black and release the dark-brown overwintering teliospores. In severe epidemics, pustules may also appear on the ears and tassels, and the leaves may become yellow and easily tattered in strong winds. Partial resistance is expressed as chlorotic or necrotic hypersensitive flecks with little or no sporulation.

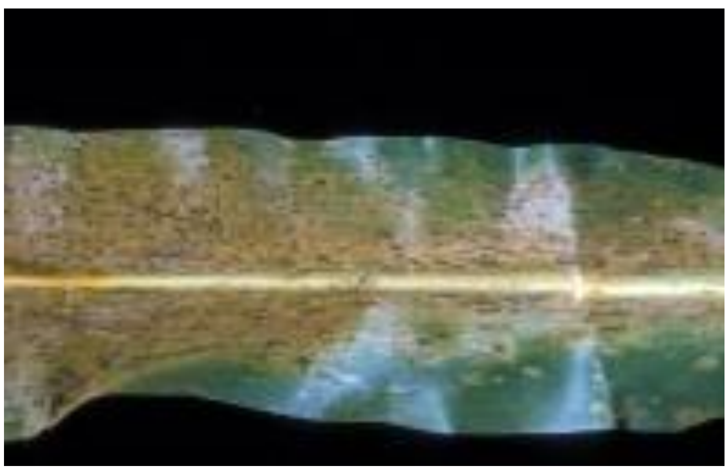
Disease cycle:

The life cycle of *P. sorghi* involves two hosts (maize and *Oxalis* species) and five spore stages (teliospores, basidiospores, spermatia, aeciospores and urediniospores). In tropical or subtropical regions, urediniospores can overwinter and serve as the primary source of inoculum in subsequent seasons. Urediniospores are disseminated by wind over vast distances (hundreds of kilometers) and frequently spread from tropical/subtropical regions to temperate regions in spring and summer when maize is cultivated. The sexual stage of the life cycle occurs predominantly in tropical and subtropical regions.

Turcicum leaf blight **Maydis leaf blight** **Brown spot**

Banded leaf and sheath blight Common rust
(Photo courtesy: Shekhar *et al* 2011)



Polysora Rust (Photo courtesy: https://wiki.bugwood.org/Puccina_polysora)

DOWNY MILDEWS

Brown Stripe Downy Mildew (BSDM)

Distribution: Himachal Pradesh, Sikkim, West Bengal, Meghalaya, Punjab, Haryana, Rajasthan, Uttarakhand, Bihar, Madhya Pradesh and Gujrat

Diagnostic symptoms:

Sclerophthora rayssiae var. *zeae* causes leaf lesions only. In early stages of infection leaves will show narrow chlorotic or yellowish stripes, 3 to 7 mm wide. In some maize genotypes, these stripes will be reddish to purple. The lesions have well defined margins and extend parallel with and are delimited by the leaf veins. Advanced striping and blotching occurs with confluence of adjacent lesions. The disease may first be noticed on the lower leaves, which will show the greatest degree of striping. The pathogen apparently does not systemically infect the plant.

Disease cycle:

The seed surface may carry plant debris containing viable oospores and the seed may carry oospores or mycelium within the embryo. Oospores in air-dried leaf tissue can remain viable for 3 to 5 years although infected seed dried to 14 per cent moisture or less and stored for 4 or more weeks will not be capable of transmitting the disease.

Brown Stripe Downy Mildew

Rajasthan downy mildew (RDM):

Distribution: Rajasthan and Surrounding areas

Diagnostic symptoms:

The typical symptoms are "*half diseased leaf*" which is characterized by the pale appearance of bases of second and third diseased leaves of the seedling. On infected leaves, yellow stripes at the base also extend up to upper green portion. Severely infected plants give yellowish appearance even from a distance. Most of the infected plants die at about knee-high stage. In some cases leaves tend to become yellow in colour, erect and closer in position on the stem. Systemically infected maize plants generally do not form cob and if formed, these are small, poorly filled and even if tassel appears, there is no pollen formation in anthers.

Disease cycle:

P. heteropogoni produces abundant conidia and oospores on leaves of *H. contortus* and *H. melanocarpus* which act as a collateral hosts, but produces only conidia on maize leaves. Oospores formed on grass are thus the primary source of inoculum which first infect the grass and then maize at 2-3 leaves stage. Systemically infected leaves of grass and maize produce abundant conidia in between 2.30 - 3.00 AM on both the surfaces.

Sorghum downy mildew (SDM):

Distribution:

Gujarat, Maharashtra, AP, Telangana, Karnataka and Tamil Nadu

Diagnostic symptoms:

Systemic infection of the disease appears in the seedlings soon after their emergence. The affected seedlings have pale yellow, narrow leaves covered with a fine downy growth consisting of the conidial stage of the fungus. Infected leaves have a downy growth more common on lower surface, toward the basal part. Owing to the formation of oospores, infected plants are chlorotic, stunted and sterile and have striped leaves.

Disease cycle:

Primary source of inoculum is oospores and sporangia (conidia) produced in soil and infected crop debris respectively. Oospores germinate at soil temperatures of >20°C in response to root exudates. The germ tube infects the underground sections of maize plants leading to characteristic symptoms of systemic infection. After colonization of host tissues, sporangia (conidia) are produced from sporangiophores (conidiophores) in stomata in night and are disseminated by wind and rain splash, and initiate secondary infections.

STALK ROTS
Pre-flowering stalk rots:
Bacterial stalk rot (BSR):
Distribution:

HP, Sikkim, WB, Rajasthan, UP, Bihar, MP, AP, Telangana, Delhi, Punjab and Haryana
Diagnostic symptoms:

Primary symptoms generally appear in mid season when plant suddenly falls over scattered in field. One to several internodes above soil level may be affected. Tan to dark brown, water soaked slimy lesions on leaf sheath and stalk appear. The infected tissues are macerated and emit foul odour. Affected plants may remain green for several days.

Disease cycle:

The bacterium lives saprophytically on infested residue in soil and is seed borne. The enzyme xylanase is produced by the pathogens which kill and macerate tissue in monocotyledons. The pathogen survives on infected plant debris up to one year.

Post-flowering stalk rots
***Fusarium* stalk rot (FSR):**
Distribution:

Jammu and Kashmir, Punjab, Haryana, Delhi, Rajasthan, Madhya Pradesh, Uttar Pradesh, Bihar,West Bengal, Andhra Pradesh, Telangana, Tamil Nadu and Karnataka, where water stress occurs after flowering stage of the crop

Diagnostic symptoms:

The symptoms become conspicuous when the crop enters senescence phase in dry and warm areas. There are no signs of the fungus that make it easily recognizable. The pathogen commonly affects the roots crown regions and lower internodes. When split open, the stalk shows pink-purple discoloration. The disease causes a permanent wilting, leaves become flabby and basal stalk tissues obtain a pinkish to purple tinge coloration. Pre-mature drying of green plants is a conspicuous symptom in the field.

Disease cycle:

F. verticillioides survives on crop residue in the soil or on the soil surface. Underfavorable condition, it may infect roots as well as stalk. *Fusarium verticillioides* may be present throughout the life cycle of the plant, originating from infected seed.

Charcoal rot (ChR):

Distribution:

J&K, WB, Rajasthan, Punjab, Haryana, UP, Bihar, MP, AP, Telangana Karnataka, Tamil Nadu and Delhi.

Diagnostic symptoms:

After flowering, initial symptoms are the abnormal drying of upper leaf tissue, stem lodging and premature death. At maturity, the lower stem internodes (usually limited to the first 5 nodes) show a typical charcoal, grey-black discoloration. When stem is cut open, numerous minute black specks (microsclerotia) are visible on the shredded vascular bundles and on the inside of the stem, giving the interior parts of the stem a charred appearance. Survival bodies or microsclerotia can best be seen through a magnifying glass or hand lens. Brown, water- soaked lesions, which later turn black are present on the roots. Infected kernels showing symptoms are pale yellow with black streaking below the pericarp, and the ear is loose and chaffy. Kernels are easily removed from the cob, and they show small, round, black, pinhead-like sclerotia on the surface.

Disease cycle:

M. phaseolina overwinters as sclerotia in the soil and can remain viable for several years. In dry and hot conditions fungi infect the roots of maize plants and colonize the lower stalk, eventually giving rise to characteristic symptoms (abundant, minute, black sclerotia and charring and shredding of the pith tissue).

Rajasthan downy mildewSorghum downy mildew Charcoal rot

EAR ROTS

Number of fungi invades the ear and kernels before harvest while in the field which affects the quality and appearance of kernels. The common fungi responsible for the ear rots in India are *A. flavus, Fusarium verticillioides, Gibberella, Trichoderma, Penicillium* etc. Among them *A. flavus* and *F. verticillioides* are important.

Aspergillus ear rot (AER):

Diagnostic symptoms:

Aspergillus may invade in field as well as in the storage causing ear and kernel rot. *A. flavus* form yellow green masses of spores while *A. niger* produces black powdery masses of spore on both cob and kernel.

Disease cycle:

The pathogen overwinters in infected crop debris. Mycelium in infected crop debris produce macroconidia and microconidia that are wind and rain splash disseminated, infecting ears through silks and colonizing kernels.

Fusarium stalk rot **Bacterial stalk rot** **Aspergillus ear rot**

Photo Courtesy: Fusarium stalk rot and Bacterial stalk rot (Shekhar *et al.*, 2011), Aspergillus ear rot-Denis C. McGee/Iowa State University

Integrated management of maize diseases

Integrated disease management (IDM) is an interdisciplinary way of disease management that uses various methods of disease control, energy conservation and environmental protection. Efficient means of disease management in maize include:

- Strict quarantine to prevent the entry of pathogens into fields through reducing the primary inoculum
- Effective crop rotation especially for soil borne disease control
- Preparation of raised beds generally allows for better drainage
- Seed treatment
- Optimization of agronomical practices like date of sowing, utilization of cover crop and maintenance of soil fertility (Kumar *et al.*, 2014)

- Utilization of tolerant /resistant varieties or hybrids
- Use of certified seeds free from pathogens

Integrated disease management (IDM) practices for important diseases of maize are given in Table 2.

Table 2. Integrated disease management practices in maize

S.No.	Name of disease	IDM Practices
Foliar diseases		
1.	TLB	1. Residue management through crop rotation and sanitation. 2. Use of resistant varieties/hybrids recommended for the concerned zone. 3. Seed treatment with fungicide *viz*., benomyl, carbendazim and oxycarboxin @ 2.5 g/kg seed or spraying with copper fungicides @3 g/L in the whorls of plant twice a week for four weeks before silking for management of brown spot disease (Shekhar *et al* 2011). 4. Foliar spray of mancozeb or zineb @ 2.5 g/L of water at first appearance of disease followed by 2 to 4 applications at 10 days interval (Shekhar *et al*., 2011). or Sprays of azoxystrobin 18.2% + difenoconazole 11.4% @ 1 ml/L for management of TLB (Veerabhadra swamy *et al*., 2014).
2.	MLB	
3.	BS	
4.	BLSB	1. Stripping of two basal leaves along with leaf sheath 2. Use of resistant varieties/hybrids recommended for the concerned zone. 3. Seed treatment with peat based formulation of *Pseudomonas fluorescence* @ 16 g/kg of seed or 2.5 kg /ha as soil application (Shekhar *et al*., 2011). 4. Sprays of azoxystrobin 18.2% + difenoconazole 11.4% @ 1 ml/L.
5.	PR and CR	1. Residue management through crop rotation and sanitation. 2. Use of resistant varieties/hybrids recommended for the concerned zone. 3. Cultivation of early maturing varieties. 4. Spray of propiconazole 75% EC @ 1.5 to 2 ml/L of water at first appearance of pustule (Shah and Dillard, 2003). or Spray of mancozeb @ 2-2.5 g/L of water at first appearance of pustule (Shekhar *et al*., 2011).
Downy mildews		
6.	BSDM	1. Planting before rainy season. 2. Field sanitation. 3. Rogueing and destruction of infected plants and alternate host (*Heteropogon* grass) in case of RDM. 4. Use of resistant varieties/hybrids recommended for the concerned zone. 5. Avoid maize-sorghum crop rotation in field and sowing of maize adjacent to a field of sorghum to avoid the spread of secondary infection. 6. Seed treatment with metalaxyl @ 2.5g/kg of seed in the endemic areas 7. Foliar spray of systemic fungicide such as metalaxyl @ 2.5 g/L of water at first appearance of diseases (Shekhar *et al*., 2011).
7.	RDM SDM	
Pre-flowering stalk rot		
8.	BSR	1. Avoiding waterlogging and ensuring proper drainage.

		2. Planting of the crop on ridges rather than flat soil. 3. Use of resistant varieties/hybrids recommended for the concerned zone. 4. Avoiding use of sewage water for irrigation. 5. Application of bleaching powder containing 33% chlorine @ 10 kg/ha or soil drenching with bleaching powder containing 33% chlorine @3g/10 L of water at pre-flowering stage.
Post-flowering stalk rot		
9.	FSR	1. Sanitation and removal of previous crop debris. 2. Lower plant population. 3. Balanced soil fertility with increased potash (up to 80kg/ha). 4. Use crop rotation with non-host crop like soybean. 5. Use of resistant varieties/hybrids recommended for the concerned zone. 6. Avoiding water stress at flowering time. 7. Seed treatment with *Trichoderma viride*+ carbendazim along with two additional irrigations at tasselling and silking stage reduced the disease incidence (Khokhar *et al*., 2014). 8. Management of borers.
10.	ChR	1. Deep ploughing, sanitation and removal of previous crop debris. 2. Crop rotation of at least three years. 3. Use of resistant varieties/hybrids recommended for the concerned zone. 4. Avoiding water stress at flowering time. 5. Balanced soil fertility, avoid high level of N and low level of K. 6. Add *Trichoderma harzianum* formulation after mixing with FYM @ 10 g/kg and incubate for 10 days in moist condition. This mixture should be used in furrows before sowing (Shekhar *et al.*, 2011).
Ear rot		
11.	AER	1. Utilization of biocontrol agents such as *Bacillus subtilis*, *Lactobacillus* spp., *Pseudomonas* spp. *Ralstonia spp*. and *Burkholderia* spp. are effective at control and management of aflatoxins (Palumbo *et al*., 2006) 2. Optimized agricultural practices will also help in control of the toxins to a larger extent, such as timely planting, providing adequate plant nutrition, controlling weeds and crop rotation, which effectively control *A. flavus* infection in the field (Ehrlich and Cotty, 2004; Waliyar*et al*., 2013). 3. Keep storage facilities clean and store grain with moisture content of <13%.

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Fall armyworm- Status and initiatives taken for its sustainable management in maize

J. C. Sekhar[1], P. Lakshmi Soujanya[1], S. B. Suby[2] and Sujay Rakshit[3]

[1]Winter Nursery Centre, ICAR-Indian Institute of Maize Research, Rajendranagar, Hyderabad - 500030, India

[2] ICAR - Indian Institute of Maize Research, Pusa Campus, New Delhi - 110 012, India

[3] ICAR-Indian Institute of Maize Research, PAU Campus, Ludhiana, Punjab - 141004, India

1. Introduction

Maize (*Zea mays* L.) is a potential crop for doubling farmer's income and is one of the most important cereals consumed as food, feed, fodder and industrial purposes. In India maize is grown in 9.2 mha with production of 28.75 mt. The country represents 4% of global maize area and 2% of global production. Maize was a rainy season (Kharif) crop predominantly in India. It was largely grown in northern India in the states of Uttar Pradesh, Bihar, Rajasthan and Madhya Pradesh. After 1980s a significant shift in area towards peninsular region was noticed. Currently this region represents nearly 40% of the total area under maize and over 52% of production. The major maize growing states are Karnataka (14.8%), Maharashtra (10.9%), Madhya Pradesh (10.8%), undivided Andhra Pradesh (10.4%), Rajasthan (10.6%), Uttar Pradesh (8.3%), Bihar (7.9%), Gujarat (5.0%) and Tamil Nadu (3.6%), accounting for nearly 80% of the total maize area of the country.

2. Distribution and Spread of FAW

Fall armyworm (FAW), is native to tropical and subtropical Americas and known as a pest in the United States since 1797. FAW moths were reported to fly 100 km per night (Johnson 1987), making it potential to invade large swath of land and large area. Simulations based on nightly flight activity of FAW combined with the time gap in the starting and stopping point of migratory path in the USA suggest the pest is aided by regional air transport systems (Westbrook et al. 2016). Outside Americas FAW first invaded Africa, reported from Sao Tome, Nigeria, Benin and Togo during 2016 (Goergen et al. 2016). Subsequently it spread to sub-Saharan Africa invading 44 countries by 2018 (www.cimmyt.org). In the absence of any control measures, FAW is predicted to cause 21-53% loss in annual maize production in Africa (Day et al. 2017). In 2018, the pest invaded Asia probably from Yemen due to its proximity to Africa. In India, its presence was confirmed in May 2018. Since then it has spread within the country and moved eastwards to countries bordering India, *viz.*, Sri Lanka, Bangladesh, Myanmar (December 2018, https://www.ippc.int), China (January 2019, https://www.ippc.int) and Nepal; and to Thailand (December 2018, https://www.ippc.int), South Korea and Japan by July 2019 according to the latest report (https://www.cabi.org/isc/datasheet/29810#todistribution).

The incidence of FAW in India was first observed in Shivamogga district of Karnataka on 18th May, 2018 (by UAHS, Shivamogga). Since then FAW gradually spread to various states. Rakshit et al. (2019) have documented the temporal spread of FAW within India since its report from the state of Karnataka in May 2018. By July, 2018 it was reported from Tamil Nadu and parts of Telangana and Andhra Pradesh (reported by State Agricultural Universities, SAUs). By August and September 2018, it further spread to Maharashtra, Chhattisgarh, and Madhya Pradesh and by September it reached Gujarat (reported by SAUs and DAC). By October 2018, FAW was reported from Bihar and West Bengal in east and from Rajasthan in West (reported by AICRP on Maize) (Fig. 11). It was observed in Kerala by December 2018 (reported by SAU). By March 2019, it reached in the NEH zone in Tripura and Mizoram (reported by DAC), and by

April 2019 it spread to Nagaland (reported by AICRP on Maize). By May 2019, it was recorded in Manipur, Meghalaya, Arunachal Pradesh and Sikkim (reported by ICAR Complex for NEH). Assam, Jharkhand and Uttar Pradesh reported FAW in June 2019 (reported by DAC). FAW incidence was reported in Uttarkhand (reported by AICRP on Maize) and Delhi (reported by ICAR-IIMR) on 31st July and by 6th August in Haryana (reported by AICRP on Maize) and 15th August in Punjab (reported by ICAR- IIMR). Till date, fall armyworm had spread to almost all states except Himachal Pradesh and Jammu and Kashmir.

3. Host Range

FAW is a highly polyphagous pest. Montezano et al. (2018) reported 353 host species for FAW belonging to 76 plant families. Maximum number of host taxa (106) belongs to Poaceae family, followed by 31 taxa each to Asteraceae and Fabacea families. Hardke et al. (2015) reported that though the pest can attack large number of cultivated species, it can cause maximum damage to maize and sorghum. Early et al. (2018) recorded FAW to feed on 182 plant species from 42 families. However, it is primarily a pest of grasses, *i.e.* prefers plant species of Poaceae family, in which maize, rice, sorghum, millets, wheat, oat, fodder and pasture grasses are damaged economically. Non-graminaceous crops, *viz*., soybean, alfalfa and cotton are also economically affected by FAW (Murua et al. 2006, Nagoshi et al. 2018). FAW consists of two strains, *viz.*, corn strain "C" which feeds predominantly on maize, sorghum and cotton; and rice strain "R" which prefers rice and turf grass dominated habitats (Juarez et al. 2014, Nagoshi and Meagher 2016). In India, FAW damage has been documented in sorghum, sugarcane and other millets etc. However, maize is its first preference.

4. Damage by FAW

FAW attacks all crop stages of maize from seedling emergence (V2) to ear development (R6). The young larvae of FAW feed on the opened leaves by scraping and skeletonizing the upper epidermis leaving a silvery transparent membrane resulting into papery spots. The damage also results in pinhole symptoms on the leaves. Later on the larva enters the whorl and start feeding between the leaves. The damage by late instars (3rd instar onwards) result in extensive defoliation of leaves and presence of large amounts of faecal pellets in whorls. Damage during vegetative stage leads to leaf damage but if damage happens during reproductive stage it may infest tassels or may bore inside the cob and eat away the grain. The whorl damage by FAW results in significant yield losses while ear feeding results in both quality and yield reduction.

5. **Initiatives for the management of fall armyworm**

Soon after the report of FAW in India, ICAR mainly through its two institutes, *viz.*, ICAR-Indian Institute of Maize Research (ICAR-IIMR), Ludhiana and ICAR-National Bureau of Agricultural Insects Resources (ICAR-NBAIR), Bangalore, took pro-active measures to contain the damage by FAW. ICAR coordinated with Department of Agricultural and Cooperation, Ministry of Agriculture and Farmers Welfare, Govt. of India towards development of policy interventions to contain the spread and damage by FAW. ICAR-IIMR through its AICRP on Maize network took comprehensive steps to create awareness among the stakeholders as well as policy makers to control the spread and damage by FAW. ICAR-NBAIR and its AICRP on Bio-control partners took extensive measures to control the damage by FAW through biological means. Various modules developed by ICAR-IIMR and ICAR-NBAIR together being implemented through the above two AICRP networks and the network of KVKs under ATARI, Hyderabad, Zone X.

Since the conformation of fall armyworm attacking maize in India, ICAR has undertaken several initiatives to strengthen capacity of the country to respond to fall armyworm attack through ICAR–IIMR, ICAR-NBAIR, AICRP centres. Major initiatives by ICAR-IIMR are given below.

Date	**Action**
Aug 3, 2018	Preliminary management schedule of FAW prepared and sent by Director ICAR-IIMR to Mandya and Coimbatore centres
Aug 7, 2018	Director ICAR-IIMR issued FAW alert to AICRP on Maize Centres and advised to start surveillance
Aug 9, 2018	Meeting in Bengaluru with state agriculture department officials and scientists of CIPMC, ICAR-IIMR and ICAR-NBAIR to discuss management options for FAW under the chairmanship of Joint Director (PP), DPPQ&S
Aug 10, 2018	Management schedule finalized and communicated by Director ICAR-IIMR to DAC&FW
Aug 20,2018	Meeting in Delhi to discuss the outbreak of FAW under chairmanship of Secretary DARE and DG, ICAR
Aug 26, 2018	Fresh management schedule of FAW issued by Director ICAR-IIMR to AICRP on Maize centres adding more chemicals
Aug 28, 2018	Pre-Rabi advisory on FAW management was prepared by ICAR-IIMR for DAC&FW–ICAR interface 2018-19
Sep 26, 2018	CABI – ICAR meeting in Delhi for collaborative Project Proposal (2018-2020) on deployment of proven IPM technologies against FAW
Oct 1, 2018	IPM for rabi season was prepared by ICAR-IIMR with inputs from NBIAR and sent to ADG PP&B
Oct 3, 2018	FAW alert was issued to Director, Agriculture of Bihar govt. and SAU/CAU in Bihar by Director ICAR-IIMR
Nov 2, 2018	Integrated pest management (IPM) schedule for FAW was developed by ICAR-IIMR in collaboration with NBAIR and circulated to AICRP centres
Nov 5, 2018	Director ICAR-IIMR issued FAW alert with IPM schedule to Directors of Agriculture of Zone I, II, III and V
Nov 11, 2018	FLDs on management of FAW were initiated. Two hundred fifty pheromone traps and 800 lures for mass trapping and monitoring of FAW were distributed in Telangana by ICAR-IIMR
Nov 16, 2018	Director ICAR-IIMR conducted meeting on management of FAW with Director, Agriculture and district officials in West Bengal
Nov 29, 2018	Director ICAR-IIMR attended meeting on management of FAW with district agriculture officers of Bihar at Patna
Jan 8, 2019	FAW management package of practice was supplied to DAC, which was adopted in office memoranda dt. May 6, 2019, updated August 16, 2019
Jan 30, 2019	Director ICAR-IIMR issued FAW alert for spring maize for AICRP centres
Feb 10, 2019	To monitor entry of FAW in spring maize pheromone traps were supplied to AICRP Maize centers of NWPZ
Feb 27, 2019	An alert on the possible incidence of FAW was issued to Mizoram Govt. by

	Director, ICAR-IIMR
March 1,2019	ICAR-IIMR organized an interactive session on FAW awareness and management with 26 AICRP on Maize centres at WNC, ICAR-IIMR, Hyderabad
March 12, 2019	FAW management trials at WNC IIMR, Hyderabad was visited by DDG(CS), ICAR and Joint Director (PP), DPPQ & S
April 10, 2019	The incidence of FAW was confirmed in Mizoram by ICAR-IIMR team and documents on FAW identification and management schedule was sent to the state by Director, ICAR-IIMR
April 24, 2019	A quick action strategy as well as integrated pest management module was sent to Director of Agriculture Research and Education, Govt. of Mizoram by Director ICAR-IIMR
May 7, 2019	Director ICAR-IIMR sent advisory on the management of FAW to Director of Agriculture of all the NE states
May 24, 2019	Director ICAR-IIMR sent advisory on the management of FAW and forwarded links of SAWBO Video on "How to identify and scout for fall armyworm" to Director Agriculture and Horticulture of all states. Also sent folder on "Identification and management of Fall armyworm" developed by ICAR-IIMR.
June 20, 2019	For FAW monitoring in Kharif maize, pheromone traps were supplied to all AICRP centres
July 25, 2019	Management strategies for FAW were reviewed under the Chairmanship of Agriculture Commissioner. Biopesticides were distributed by ICAR-IIMR to AICRP Entomology Centres under Peninsular Zone for the management of FAW
Aug 5, 2019	Revised Package of practices for FAW management with inclusion of few new interventions by DAC&FW
Aug 15, 2019	Punjab Agricultural University was alerted regarding detection of FAW at Ludhiana fields
Aug 17, 2019	Survey of maize fields in Punjab by team of ICAR-IIMR and AICRP on Maize, PAU was conducted. Director ICAR-IIMR issued alertness on scouting and control of FAW to Director of Agriculture Bihar, Director of Research, Samastipur and Bhagalpur, Bihar
October 1, 2019	
October 31, 2019	

6. Information Education and Communication Initiatives against FAW

As soon as the pest was reported, the network research system of All India Co-ordinated Research Project (AICRP) on Maize and Bio-control were alerted to scout for the pest and pictures of damage symptoms and pest were shared on android platforms. Regular surveys, surveillance and monitoring were conducted by the Central Integrated Pest Management Centres (CIPMCs) in collaboration with the State Department of Agriculture, SAUs and ICAR institutes.

A. Inter-phase Meetings with State Government

AICRP centres functioning under various SAU's held consultative inter-phase meetings with State Government officials to ensure coordinated response for effective action in response to the rapid outbreak of fall armyworm. Survey of the existence of fall armyworm in maize crop was conducted by constituting State Level Teams comprising of Scientists from different AICRP Centres, CIPMC and Plant Protection Officers of DDA (PP) and State Govt. Officials. Teams visited the fall armyworm infested plots immediately after getting the information about the incidence. All the AICRP centres constituted survey team for different districts and reported to Government.

B. Training programmes

IIMR in coordination with its AICRP centres sensitized towards information dissemination in different training programmes. Campaigning and awareness programmes are being conducted in different states. Awareness was also created by field functionaries in the village level by conducting group meetings. Further efforts are also going on for proper monitoring, awareness and sustainable management of fall armyworm following IPM strategies. Till now ICAR institutes with its coordinating networks have organized 589 major training programmes across the country, where 100 programmes were organized by ICAR-IIMR and/or its AICRP on Maize partners benefitting 11564 personals, 24 by ICAR-IIMR and ICAR RC for NEH benefitting 1782 personals and 30 programmes were organized by ICAR-NBAIR and AICRP Biocontrol centres benefitting 1770 personals, respectively. In addition to this, ICAR-KVKs have been actively involved with state functionaries and NGOs in organizing awareness programmes on FAW management. A total of 407 training programmes were conducted on awareness of FAW by KVK's in Zone X under ATARI, Hyderabad benefitting 33,132 personals.

C. Extension Folders/Leaflets/Pamphlets

IIMR and its AICRP Maize centres have prepared folders/leaflets/pamphlets on the identification and management of fall armyworm and issued advisories. Advisory has been developed based on ICAR-IIMR advisory from the side of the State Department and sent to all concerned authorities for necessary action for the management of fall armyworm. ICAR -IIMR prepared extension folder titled "Identification and management of fall armyworm (*Spodoptera frugiperda*)" in English and translated to Hindi and Punjabi languages.

D. Radio/TV talks

AICRP centres on Maize and Biological Control actively participated in 21 radio/TV talks on FAW in various languages which helped in dissemination of the awareness and information on FAW.

E. Awareness through mass media

Tremendous efforts have been made by IIMR and its AICRP centres in collaboration with State Government officials towards creating awareness of fall armyworm to the maize growing community. The information has been disseminated in big way through media/ news papers.

7. Research Initiatives

On the research side, ICAR-Indian Institute of Maize Research (ICAR-IIMR), Ludhiana and ICAR-NBAIR started a collaborative action where IIMR is working on mass awareness, pest forecasting and management of fall armyworm, whereas NBAIR is working on identification and mass production of biological control agents and microbial pesticides. Integrated pest management schedule was prepared by ICAR-IIMR and ICAR-NBAIR. The same was updated from time to time and circulated through a hierarchy of stake holders through DAC. Cultural techniques, life cycle studies and response of existing lines and land races against FAW has been worked out. Six multi location trials have been constituted by ICAR-IIMR based on the inputs from both ICAR-IIMR and ICAR-NBAIIR, where monitoring the pest in 32 AICRP-Maize centres using ICAR-NBAIR slow releasing dispensor is the notable one, which was aimed at developing a forecasting model for the pest.

8. Collaborations

1. ICAR-IIMR is in collaboration with ICAR-NBAIR to evaluate biocontrol technologies in maize. It is also in collaboration with ICAR-National Centre on Integrated Pest Management (ICAR-NCIPM) to validate and deploy the IPM technologies.
   ICAR-IIMR is also in collaboration with private partners to evaluate chemical pesticides, mating disruption techniques using FAW pheromone and development for FAW forecasting model.

2. ICAR-IIMR is in constant touch with international organizations, especially CIMMYT to share the experiences, germplasm exchange etc. ICAR-NBAIR is in collaboration with CABI in deploying biological control technologies.
3. ICAR-IIMR collaborated with the University of Michigan and SAWBO, to translate SAWBO animated video on FAW identification, scouting and management into different Indian languages (Hindi, Punjabi, Gujarati, Telugu, Kannada, Tamil, Odiya, Bengali, Marathi, Manipuri, Mizo, Nagamese, Malayalam). These are available online in the following links. Apart from this, Malayalam and Marathi translations of the same were coordinated by ICAR-KVK and 6 Grain corp. respectively.

- Hindi - https://youtu.be/LlNDUhFCBTs
- Bengali- https://youtu.be/FjIF43ViQEw
- Gujarati- https://youtu.be/s7CcvyaxX7g
- Punjabi- https://youtu.be/4twy79A0Tcc
- Tamil- https://youtu.be/6P2NvZBNDb0
- Telugu- https://youtu.be/DU2lDjnTDLY
- Kannada- https://youtu.be/FwNe4Q-BZT8
- Odia- https://youtu.be/jqE1esjE5_4
- Manipuri- https://youtu.be/_kkbOOxdQxI
- Mizo- https://youtu.be/w0r8j--ZEzo
- Marathi - https://youtu.be/fprog39tUmM
- Malayalam- https://youtu.be/PIZCDvq7kNI
- Nagamese- https://youtu.be/rR81gTgquzc

It can be concluded that fall armyworm has spread all over India except Himachal Pradesh and Jammu and Kashmir and has potential to stretch to other crops such as wheat, rice, sugarcane, sorghum, cotton, pigeon pea and vegetables. Intensive studies, rapid and coordinated action, enormous awareness creation, technological innovation, national, regional and international collaborations are required to tackle the intensity of fall armyworm.

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Identification, Biology, Symptomatology, Monitoring and Scouting for Management of Fall Armyworm

Suby S.B., Lakshmi Soujanya P., Sekhar J.C.
ICAR- Indian Institute of Maize Research, Ludhiana, Punjab-141004, India

Introduction

Maize is infested by over 130 insects from sowing till harvest, of which three insect pests, *viz*., spotted stem borer (*Chilo partellus* Swinhoe), pink stem borer (*Sesamia inferens* Walker) and shoot fly (*Atherigona* spp.) were of major consequences (Sarup *et al*., 1978, Reddy and Trivedi 2008) till the report of the invasive pest fall armyworm (*Spodoptera frugiperda* J. E. Smith) in May 2018. Fall armyworm (FAW) is native to Americas and is known as a pest in the United States since 1797. It invaded Africa in 2016, where in a span of two years it has spread to 44 countries (www.cimmyt.org). Since its invasion in May 2018 in India, its rapid spread to more than 90 % of maize growing area of diverse agro-ecologies in a span of 16 months presents a major challenge to small holder maize farmers, maize based industry, as well as food and nutritional security. There is no single tool available for controlling FAW, but Integrated Pest Management (IPM) is mooted as a crop protection package to keep FAW population below economic threshold level. Regular monitoring of a pest is the basis of IPM decision making, where, information on identity, current stage in the life cycle of a pest and severity of its damage is gathered. This will help to decide the IPM tool to be used for the time. The chapter elaborate on identification, biology, symptomatology, monitoring and scouting for management of FAW in maize.

Identification

The larvae of fall armyworm appear in shades of green, olive, tan and grey with four black spots in each abdominal segment (Fig. 2) and has three creamy yellow lines running down its back (Fig. 2 d, e & f). It is easily identified from any other armyworm species by its tail end, where the black spots are bigger and arranged in square pattern on abdominal segment 8 (Fig. 2 a) and trapezoid on segment 9 (Fig. 2 b). The head has a predominant white, inverted Y - shaped suture between eyes (Fig. 2 c). Male moth has two characteristic markings, *viz*., a fawn colored spot towards the centre and a white patch at the apical margin of forewing (Figure 3A). Forewing of female is dull with faint markings (Figure 3B).

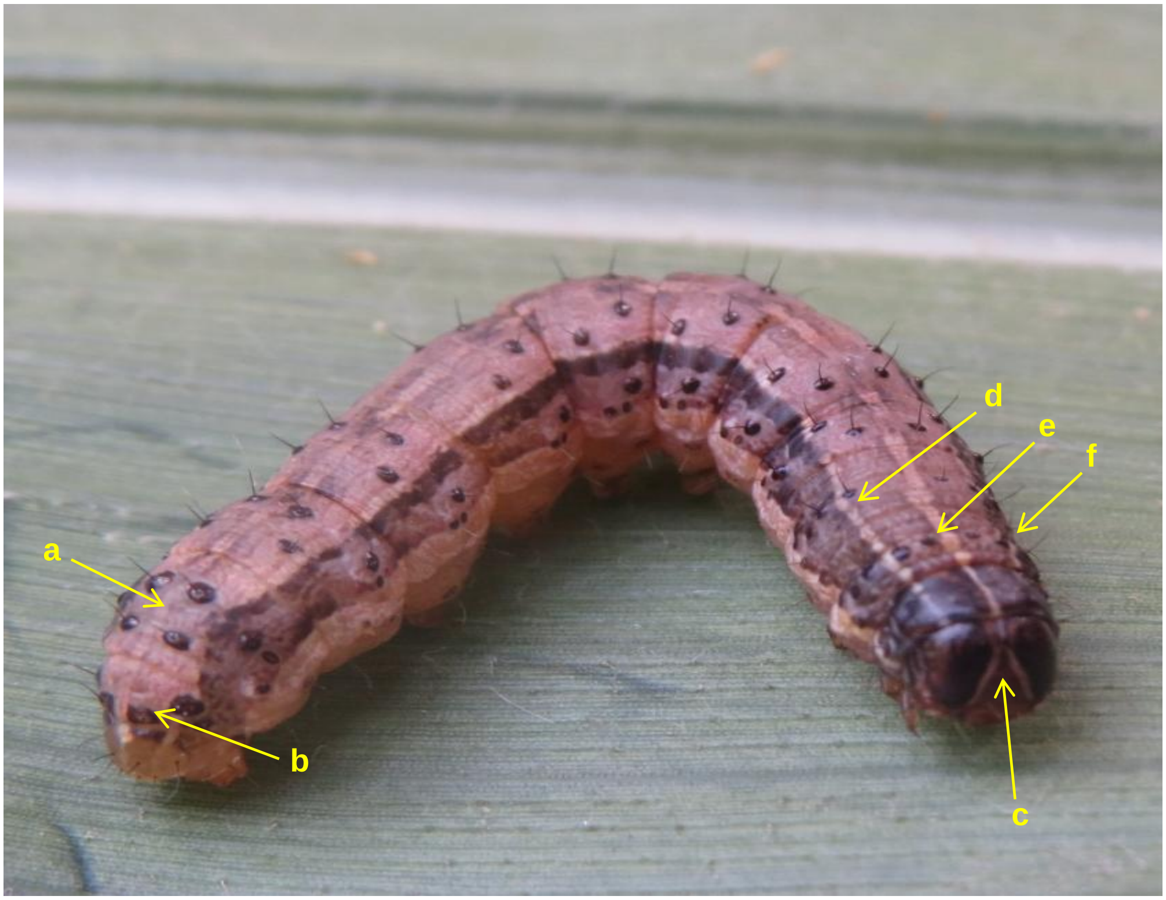

Fig. 2. Fall armyworm larva with characteristic identification marks, *viz*., four bigger spots arranged in square on abdominal segment 8 (a) and trapezoid on abdominal segment 9 (b), white Y- shaped suture on head (c) and three prominent lines on back (d, e & f).

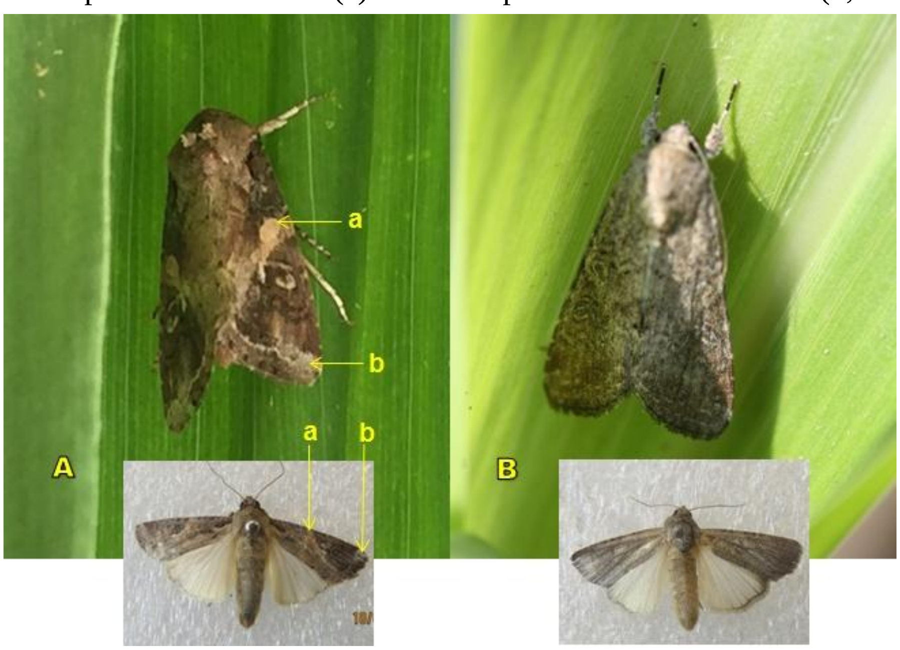

Fig. 3. Fall armyworm Male moth (A) has fawn coloured spot (a) and white a patch (b) at the apical margin of the wing. Female (B) is dull with faint markings

Fall armyworm's life cycle

A female moth lays over 1000 eggs in single or multiple clusters, covered with hairs (Figure 3A a). Incubation period varies from 4.30±0.57 to 5.67±0.58 days. New born larvae in groups disperse from the hatching site and reach to feed on epidermal layers of lower surface of young leaves. Larvae undergo 6 stages called instars (Figure 4 B 1st to 6th) in its growth of 14.33±0.58 to 17.60±0.57 days and then undergo pupation. Pupa is reddish brown in colour (Figure 4 A c) and takes 7.33±0.58 to 8.30±2.30 days to emerge into adult moth (Figure 4A d). Adult moth can survive 3.67±0.58 to 6.30±1.52 days. The total life-cycle takes 30.67±1.15 to 34.60±2.88 days (Figure 4 A) as observed from August to January under natural rearing conditions in ICAR-IIMR Winter Nursery Centre, Hyderabad. Only the larval stage of FAW damages maize.

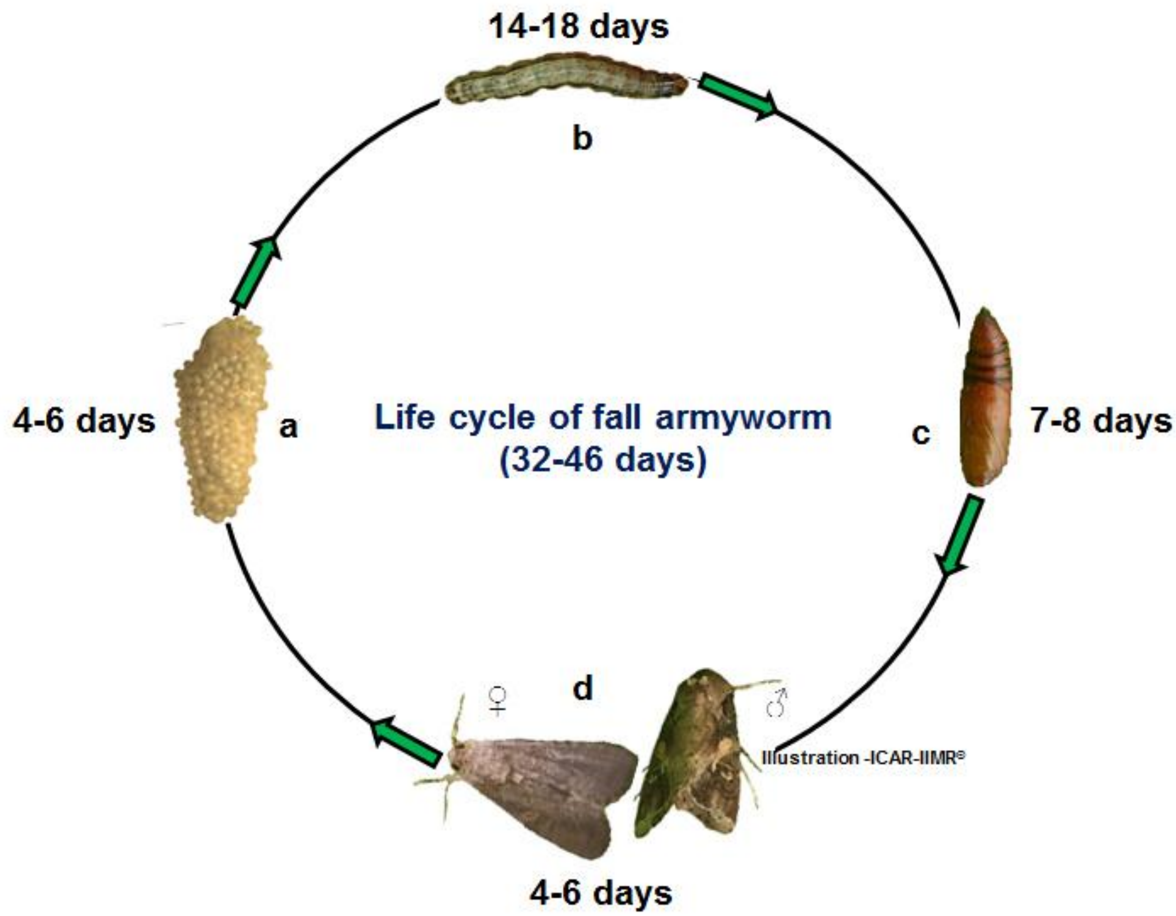

Fig. 4 A Life-cycle of fall armyworm a. Egg mass; b. Larva; c. Pupa; d. Adult female (♀) and male (♂) moths.

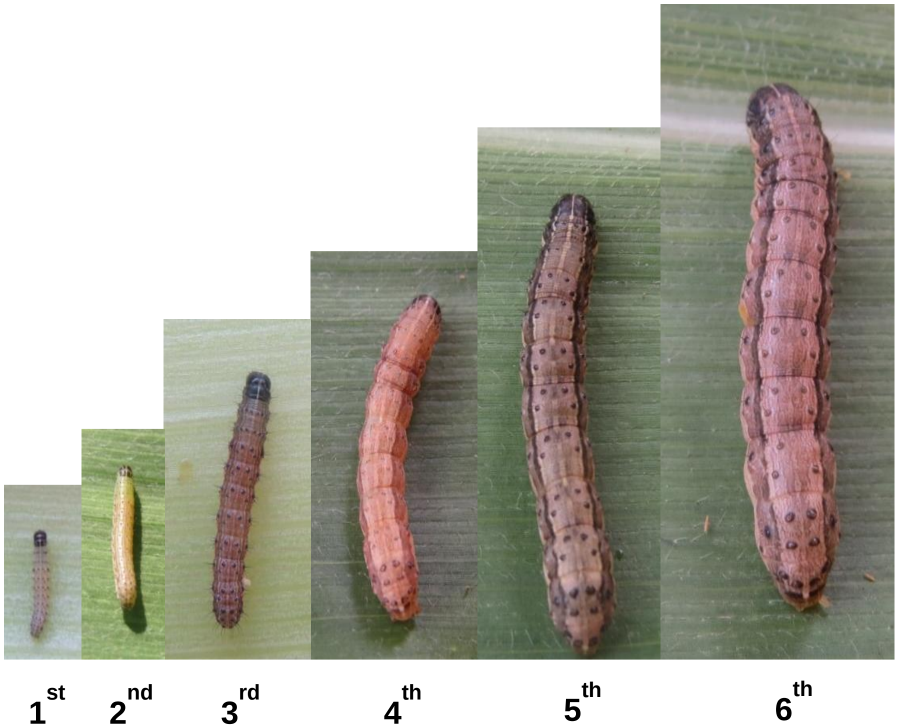

Fig. 4 B. First (1st) to sixth (6th) larval instars of fall armyworm

Symptomatology

FAW attacks all crop stages of maize from seedling emergence to ear development. First and second instar larvae of FAW feed on the opened leaves by scraping and skeletonising the upper epidermis leaving a silvery transparent membrane resulting into papery spots (5 A). The damage by third instar results in shot hole symptoms on the leaves (5 B). The size of the holes increases as the larva grows and damage by late instars results in extensive defoliation of leaves and presence of large amounts of faecal pellets in whorls (5 C, D & E). If infestation continues during reproductive stage, it may damage tassels (Fig. 6 A) or may bore inside the developing ear (Fig. 6 B) and eat away the grain (6 C). The whorl damage by fall armyworm result in significant yield losses while ear feeding results in both quality and yield reduction.

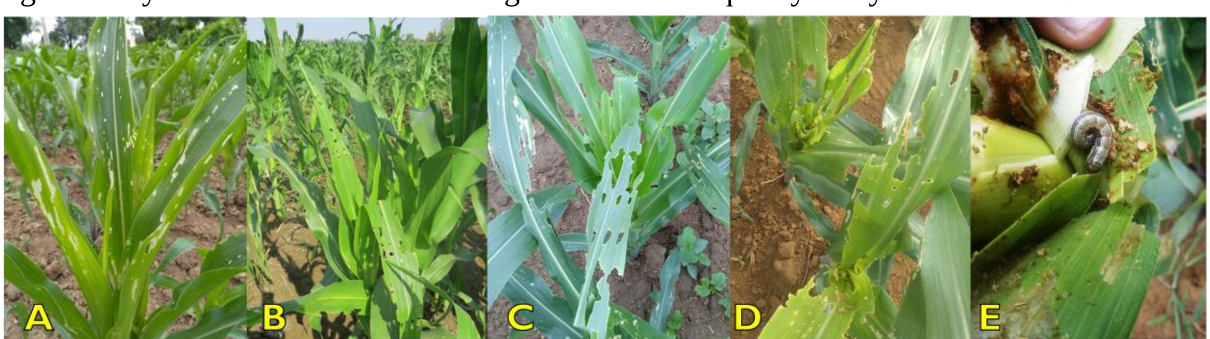

Fig. 5 Progression of symptoms of FAW infestation a. 1st and 2nd instar, b. 3rd instar c. 4th instar d. 5th instar e. 6th instar

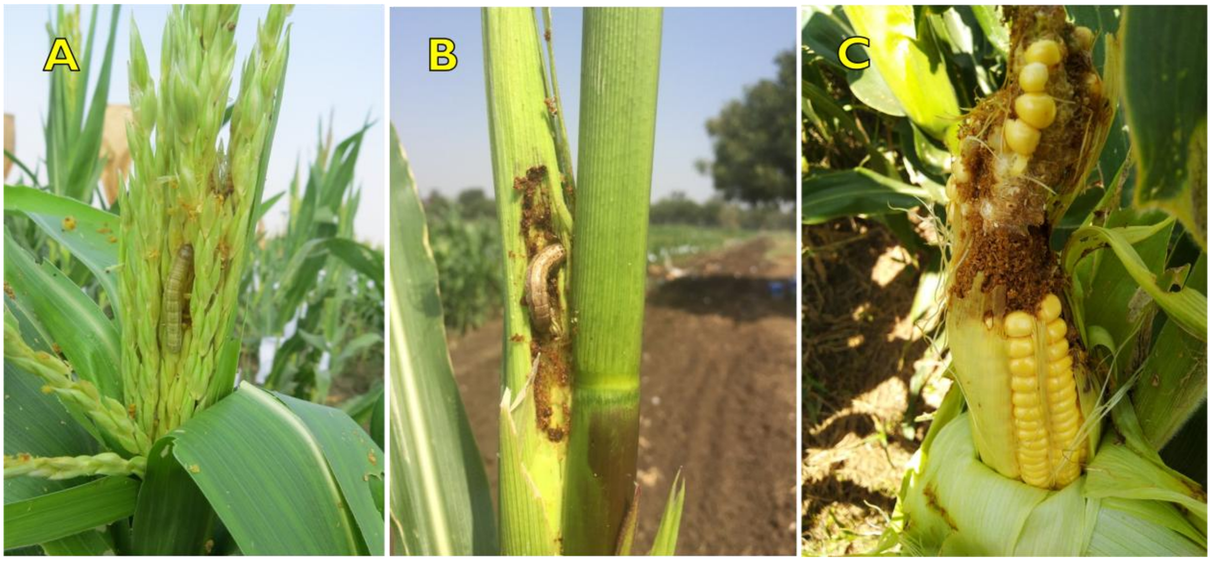

Fig. 6 Damaged Tassel (A) and developing ear (B) and sweet corn (C) by FAW larvae

Monitoring

Early detection and adoption of control measures at the earliest is the motto of FAW management. This is because first to third instar larvae of FAW are quiet small and eat less than 2% of the total foliage consumed in its life cycle, while as it grows to 6th instar, it devours 77% of the total consumption (Sparks 1979) in a span of 2-3 days. Since the severity of damage depends upon size of larvae, the choice of pest control intervention is chosen upon the prevailing symptom. Thus for early detection, monitoring the arrival of moths and its current population is done by installation of pheromone traps @ 4/ac before germination of the crop. On observation of one moth/trap/day or 5% FAW infestation on crop, spray with 5% neem seed kernel extract (NSKE) or azadiractin, 1500 ppm (1 litre/acre) @ 5ml /litre is recommended as the first intervention since it reduce egg hatchability, harm early instar larvae by antifeedant action and direct mortality, and repel gravid females for sometime from egg laying.

Scouting

A few plants showing FAW damage need not warrant pesticide application; it would not be economical. Also, the threshold level of infestation for deciding control measures increases with crop growth, since the foliage compensation ability of maize increases with growth. Action threshold is determined by 'scouting' which is closely observing/ sampling plants by walking in such a way to cover entire filed. A simple method is by walking in "W" pattern in the field after leaving 4-5 outer rows. Observe 10 plants at each stopping point representing the corners of "W" (Figure 7) and record the number of damaged plants.

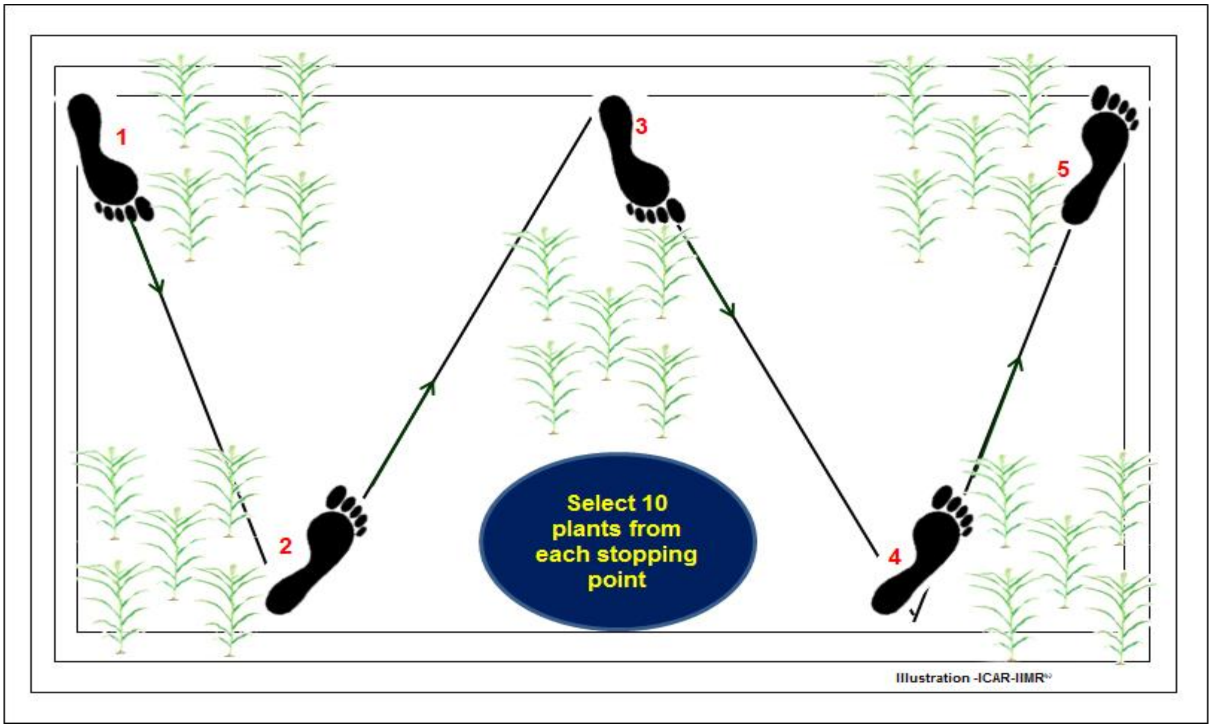

Fig. 7 Scouting methodology to determine action thresholds for management of fall armyworm

Derive the percent infested plants at each stopping point. For instance, if one plant is infested out of ten plants sampled, the percent infestation is 10%. Derive average percent infestation of all stopping points. It warrants a pesticide spray if the average percent infestation is 10% at seedling to six leaf stage, but 20% if the six leaf stage stage is crossed. Scouting should begin as soon as plants germinated or by indication of arrival of FAW by pheromone trap. Scouting should be conducted every week and should continue until the crop is harvested or the risk of pest pressure has passed as in harsh winter and summer months of North India.

Conclusion

The most reliable, but challenging aspect of FAW IPM is early detection of symptoms and determination of action thresholds. For this, scouting must be stressed in extension programmes. The information on the same has been disseminated through various media. However, the most potential one is the animated video at https://youtube.com on FAW identification, scouting and management by Scientific Animations Without Borders (SAWBO), University of Michigan. SAWBO made it available in Hindi, Punjabi, Gujarati, Telugu, Kannada, Tamil, Odiya, Bengali, Manipuri, Mizo and Nagamese in collaboration with ICAR-IIMR and in Malayalam and Marathi in collaboration with ICAR-KVK and 6Grain corp., respectively.

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Management of Fall Armyworm in Maize through Integrated Pest Management

Suby S.B.[1], Lakshmi Soujanya P.[1], MLK Reddy[2], Vennila S.[3], J.C. Sekhar [1], Sujay Rakshit[1]

[1]ICAR- Indian Institute of Maize Research, Ludhiana, Punjab-141004, India
[2]Professor Jayashankar Telangana State Agricultural University, Hyderabad- 500020
[3]ICAR- National Centre for Integrated Pest Management, New Delhi-110012, India

Introduction

Maize is infested by over 130 insects from sowing till harvest, of which the native insect pests, *viz*., spotted stem borer (*Chilo partellus* Swinhoe), pink stem borer (*Sesamia inferens* Walker) and shoot fly (*Atherigona* spp.) and the invasive pest fall armyworm (*Spodoptera frugiperda* J. E. Smith) pose major consequences. Fall armyworm (FAW), a native of Americas, invaded Africa in 2016, and subsequently entered Asia in May 2018 in India. FAW is considered the most destructive invasive pest in recent times owing to its rapid spread and threatening livelihoods depended on maize, the most remunerative grain crop globally. There is no single tool available for controlling FAW, but Integrated Pest Management (IPM) as a crop protection package is recommended to keep FAW population below economic threshold level. IPM is an eco-friendly approach that focuses on long-term management of pests through a combination of techniques such as deployment of resistant varieties, modification of cultural practices, habitat manipulation and biological control.

In this chapter, tools of IPM and its integration, and guides on action threshold based management is discussed.

Tools of Integrated Pest Management

- **Monitoring**: Installation of pheromone traps @ 4/acre in the current and potential area of spread in crop season and off-season.
- **Scouting:** Start scouting as soon as maize seedlings emerge. Action thresholds and interventions are discussed in Table 1.
- **Cultural Measures:** Cultural measures include tillage and other agronomic practices like intercropping, trap cropping, clean cultivation, balanced use of fertilizers, etc. .
- **Mechanical control:** Hand picking and destruction of life stages of the pest, application of abrasive substances like sand, dry sand, mass trapping of male moths using pheromone traps, etc. are options under this category.
- **Bio Control:** *In situ* protection of natural enemies, and erection of bird perches etc. are conservation biocontrol options. This is complemented with augmentative release of parasitoids and applications of microbial and botanical pesticide formulations.
- **Chemical Control:** This encompasses seed treatment, foliar spray and poison baiting etc. with recommended chemical pesticides

Integration of different tools in pest management based on crop stage

IPM encompasses different tools logically integrated in synchrony with crop phenology. It starts well before sowing.

Pre-planting practices

- Deep plough the fields to expose pupae to sun light and predatory birds
- Add neem cake @ 200kg/acre to the fields when maize is grown with zero tillage or wherever possible

- Maintain field bunds clean and plant flowering plants such as marigold, sesame, niger, sunflower, coriander, fennel etc. to attract natural enemies

Sowing to six leaf stage

- Timely and uniform sowing over larger area
- Follow ridge and furrow planting method instead of flat bed sowing
- Apply only the recommended dosage of NPK as basal dose
- Seed treatment: Cyantraniliprole 19.8% + Thiamethoxam 19.8% FS @ 6 ml/kg of seed offers protection for 15-20 days of crop growth **$**
- Plant 3-4 rows of napier grass/hybrid napier as trap crop around maize fields
- Intercrop maize with legumes *viz.,* pigeonpea, cowpea, black gram, kidney bean etc. in 2:1 to 4:1 ratio
- Erect bird perches @10/acre to encourage natural FAW predation by birds
- Install pheromone traps @ 4/acre soon after sowing and monitor moth catches**#**
- Adopt clean cultivation to eliminate possible alternate hosts
- Destruction of egg masses and larvae by crushing
- Application of sand or soil mixed with lime in 9:1 ratio into whorl of maize plants
- First spray should be with 5% neem seed kernel extract (NSKE)^ or azadiractin, 1500 ppm (1 litre/acre) @ 5ml /litre after observation of one moth/trap/day or 5% FAW infestation on trap crop or main crop
- If monitoring indicates more than one moth/trap/day install pheromone traps @ 15/acre for mass trapping [*Note: For success of mass trapping go for community action*] **OR** release egg parasitoids *viz.,Telenomus remus* @ 4000/ acre or *Trichogramma pretiosum* @ 50,000/acre. Two releases of parasitoids at weekly interval should be done. [*Note: Release of parasitoids should not be opted if mass trapping is followed*]
- At 5-10% infestation whorl application of *Bacillus thuringiensis* v. *kurstaki* formulations (400g/acre) @ 2g/litre or *Metarhizium anisopliae* or *Beauveria bassiana* with spore count of 1×10^8 cfu/g (1 kg/acre) @ 5g/litre or SfNPV (600 ml/acre) @3ml/litre or entomopathogenic nematode (EPN) (4kg/acre) @10g/litre of water is recommended
- If infestation is more than 10%, whorl application of anyone of the recommended insecticides with label claim , *viz.,* Chlorantraniliprole 18.5 SC (80 ml/acre) @ 0.4 ml/litre or Thiamethoxam 12.6 % + Lambda cyhalothrin 9.5% ZC (50ml/acre) @ 0.25 ml/litre or Spinetoram 11.7 % SC (100ml/acre) @ 0.5 ml/litre

Seven leaf stage to flowering

- Monitoring of FAW using pheromone traps @ 4/acre should be continued**#**
- Spray 5% NSKE^ or azadiractin, 1500 ppm (one litre/acre) @5 ml /l after observation of one moth/trap/day or 5% of fresh FAW infestation
- If infestation is more than 10%, whorl application of *Bacillus thuringiensis* v. *kurstaki* formulations (400g/acre) @ 2g/litre or *Metarhizium anisopliae* or *Beauveria bassiana* with spore count of 1×10^8 cfu/g (1 kg/acre) @ 5g/litre or SfNPV (600ml/acre) @3ml/ litre or entomopathogenic nematode (EPN) (4kg/acre) @10g/litre of water is recommended
- If infestation is more than 20%, spray with anyone of the recommended insecticides with label claim *viz.,* Chlorantraniliprole 18.5 SC (80 ml/acre) @ 0.4 ml/litre or Thiamethoxam 12.6 % + Lambda cyhalothrin 9.5% ZC (50ml/acre) @ 0.25 ml/litre or Spinetoram 11.7 % SC (100ml/acre) @ 0.5 ml/litre

- Poison baiting is effective for late instar larvae and is optional. Mix 10 kg rice bran + 2 kg jaggery with 3 litres of water. Keep the mixture for 24 hours to ferment. Add anyone of the recommended insecticides mentioned above at their recommended dosages and 1 kg of sand just half an hour before application. Make into small pellets and apply into whorls of infested plants only. [Use hand gloves during mixing and application]

Flowering to harvest

- Hand picking and destruction of larvae boring into ears
- At 10% ear damage, application of *Bacillus thuringiensis* v. *kurstaki* formulations (400g/acre) @ 2g/litre or *Metarhizium anisopliae* or *Beauveria bassiana* with spore count of 1×10^{8} cfu/g (1 kg/acre) @ 5g/litre or SfNPV (600ml/acre) @3ml/ litre or entomopathogenic nematode (EPN) (4kg/acre) @10g/litre of water is recommended

Guides on action threshold based management

Bio-pesticides are recommended for initial symptoms and low infestation rates, while chemical pesticides are recommended at higher infestation levels considering its quick and efficacious control. However, chemical pesticides are the last resort in IPM owing its non-target effects, thus to be used only after monitoring/scouting indicates that they are needed according to action thresholds. Determining action threshold is elaborated in a different chapter in these manual, while choosing a pesticide based on action threshold is given below.

Table 1 Guide on action thresholds and management intervensions in grain corn

Crop stage	Action threshold	Intervention options
Sowing to six leaf stage	One moth/trap/day or 5% infestation on trap or main crop	Application of 5% neem seed kernel extract (NSKE) or azadirachtin 1500ppm @ 5ml/litre (1 litre/acre) of water
	One moth/trap/day caught in traps kept for monitoring	Install pheromone traps @ 15/acre for mass trapping of male moths [For success of mass trapping go for community action] **[Mass trapping should not be an option if parasitoid releases are planned]**
		Release egg parasitoids *viz.*,*Telenomus remus* @ 4000/ acre or *Trichogramma pretiosum* @ 50,000/acre. Two releases of parasitoids at weekly interval should be done. [**Release of parasitoids should not be opted if mass trapping is followed**]
	5-10% infestation	Whorl application of *Bacillus thuringiensis* v. *kurstaki* formulations (400g/acre) @ 2g/litre or *Metarhizium anisopliae* or *Beauveria bassiana* with spore count of 1×10^{8} cfu/g (1kg/acre) @ 5g/litre or SfNPV (600 ml/acre) @3ml/litre or entomopathogenic nematode (EPN) (4kg/acre) @10g/litre of water is recommended
	>10% infestation	Whorl application of anyone of the recommended insecticides with label claim , *viz.*, Chlorantraniliprole 18.5 SC (80 ml/acre) @ 0.4 ml/litre or Thiamethoxam 12.6 % + Lambda cyhalothrin 9.5% ZC (50ml/acre) @ 0.25 ml/litre or Spinetoram 11.7 % SC (100ml/acre) @ 0.5 ml/litre

Seven leaf stage to flowering	5% infestation	Application of 5% neem seed kernel extract (NSKE) or azadirachtin 1500ppm @ 5ml/l (1 litre/acre) of water
	>10% infestation	Whorl application of *Bacillus thuringiensis* v. *kurstaki* formulations (400g/acre) @ 2g/litre or *Metarhizium anisopliae* or *Beauveria bassiana* with spore count of 1×10^8 cfu/g (1kg/acre) @ 5g/litre or SfNPV (600 ml/acre) @3ml/litre or entomopathogenic nematode (EPN) (4kg/acre) @10g/litre of water
	>20% infestation	Whorl application of anyone of the recommended insecticides with label claim, *viz.,* Chlorantraniliprole 18.5 SC (80 ml/acre) @ 0.4 ml/litre or Thiamethoxam 12.6 % + Lambda cyhalothrin 9.5% ZC (50ml/acre) @ 0.25 ml/litre or Spinetoram 11.7 % SC (100ml/acre) @ 0.5 ml/litre
Flowering to harvest	10% ear damage	Application of *Bacillus thuringiensis* v. *kurstaki* formulations (400g/acre) @ 2g/litre or *Metarhizium anisopliae* or *Beauveria bassiana* with spore count of 1×10^8 cfu/g (1kg/acre) @ 5g/litre or SfNPV (600 ml/acre) @3ml/litre or entomopathogenic nematode (EPN) (4kg/acre) @10g/litre of water

[$]**Seed treatment** - as given as per Department of Agriculture and Farmers Welfare (DAC&FW) recommendation dated 16th August, 2019.

[#]**Pheromone traps**– Funnel trap with FAW lure should be installed at a height adjusted each week matching with crop canopy. Traps should be separated by a minimum distance of 75 feet. Observe traps for number of moths caught twice or once in a week and work out the catch/day. FAW lures should be changed once in 30 days in case of monitoring and no lure change is required for mass trapping.

^ **Preparation of Neem Seed Kernel Extract (NSKE) for one acre**– 10 kg of need seed kernel is required for one acre. Grind 10 kg of need seed kernels to make powder. Soak the powder in 50 litres of water overnight. Stir and filter the contents using cotton cloth. Add 200 g detergent powder or 200 ml of soap solution to the filtered solution. Make up the volume to 200 litres by adding water.

Caution upon release of egg parasitoids - Minimum one week interval should be there between parasitoid release and application of neem or chemical insecticides

Precautions for pesticide use: Not more than two chemical sprays are to be used in entire crop duration. Same chemical should not be chosen for second spray. Sprays should always be directed towards whorl and applied either in early hours of the day or in the evening time. Use protective clothing, facemask and gloves during preparation and application of pesticides. Enter the field only 48 hours after spraying pesticide. Interval between application of chemical insecticide and harvest of corn should be minimum 30 days.

Conclusion

Success of FAW control through IPM depends upon community based and area-wide approach for implementing management strategies. This requires capacity building and mass awareness created in key stake holders through various media.

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Bio-rational integrated pest management modules and on-farm biorational inputs production techniques for better crop health in maize crop

Ravi. G*, Jesu Rajan, S and Damodara Chari, K
National Institute of Plant Health Management,
Government of India, Hyderabad 500 030, India
Corresponding author: ravigniphm@gmail.com

A pest management system that, in the context of the associated environment and the population dynamics of the pest species, utilizes all suitable techniques and methods in as compatible a manner as possible and maintains the pest populations at levels below those causing economically unacceptable damage or loss (FAO,1967). Thus, IPM is the best combination of cultural, biological and chemical measures that provides the most cost effective, environmentally sound and socially acceptable method of managing diseases, insects, weeds and other pests. IPM is a knowledge intensive sustainable approach for managing pests by combining compatible cultural, biological, chemical, and physical tools in a way that minimizes economic, health, and environmental risks with the help of pest scouts. IPM relies heavily on knowledge of pests and crop interaction to choose the best combination of locally available pest management tools. Therefore, IPM is not a single product that can be stored on shelves like pesticide, and it does not rely on single method to solve all our pest problems. Pests also co-evolve and adapt very quickly to single control tactics through natural selection, and that multiple methods used simultaneously, or an "integrated" approach, is the most effective for long-term, sustainable management programs.

IPM is neither organic nor it rely solely on biological control to achieve the desired sustainable outcomes. It does often try to assist and augment the effectiveness of natural enemies by limiting the impact of pesticide on their populations and provide clean and safe niche. It seeks to conserve balance between the crop and the natural environment. The World Bank policy (OP 4.04 - Natural Habitats) also promotes the conservation of natural habitats, and enhancement of the environment for long-term sustainable development. In the IPM concept, use of pesticides involves a trade-off between pest control and the risks of adverse effects on non-target organisms, such as natural enemies, pollinators, wildlife, and plants, contamination of soil and water.

Insect Pests of Maize

More than 130 insect pests have been recorded causing damage to maize in India, among these about half a dozen insect pests are of economic importance, major and minor insect pests of Maize are:

Major insect pests of Maize			
Pests	**Scientific Name**	**Family**	**Order**
Fall Aryworm	*Spodoptera frugiperda*	Noctuidae	Lepidoptera
Maize shoot fly	*Atherigona varia soccata*	Muscidae	Diptera
Stem borer	*Chilo partellus*	Pyralidae	Lepidoptera
Pink stem borer	*Sesamia inferens*	Noctuidae	Lepidoptera
Maize cut worm	*Mythimna separata*	Noctuidae	Lepidoptera
Cob worm/ Earworm	*Helicoverpa armigera*	Noctuidae	Lepidoptera
Aphid	*Rhopalosiphum maidis*	Aphididae	Hemiptera
Shoot bug	*Peregrinus maidis*	Delphacidae	Hemiptera
Minor insect pests of Maize			
Maize leaf hoppers	*Cicadulina sp.*	Cicadellidae	Hemiptera
Sugarcane Leafhopper	*Pyrilla perpusilla*	Lophopidae	Hemiptera
Red headed Hairy Caterpillar	*Amsacta albistriga*	Arctiidae	Lepidoptera
White Grubs	*Holotrichia serrate*	Scarabaeidae	Coleoptera
Chaffer beetle	*Chiloloba acuta*	Scarabaeidae	Coleoptera
Termites	*Odontotermes obesus*	Termitidae	Isoptera

Integrated pest management for Major pests of Maize

Cultural Practices: Deep summer ploughing followed by fallowing helps in exposing resting stage of pests, inter-cropping with legume reduces borer incidence, maize-soybean/Maize-Cowpea/ Maize-Green gram are some of the good examples, use of well decomposed farm yard manure (FYM) reduces termite attack, plant spacing 75 cm x 20 cm in Kharif and 60 cm x 20 cm in Rabi is recommended, balanced use of fertilizers (NPK 120:60:40) kg/ha and supplement of micronutrient are the some of the key cultural practices recommended.

Mechanical control: For effective management for insect pests various practices like removal of dead hearts will help to reduce second generation infestation, use of bird scarer prevents seed damage, manual collection and destruction of white grub and chaffer beetle during adult emergence period reduces the pest population, use of pheromone traps @5/ha and light traps @ 1 per ha. are recommended.

Biopesticides: Soil application of neem cake @ 200 kg /ha is effective an effective biopesticides option suggested for control of nematode and chaffer beetle

Parasitoids: For the management of lepidopteron pest in maize crops, use of egg parasitoids like *T. chilonis* @ 2 cc/ release and *Cotesia flavipes and Campoletis chlorideae* larval parasites @ 2000 to 3000/ acre are recomented accordingly dominant stage of the insect pests. The larval and pupal parasitoid *Sturmiopsis parasitica* also recommended for pest management in maize crops.

Predators: *Chrysoperla carnea* @ 5000 first instars grub/acre for two releases for 15 days to control maize aphids, *Rhopalosiphum maidis* and conserve predators such as mirid bug, lady birdbeetles, lacewing, wasp, dragonfly, spiders, robber fly, reduviid bug, praying mantis, fire ants, big eyed bugs, pentatomid bug, earwigs, ground beetles, rove beetles etc.

Flowering plants that attract natural enemies/ repel pests: Cosmos, Sunflower, Okra, Hibiscus, Marigold, Fennel, Coriander, Mustard, Radish, Tridax, Ageratum *sp*., Alfalfa, Chrysanthemum, Carrot.

Fall Armyworm (FAW) and its management

The Fall Armyworm (FAW) *Spodoptera frugiperda* (Lepidoptera: Noctuidae) is native to the tropical and subtropical region of America. It has invaded many African and Asian countries and caused huge economic losses. Fall Armyworm has infested crops in over 50 countries across two continents in just over two years. Incidence of FAW reported in India during May 2018 and the phylogenetic analysis has revealed that Indian Maize FAW clustered with Florida (rice strain), Ghana, Nigeria, Uganda on maize.

The techniques and options involved for FAW management are detailed below

Monitoring**:** Installation of pheromone traps @ 5/acre in the current and potential area of spread in crop season and off-season. Fix the traps to the supporting pole at a height of one foot above the plant canopy. Change of lures should be made at 2-3 week interval (regular interval). During each week of surveillance, the number of moths/trap should be counted and entered.

Scouting: Start scouting in **'W'** manner as soon as maize seedlings emerge. At seedling to early whorl stage (3-4 weeks after emergence) action need to be taken if 5% plants are damaged and at Mid whorl to late whorl stage (5-7 weeks after emergence) action need to be taken if 10% whorls are freshly damaged in mid whorl stage and 20% whorl damage in late whorl stage. At tasseling and post tasseling (Silking stage) no pesticide spray is advised however, if the ear damage exceed 10% damage that may needs action provided the crop is planted in sufficient wider spacing for any spray interventions.

***Cultural control*:** Cultivation of maize hybrids with tight husk cover will reduce ear damage by FAW and during off season deep ploughing is recommended before sowing to expose FAW pupae to predators and solarisations. In order to achieve uniform crop growth stage timely sowing is advised and staggered sowings is not recommended as the late sowing crop may invite infestation by migrating broods. Intercropping of maize with suitable pulse crops of particular region (eg. Maize + pigeon pea/black gram /green gram) is also a ecological engineering concept that helps in minimising FAW damage. To attract the action of erection of bird perches @ 10 /acre during early stage of the crop (up to 30 days) is advice. Sowing of 3-4 rows of trap crops (eg. A sustainable napier grass) around maize field and spray with 5% NSKE or azadirachtin 1500 ppm as soon as the trap crop shows symptom of FAW damage. Clean cultivation and balanced use of fertilizers including use of VAM is also important for better crop health.

***Mechanical control*:** Hand picking and destruction of egg masses and neonate larvae in mass by crushing or immersing in kerosine water is most effective in early crop stages. Application of dry sand in to the whorl of affected maize plants soon after observation of FAW incidence in the field.

***Biological control*:** In *situ* protection of natural enemies by habitat management: Increase the plant diversity by intercropping with pulses and ornamental flowering plants which help in build-up of natural enemies. Augmentative release of *Trichogramma pretiosum* or *Telenomus remus* @ 5 cc per acre at weekly intervals or based on trap catch of 3 moths/trap.

Biopesticides: Biopesticides like *Metarhizium anisopliae, Nomuraea rileyi, Bacillus thuringiensis* are effective at 5% damage in seedling to early whorl stage and 10% ear damage. The entomopathogenic fungal formulations *Metarhizium anisopliae* talc formulation ($1x10^8$ cfu/g) is affective when applied @ 5g/litre whorl application at 15-25 days after sowing. Another 1-2 sprays may also be given at an interval of 10 days depending on pest damage (or) *Nomuraea rileyi* rice grain formulation ($1x10^8$ cfu/g) @ 3g/litre whorl application at 15-25 days after sowing. Another 1-2 sprays may also be given at an interval of 10 days depending on pest damage. The bacterial formulation of *Bacillus thuringiensis* var *kurstaki* @ 2g/litre (or) 400g/acre is also effective in managing FAW in the early stages of the crops.

On-Farm Production Techniques for Biorational Inputs

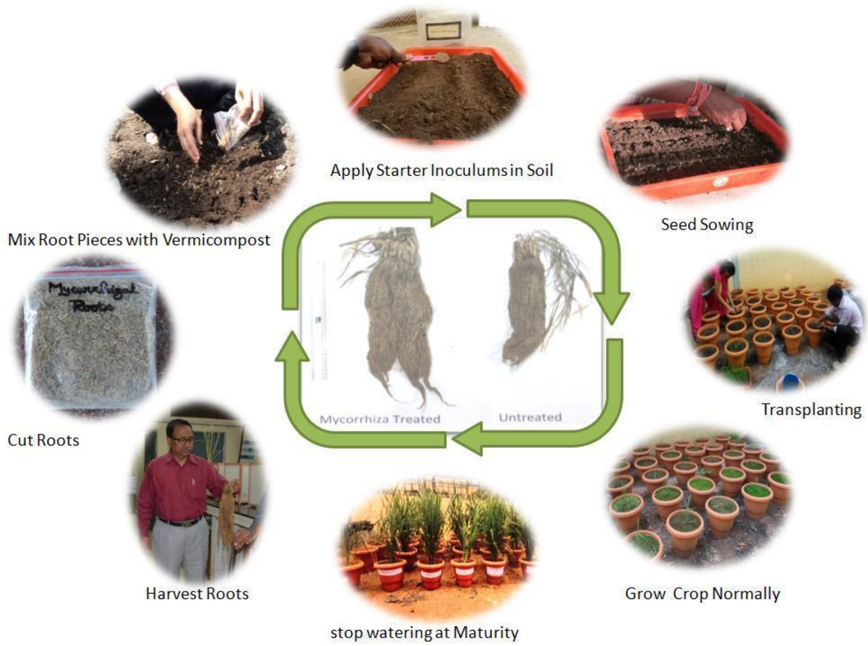
For on-farm production of biocontrol agents, biopesticides and biofertilizers like VAM, NIPHM is facilitating custom made on-campus and off-campus capacity building programme for official and farmers on continues basis. The on farm production protocol for the bio-rational inputs for plant health management in maize crop are as follow:

1. On-farm production of VAM:

The maize crop removes large quantity of nutrients from soil, particularly NPK. Among these major nutrients, the efficiency of applied P through chemical fertilizers is very low i.e. 15 to 20 percent. This is because of the fixation of applied phosphorous in the soil into unavailable form. Therefore, there is need to enhance the phosphorous availability by using phosphorous solubilizing microorganisms (PSM) and their by increasing the health and vigor of the plant to fight against invading pest and diseases. Among PSM, different species of mycorrhizal fungi have been reported to be effective in increasing growth and uptake of phosphorous by different plant species. Mycorrhiza filaments extend from the roots into the soil, reaching several times beyond the root hairs. Efficient species of mycorrhiza (VAM &AM) are symbiotic endophytic soil fungi, which colonize the roots of approximately 80% plants. Nutrients are taken up by the hyphae and carried to the plant. This results into rhizosphere improvement through efficient mobilization & uptake of phosphorous and other nutrients by plants. VAM soil root based culture 10 kgs to be mixed with 1000 kgs of vermicompost or FYM. It is applied along with seed sowing in the main field in a directly sowing crops or applied two days prior to transplanting of seedling in transplanted crops.

No infrastructure like equipments, specific equipment's, machines are not required for mycorrhiza production at farm level. The multiplication of VAM can be done at farmers field with materials like Plastic Pots or Poly bags, Soil, Vermicompost, Starter Inoculum and Seed Material (Sorghum/Mize/Ragi/Rice, etc). Mycorrhiza can be produced at farm level by farmers after undergoing a few days training and hands on practice. For this purpose, following steps have to be followed sequentially.

Sterilize soil by heating for 2-4 hours using a big metal pan or by drying under intense heat of the sun for 2-3 days, place the sterilized soil in thoroughly cleaned and dry clay pots, after cooling the soil, place a pinch of root starter inoculants then cover with a thin layer of soil, sow 3-5 seeds in each pot, grow the plants for three months under normal conditions, protect the plants from pest and diseases, stop watering the plants after 3 months, do not use chemical fertilizer/ fungicide in pots/ seedbed before sowing if VAM is to be applied, cut the plants or stalks when they are completely dried, allow the soil in the pot to dry further, remove the plant from pot and remove soil adhering to the roots, cut the roots finely and save some root inoculants for future use, mix the finely cut roots with the soil from the pot to produce VAM soil inoculants or 5% of cut roots mix with vermicompost for products, store the root and soil inoculants in sealed plastic bags in a dry and cold place



2. On-Farm Production of *Trichogramma* (Egg Parasitoids):

Rearing basins: The host rearing containers (basins) are made of materials which are non-toxic, cheap and optimum sized to permit mating and host searching and amenable to easy cleaning. The basins (16 or 18dia) used for Corcyra multiplication are thoroughly cleaned with.5% detergent wash and rinsing in tap water followed by wiping with dry, clean – used towel and shade drying. Whenever the trays are emptied after a cycle of rearing, they have to be cleaned preferably to 2 per cent formaldehyde and returned to storage until further use. On reuse the cleaning steps are repeated.

Preparation of feed material: The requisite quantum of sorghum is milled to make 3-4 pieces of each grain. Sorghum grains are heat sterilized in oven at 100◦C for 30 minutes and the grains are sprayed with 0.1% formalin. This treatment helps in preventing the growth of moulds as well as to increase the grain moisture to the optimum (15-16%), which was lost due to heat sterilization. Then grains are air dried.

Preparation of Corcyra eggs: The primary source of Corcyra eggs is reputed laboratories, commercial producers for bulk preparation. If it is intended to begin the production with nucleus colony, the adult moths can be collected from warehouses where the food materials are stored. The eggs used for building up the colony of Corcyra have to be free from contaminants like the moth scales and broken limbs and not exposed to UV light. The collections of overnight laid eggs are measured volumetrically to ascertain the number of trays that can be infested with eggs. One cc of eggs is known to contain approximately 16000 18000 eggs.

Corcyra charging: The overall production scheme involves initial infestation of the Sorghum medium with Corcyra eggs in desired quantities. This is accomplished by sprinkling the freely flowing eggs on the surface of the medium in individual basins. Per basin 0.5 cc eggs of Corcyra is infested. The basins are then covered with clean khada cloth and held tightly with rubber fasteners. Yeast, groundnut kernel and streptomycin is added to enhance egg laying capacity of the adult moths and for enriching the diet. The basins are carefully transferred to the racks.

Handling the trays: The larvae that hatch out in 3-4 days begin to feed the fortified Sorghum medium. At this stage, light webbings are noticed on the surface. As the larvae grow up they move down. During this period the larvae are allowed to grow undisturbed in the trays.

Collection of moths: After about 35-40 days of charging, moths start emerging and the emergence continues for two months. 10 to 75 moths emerge daily with the peak emergence being between 65th and 75th day. Adults are either aspirated with mechanical moth collector or collected with specimen tubes. The whole operation is carried out in a tent of mosquito net. This prevents the large-scale escape of the moths, which if uncontrolled can migrate to the storage area and spoil the grains stored by laying eggs. Workers involved in the collection of moths should wear face moths continuously to avoid inhalation of scales. Collect the moths daily and transfer to the specially designed oviposition cages. The adults are provided feed containing honey solution. The adult feed is prepared by mixing 50 ml honey with 50 ml water and 5 capsules of vitamin E (Evion). The feed is stored in refrigerator and used as and when required. Piece of cotton wool tied with a thread is soaked in the solution and inserted into the drum through the slot at the top. From a basin, moths can be collected up to 90 days after which the number of moths emerging dwindles down and keeping the basins is not economical for the producer.

Preparation of Trichocards: The parasitisation of *Trichogramma* spp., in laboratory condition on one cc eggs of *Corcyra cephalonica,* which are uniformly spread and pasted on a card measuring 15 cm x 10 cm is called as Tricho card. The card has 12 demarcations (stamps). About 12,000 *Trichogramma* adults emerge out from this card in 7-8 days after parasitisation. To delay the emergence of *Trichogramma,* these cards can be stored in refrigerator at 5-100C for 10-15 days. On removing the cards to room temperature, the parasitoids emerge normally. Trichocards have a shelf life of 2-3 days. However, these can be stored in a refrigerator for a period of 1 month without any spoilage. Label information on the manufacturer, species of the parasitoid, date of parasitization and expected date of emergence are given in the left over spaces. A coat of 10% gum arabic is applied on the grids and the eggs are sprinkled uniformly in a single layer with the aid of a tea strainer. The excess eggs pasted are removed by gently passing a shoe brush over the card after sufficient air drying under fan. The egg cards are placed into polythene bags of suitable size and the nucleus card of *Trichogramma* are introduced in it. The easiest way to accomplish this is to place a piece of ‗Tricho egg card' containing parasitized eggs (i.e. pharate adults) that are ready to yield the adults and to hold them in subdued light for 2 to 3 days. The emerging parasites readily parasitize the fresh eggs.

3. On-Farm Production of Green lacewing for Managing Sucking Insect Pests:

Mass Production procedure: In mass production, the adults are fed on various types of diets. The larvae are either reared in plastic tubes or empty injection vials or in groups in large containers or in individual cells. The adults are collected daily and transferred to big glass jars. The rearing jars are covered with perforated brown sheet which act as egg receiving card. About 25 adults (60% females) are allowed into each trough and covered with white nylon or georgette cloth secured by rubber band. On the cloth outside three bits of foam sponge (2 $inch^2$) dripped in water is kept. Besides an artificial protein rich diet is provided in semisolid paste form in three spots on the cloth outside. This diet consists of one part of yeast, fructose, honey, Proteinex R and water in the ratio 1:1:1:1. The adults lay eggs on the brown sheet. The adults are collected daily and allowed into fresh rearing jars with fresh food. From the old troughs, the brown paper sheets along with *Chrysopa* eggs are removed. The first larvae are either taken for culture or for recycling or for field release.

Individual rearing of grubs: In the first step of larval rearing, 120 three day old chrysopid eggs are mixed with 0.75 ml of *Corcyra* eggs (the embryo of *Corcyra* eggs are inactivated by keeping them at 2 ft distance from 15 watt ultraviolet tube light for 45 min) in a plastic container (27x18x6 cms). On hatching, the larvae start feeding. On 3rd day the larvae are transferred to 2.5 cm cubical cells of plastic louvers @ one $cell^{-1}$. Each louver can hold 192 larvae. *Corcyra* eggs are provided in all the cells of each louver by sprinkling through the modified salt shaker. Feeding is provided in two doses. First feeding of 1.5 ml *Corcyra* eggs for 100 larvae and second feeding of 2 ml for 100 larvae with a gap of 3-4 days is done. Total quantity of *Corcyra* eggs required for rearing 100 chrysopid larvae is 4.25 ml. The louvers are secured on one side by brown paper sheet and after transfer of larvae covered with acrylic sheet and clamped. Brown paper is used for facilitating pupation and clear visibility of eggs. The louvers are stacked in racks. One 2m x 1m x 45 cm angle iron rack can hold 100 louvers containing 19,200 larvae. Cocoons are collected after 24 hr of formation (when they get hardened) by removing paper from one side. The cocoons are placed in adult oviposition cages for emergence (Adults are sometimes allowed to emerge in louvers and released on glass window panes from where they are collected using suction pumps).

Field release: 1-3 days old larvae are released on plants along with dust or dropped from the corrugated paper strips. paper strip with stalked *Chrysoperla* eggs stapled on the lower surface of leaf. *Helicoverpa armigera*, *Earias* spp., *Pectinophora gossypiella* 50,000 ha^{-1} twice during the season with a gap of 15 days. Aphids - 50,000 ha^{-1} or 6 larvae $plant^{-1}$ twice during the season with a gap of 15 days

4. On-farm Production of Entomopathogenic Viruses for Lepidopteran Insects:

Details of mass production:

Diet preparation: The larvae of Gram pod borer and Tobacco caterpillar can be multiplied by using chick pea based semi-synthetic diet. The composition of the diet for rearing larvae is as follows:-

	Item	Quantity
'A' fraction:	Chickpea (Kabuli chenna) flour	105.00 gm
	Methyl para-hydroxt benzoate	2.00 gm
	Sorbic acid	1.00 gm
	Streptomycin sulphate	0.25 gm
	10% formaldehyde solution	2.00 ml
'B' fraction:	Agar-agar	12.75 gm
'C' fraction:	Ascorbic acid	3.25 gm
	Yeast tablets	25 tablets
	Multivitaplex	2 capsules
	Vitamin E	2 capsules
	Distilled water	780.00 ml

390 ml of water is mixed with fraction 'A' of the diet in the blender which is run for two minutes. Fraction 'A' and 'C' are mixed and the blender is run again for 1 minute. Fraction 'B' is boiled in the remaining 390 ml water, added to the mixture of A and B and the blender is run for a minute. Formaldehyde solution is added at the end and the blender is again run for a minute.

***Production of Helicoverpa armigera NPV (Ha NPV) and Spodoptera litura NPV (SI NPV)*:** For Ha NPV and SINPV production, the synthetic diet prepared is poured at 4gm/cell in the multi-cavity trays and the diet surface is uniformly sprayed with virus prepared in distilled sterilised water at 18 x 106 POBs / ml. Eighty percent of the total 5-7 day old larvae are utilised for Ha NPV and SINPV production. The trays are incubated at 260C for 7 days. In case of virus infected larval trays, the diseased larvae dies after attaining its maximum size of 6th instar, where the dead caterpillar will have 2-6 billion poly occlusion bodies (POB) which is in terms of larval equivalent (LE). 1 LE of *H.armiegera* NPV = 6 x 109 POBs; 1 LE of *S. litura* = 2 x 109 POBs. The dead larvae have to be harvested, macerated in distilled/sterilised water and filtered through muslin cloth to get the crude suspension of the virus. The extraction is centrifuged to further clarify the solution.

Field application and dosage: Ha NPV is used for controlling H. armigera attacking cotton, redgram, bengalgram, tomato, okra, sunflower, groundnut, chillies, maize, sorgram etc., whereas, SI NPV is used for controlling tobacco caterpillar attacking tobacco, groundnut, soyabean, sunflower, cotton, cabbage, beetroot, cauliflower etc.

Directions for use of NPV: The recommended dosage is 200 ml of NPV/acre or 500 ml/ha containing 100 and 250 larval equivalent (LE) of NPV respectively as active infective material (one LE = 6 x 109 POBs). 100 ml of NPV could be diluted in 200-400 litres of water when high volume sprayer is used and in 50-70 litres of water in case of power sprayers. Preferable to spray using high volume knap-sack sprayer. Virus should be sprayed during evening hours. Spray should be initiated as soon as some newly hatched larvae are observed or three to five days after a trap catch of 5 moths per pheromone trap. Subsequent sprays should be made at 7-10 days intervals depending upon the pest population.

Compatibility with other insecticides: The viral pathogen seems to be less sensitive to chemical pesticides. When the combination of pathogen and pesticide is used, sometimes synergistic action is noticed. But is recent years mixing of NPV with insecticides is not advisable due to cross resistance problem.

5. On-farm Production of of Entomopathogenic Nematodes for Lepidopteran Insects:

***In vivo culture method**:* The approach consists of inoculation, harvest, concentration, and (if needed) decontamination. Insect hosts are inoculated on a Petri dish or tray lined with absorbent paper or another substrate conducive to nematode infection such as soil or plaster of Paris. Inoculation process is similar to the way explained in chapter except that you may need to use large number of laboratory host (may be hundreds and thousands). After approximately 2-5 days, infected insects are transferred to the White traps; if infections are allowed to progress too long before transfer, the chances of the cadaver rupturing and harm to reproductive nematode stages will increase. White traps can be prepared using circular or square plastic box (24 x 9 cm) with a perforated aluminum sheet having a slight slope towards one end. The blotting paper should be placed on aluminium sheet in such a way that the paper towards the lower end of the sheet should always be in contact with water. Now transfer the dead cadaver on the blotting paper. Distilled water containing formalin (0.1%) with not more than one cm height should be maintained in the plastic box. Incubate such traps in B.O.D at 25^{o}C. The nematodes will start emerging and collecting at the bottom of the container after 10 days. Harvest the nematodes daily thereafter, repeatedly clean them with distilled water, and concentrate to a required density and store.

Production and formulation: Entomopathogenic nematodes are currently mass - produced by different methods either in vivo or in vitro (solid and liquid culture) (Shapiro-Ilan and Gaugler, 2002). In vivo production is also arguably the most appropriate technology for grower cooperatives and for developing countries where labor is less expensive (Gaugler and Han, 2002). In vivo production is a simple process of culturing specific EPNs in live insect hosts which requires less capital and technical expertise. In vivo production system based on the White trap (White, 1929), which take advantage of the IJ's natural migration away from host cadaver upon emergence. The most common insect host used for in vivo production is the last instar of the greater wax moth (Galleria melonella), because of its high susceptibility to most nematodes, ease in rearing, wide availability and ability to produce high yields. Insect hosts are inoculated on a dish or tray lined with absorbent paper. After approximately 2-5 days, infected insects are transferred to the White are inoculated on a dish or tray lined with absorbent paper. After approximately 2-5 days, infected insects are transferred to the White

Application methods: Production and application technology is critical for the success of EPNs in biological control. Infective juveniles of EPNs are usually applied using various spray equipment and standard irrigation systems. Nematodes require a film of water around soil particles to move through the soil profile in search of a host. Therefore, it is important to ensure adequate agitation during application. Enhanced efficacy in EPN applications can be facilitated through improved delivery mechanisms (e.g., cadaver application) or optimization of spray equipment. Substantial progress has been made in recent years in developing EPN formulations, particularly for above ground applications, e.g., water-dispersible granules, nematodes on gel, micronized vermiculite, and an aqueous suspension of nematodes. Bait formulations and insect host cadavers can enhance EPN persistence and reduce the quantity of nematodes required per unit area. Finally, superior bio control applications with EPNs can also be achieved through strain improvement. Improved strains may possess enhanced levels of various beneficial traits such as environmental tolerance, virulence, reproductive capacity, etc. Methods to improve EPNs include strain or species discovery or genetic enhancement via selection, hybridization or molecular manipulation. Many researchers were reported that EPNs can be applied in combination with insecticides and other bio control agents.

	
On-farm production of *Trichogramma* parasitoid	**On-farm production of *Trichoderma* and *Pseudomonas***
	
On-farm production of *Bracon* parasitoid	**On-farm production of EPN**
	
On-farm production of insect predators and parasitoids	Mrs. Mariswari, Farmer has got **Entrepreneurship Award-2018** from Honourable Central Minister of Agriculture on the occasion of International Rural Women day

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Agro-technique for management of FAW

S.L. Jat, C.M. Parihar[1], Suby S.B., Naveen Kumar, Geetika Gambhir Chopra and J.C. Sekhar

ICAR-Indian Institute of Maize Research, Ludhiana

[1]ICAR-Indian Agricultural Research Institute, New Delhi

FAW is a polyphagous pest. Hardke et al. (2015) reported that though the pest can attack large number of cultivated species, maximum damage it can cause is to maize and sorghum. Early et al. (2018) recorded FAW to feed on 182 plant species from 42 families. However, it is primarily a pest of grasses, *i.e.* prefers plant species of Poaceae family, in which maize, rice, sorghum, millets, wheat, oat, fodder and pasture grasses are damaged economically. Non-graminaceous crops, *viz*., soybean, alfalfa and cotton are also economically affected by FAW (Murua et al. 2006, Nagoshi et al. 2018). Montezanoet al. (2018) reported 353 of host species for FAW larvae belonging to 76 plant families. Maximum number of host taxa (106) belongs to Poaceae family, followed by 31 taxa each to Asteraceae and Fabacea families. FAW consists of two strains, *viz.,* corn strain "C" which feeds predominantly on maize, sorghum and cotton; and rice strain "R" which prefers rice and turf grass dominated habitats (Juarez et al. 2014, Nagoshi and Meagher (2016). Prevalence "R" was reported in Africa, damaging maize as much as the "C" strain (Srinivasan et al. 2018), but the infestation pattern was typical to C strain *i.e.* damaging maize and sorghum only (Nagoshi 2019). Molecular genetic diversity studies suggests that the genetic stock in India belong to "R" strain (Swamy et al. 2018), but under laboratory conditions, it fed on cabbage, tomato, groundnut and sugarcane, but not on rice (Sharanabasappa et al. 2018).

The above reports suggest rice-feeding strain is not present in India and further studies are needed to confer "R" status or redefining the haplotypes in non-pan American context. In spite of these conflicting reports, to the best of our understanding FAW in India and Indian sub-continent prefers to attack maize the most followed by sorghum and other millets. However, isolated reports of FAW on sugarcane and rice are available from India but they are not found to cause economic damage or complete life cycle on these alternate crops.

Governments and other stakeholders in their haste to limit the damage caused by the pest, governments in affected regions may promote indiscriminate use of chemical pesticides," say the authors of a recent study on fall armyworm management. "Aside from human health and environmental risks," they explain, "these could undermine smallholder pest management strategies that depend largely on natural enemies."

Agro-ecological approaches offer culturally appropriate, low-cost pest control strategies that can be easily integrated into existing efforts to improve smallholder incomes and resilience through sustainable intensification. Researchers suggest these should be promoted as a core component of integrated pest management programs in combination with crop breeding for pest resistance, classical biological control and selective use of safe pesticides.

However, the suitability of agro-ecological measures for reducing fall armyworm densities and impact must be carefully assessed across varied environmental and socioeconomic conditions before they can be proposed for wide-scale implementation(Agro-ecological options for fall armyworm (Harrison et al., 2019).

Zero-tillage and FAW:

Surface crop residue retention helped in conservation of natural enemies of FAW and result in enhanced pest predation and parasitism (Murrell, 2017). Maize crop with frequent weeding and practicing zero-tillage had lower incidence of FAW, while intercropping of pumpkin was found to promote its incidence in Eastern Zimbabwe (Baudron et al. 2019). FAW damage was found to be significantly reduced by frequent weeding operations and by minimum- and zero-tillage (Baudron et al. 2019). FAW damage was found to be lower for maize crops established through zero-tillage compared to maize crops established through conventional tillage in all three models. Minimum-tillage was also found to decrease FAW damage in two models. Similar results were reported in Florida and Mexico, with lower FAW damage hypothesized to be due to higher densities of general predators (e.g., carabid beetles, rove beetles, spiders, ants) in minimum-tillage plots (Clark et al., 1993; Rivers et al., 2016).

The higher density of general predators in zero- and minimum-tillage plots may be attributed to an increase of alternative prey due to the organic mulch left on the soil surface when tillage is reduced or foregone (Landis et al., 2000). The lower FAW damage found in two of the three models when manure or compost were applied may be explained by similar mechanisms i.e., organic material on the soil surface leading to higher densities of alternative prey for general predators (Landis et al., 2000; Thomson and Hoffmann, 2007). On the other hand, Kumar and Mihm (2002) have found that zero-tillage combined with mulching tended to significantly increase damage by FAW on maize hybrids. It has been suggested that this might be due to the retention of moisture in the mulch, which provides optimum conditions for larval feeding. In addition, moisture retained in the mulch was reported to attract ovipositing moths for some other lepidopteran species (Kumar, 1994).Crop nutrition also plays an important role in managing FAW damage and needs standardization in Indian conditions. By improved crop nutrition and soil health, plants develop well before the pest significantly affects yield components; and also invest more in defense (Chapin 1991).

Intercropping with legumes

Cropping systems and cultivation practices can change the FAW incidence in various agro- ecologies. Inter-cropping with legumes reduces pest damage by improving soil health and fertility, preventing female moths from laying eggs probably by olfactory disruption, inhibiting movement of larvae among from plant to plants and provide habitat for natural enemies (Harrison et al. 2019). Also intercropping with repellent plants such as *Tephrosia*and *Desmodium* repel the adult female FAW moths and reduce the number of eggs laid on host plants (Harrison et al. 2019). Legume species intercropped with maize viz., cowpea, groundnut, and common beanfound to have lower incidence of FAW due to repelling effect. Intercropping of pigeonpea in strips of alternate row found to be effective for decreasing FAW incidence in India.

Identifying the location specific intercropping/mixed cropping systems suited to varied agro-ecological region for India could be the most sustainable technology especially for small holder farmers as it is based on locally available plants and not depending upon expensive external inputs. It is a core component of integrated pest management programs in combination with breeding for pest resistance, biological control and safer pesticides. Manipulating the time of host plant development relative to pest pressure including early planting, crop rotations works well for FAW management.

Conversely, pumpkin intercropping was found to significantly increase FAW damage (Baudron et al. 2019). Pumpkins (*Curcubita* spp.) are known to be FAW host plants (https://www.cabi.org/isc/datasheet/29810) but in our study, only maize plants were scouted. Pumpkins may provide better shelter habitat than maize for FAW moths during the day. The closed canopy leaves of pumpkins may also offer 'bridges' to larvae which fall short of their 'landing zones' when ballooning from the maize plants where they hatched (Zalucki et al., 2002).

Best weed management:

FAW damage was found to be significantly reduced by frequent weeding operations, as graminaceous weeds, which are dominant in the agroecologies considered, are likely to host FAW.Frequent weeding tended to decrease FAW damage in all three models. This may be explained by the fact that the weed flora in the study areas tends to be dominated by graminaceousspecies that may be FAW hosts. Similarly, the fact that FAW damage tended to be higher for maize crops following a fallow – in all three models – may be due to the dominance of graminaceous species in short-term fallows. However, we should be cautious with this finding as native grasses and weeds may also host natural enemies of FAW (e.g., Hay-Roe et al., 2016). Conversely, they may also host other crop pests like stemborers (*B. fusca* and *C. partellus*) with which FAW shares the same habitat (Le Rü et al., 2006; Moolman et al., 2014; Van den Berg, 2017). If research confirms that graminaceous weeds attract FAW, it could be recommended to avoid having graminaceous plants mixed with maize within the field, but graminaceous plants could be planted around the field as a trap crop. This is one of the key principles of the push-pull technology, originally developed to control lepidopterousstemborers (Khan et al., 1997). Midega et al. (2018) recently demonstrated the effectiveness of the push-pull technology in controlling FAW as well.

Push-pull technology:

Midega et al. (2018) reported that farmers who implemented the Push-Pull approach reduced FAW infestation and crop damage by up to 86%, with a 2.7-fold increase in yield relative to neighboring fields that did not implement the approach. In this approach, pest repelling legumes like *Desmodium*spp. or *Tephrosia*plants intercrop for push the insect outside crop areas while on the border pest-attractive trap plant species such as napier grass (*Pennisetumpurpureum*Schumach.) or *Brachiaria*spp planted to 'PULL' the pest towards them. Hence, the pest will deter from main field due to volatile produced from these legume intercrops and will move to border for attractive crop. Such systems are characteristic of subsistence agriculture and smallholder farmers in India.

In addition to a trap crop, the push-pull technology is based on the use of a repellent crop – generally *Desmodium* spp. or another legume – intercropped with maize (Khan et al., 1997).However, and although this was not demonstrated for FAW, Kebede et al. (2018) found common bean to be as effective as *Desmodium* spp. in repelling *B. fusca*. Thus, although the potential to control FAW through push-pull appears high in sub-Saharan Africa, further research is needed to determine which companion crops (trap crops and repellent crops) would be the most efficient in controlling FAW and the most acceptable to smallholders.

So, agroecological practices such as intercropping, conservation agriculture, agro-forestry improve the health of the crop, provide shelter and alternative food sources to natural enemies and ultimately reduced the ability of FAW larvae to move between host plants (Thierfelder et al. 2015). Some of the promising practices identified are given in Table 1.

Table 1. Cultural and landscape management options for control of FAW

S. No.	Method	Description	Reference
1.	Planting at recommended/optimal time	Planting to be done with the first effective rains, as FAW populations build up later in the crop season.	Vanden Berg and Van Rensburg (1991)
2.	Plant Nutrition	Adequate nutrient supply through mineral fertilizer, use of fertilizer trees and nitrogen- fixing legume crops, organic manures, or compost support healthy plant growth.	Altieri and Nicholls (2003)
3.	Intercropping with compatible companion crops or fertilizer trees	Planting of additional crops in strips, rows, or stations between the main crop (e.g., pigeonpea, cassava, sweet potatoes, cowpea, beans, pumpkins, or fertilizer trees [e.g., *Tephrosia*, *Gliricidia*]	Landis et al. (2000); Pichersky and Gershenzon (2002)
4.	Conservation Agriculture	Combined use of no-tillage, residue retention, and rotation increases and diversifies biological activity of macro-	Rivers et al. (2016)

S. No.	Method	Description	Reference
		(spider, beetles, ants), meso- (fungi), and microfauna(bacteria). These practices also lead to improvement of soil health, which contributes to more vigorous growth of the crop.	
5.	Increased ground cover	Cover crops like mucuna, lablab beans, jack bean, sunnhemp, *etc.*, contribute to plant species diversity that enhances biological activities and provides shelter for natural enemies (spiders, beetles, ants).	Altieri et al. (2012)
6.	Hedge rows and live fences	Complex cropping systems influence interactions of biota and increase effectiveness of parasitoids. Provides extra-field diversity and habitats for natural enemies to proliferate and contribute to control of the pest (birds, spiders, ants). Planting of live fences or hedgerows, maintenance of uncultivated areas, reduced weeding in part or all of the crop, planting of other crops or fruit trees in neighbouring fields.	Veres et al. (2013)
7.	Enhance agroforestry systems at landscape level	Plant trees/shrubs between maize especially neem, *Tephrosia*, *Gliricidia*etc., to enhance diversity for natural enemies (beneficial insects and birds).	Hay-Roe et al. (2016)

Source: CABI Evidence Note (2017)

Principal agro-ecological components of IPM module of FAW management in maize are as follows:

- Selection of Single cross maize hybrids with tight husk cover, especially for sweet corn.
- Planning of sowing time at community level to follow synchronous planting.
- Planting of crop before arrival of monsoon in kharif season for seedling stage escape from crop damage.
- Deep ploughing after harvest of crop to expose FAW pupae to sun light and predators. Under zero-tillage, application of neem cake @ 500kg/ha to be done. Fields to be kept weed free and balanced fertilizer application to be followed.

- For maximizing plant diversity, intercropping of maize with suitable pulse crops of particular region is advisable. Eg: Maize + pigeon pea/black gram /green gram. Planting of Napier grass in the border rows to act as FAW trap crop.
- Pest repelling legumes like *Desmodium*spp. or *Tephrosia*plantedas intercrop push the insect outside crop areas while on the border pest-attractive trap plant species such as napier grass (*Pennisetumpurpureum*Schumach.) or *Brachiaria*spp planted to 'PULL' the pest towards them.
- Hill planting of maize is to be avoided; one plant should be maintained per hill by thinning.
- Application of nitrogen and irrigation after control measures will boost up the crop growth.

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Fall army worm (FAW) *Spodoptera frugiperda* (J.E.Smith) in Millets

G. Shyam Prasad, K Srinivasa babu, B Subba rayudu and A Kalaisekar
Indian Institute of Millets Research, Rajendranagar, Hyderabad- 500030

Fall Army worm, *Spodoptera frugiperda* (J.E.Smith) is native to Americas and is distributed throughout the Western Hemisphere from Southern Canada to Chile and Argentina. FAW is polyphagous feeding on over 100 recorded plant species belonging to 27 families (Goergen et al. 2016). However, it prefers plants from Gramineae family including many economically important plants such as maize, sorghum, sugarcane, rice, wheat etc.

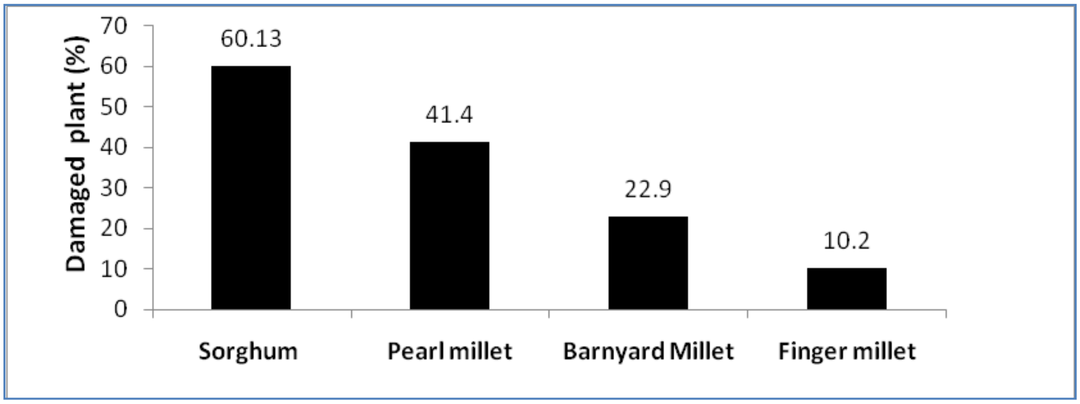
Spread of fall armyworm

A severe outbreak of FAW on corn and millets was documented in 1912 (Walton and Luginbill 1916, Sparks, 1979It invaded Africa in 2016, first reported from Sao Tome, Nigeria, Benin and Togo (Goergen et al. 2016) and subsequently spread to sub-Saharan Africa invading 44 countries by 2018 (www.cimmyt.org). In 2018 it invaded Asia probably in Yemen first due to its proximity to Africa; however its presence was confirmed in July 2018. In India, its presence was conformed in May 2018. Since then it has spread eastwards to countries bordering India viz., Sri Lanka, Bangladesh, Myanmar (December 2018, https://www.ippc.int), China (January 2019, https://www.ippc.int) and Nepal; and beyond it to Thailand (December 2018, https://www.ippc.int), South Korea, and Japan the latest report in July 2019 (https://www.cabi.org/isc/datasheet/29810#todistribution). In India by July 2019, it has covered all maize growing states except the northern states of India viz., Haryana, Punjab, Uttarakhand, Himachal Pradesh, and Jammu & Kashmir. FAW presents a major challenge to small holder maize farmers and the feed and processing industry sectors, the largest consumers of maize. However, to add to the problem sporadically FAW has been reported affecting millet crops as well. Thus, threatening the food as well as nutrition security of the country as whole.

Host preference and economic damage

In Latin America, FAW was observed to cause upto 73% yield losses in maize (Hruska and Gould 1997, Murúa *et al.* 2006). In the absence of any control measures, FAW was predicted to cause 21%-53% loss of the annual maize production in Africa (Day et al. 2017). The pest was closely monitored in sorghum, Pearl millet and small millet (Barnyard, finger millet) and the damage ranged from 1-2 % during kharif, 2018 and it was sporadic. But the rabi sown crop during i.e September – October has experienced medium to severe damage during October – November, 2018.

Fig 1. Incidence of Fall armyworm in Millets (Rabi, 2018, IIMR, Hyderabad)



The observations recorded indicated that among them millets sorghum was most preferred followed by Pearl Millet, Barnyard millet and Finger millet suggesting that the severity of infestation was due overlapping generations as evident from presence of first, third, fourth, fifth instars and adults. The sudden outbreak of the pest is also attributed to the vacation of maize crop present in the vicinity. However, multiple management options tried to contain the pest, which were found to be very effective. However, the second damage assessment after management measures revealed reduction in crop damage on sorghum crop in the range of 18 to 40 per cent (Fig 1). It was observed that with the panicle initiation in sorghum ie by 50 – 60 days of seedling emergence the FAW abandons crop and migrates to younger crop or alternate host, thereafter the crop recovers if care is taken by providing irrigation. No damage to panicles was observed in sorghum and other millets.

Symptoms:

Treatments based on the symptoms are the main line of management of FAW as the progression of the damage symptoms gives clue about larval stage and the choice of toxicant based on the larval stage.

Papery patches on leaves: These symptoms are caused by young larvae upto 2^{nd} instar.

The young larvae of FAW feed on the opened leaves by scraping and skeletonising the upper epidermis leaving silvery transparent membrane. The larvae scrape both surfaces of leaf leaving papery patches on leaves in seedling to early whorl formation stage. At this stage it is very easy to manage pest by applying neem based insecticide (5 % NSKE) or 1500 ppm azadiractin. Or using fungal pathogen, *Nomurea rileyi* (1 x 10^8 cfu@ 3 grams per liter of water.

Ragged edged holes: These are caused by 3^{rd} instar larvae, the larvae enter the whorl and inflict ragged edged oblong holes on leaf lamina.

Extensive leaf damage: Once the larvae reaches fifth instar it feeds voraciously causing extensive defoliation of the whorl and large amount of soggy fecal matter can be seen. On an average 1-2 larvae were found in each whorl.

Scouting of field: To ascertain the crop damage by FAW in Sorghum, periodically scouting need to done at weekly basis. It is done by entering into the field leaving outer 3-4 rows and moving in “W” pattern stopping at 5 points. At each point access damage in 10 plants. Count the damaged plants in proportion to total plants from all 5 points. Based on scouting insecticidal managements need to be taken if 10 % damage is observed at seedling stage (7 – 20 day old crop); 10- 20 % damage is observed in early whorl stage (20 – 40 day old crop) and > 20 % damage is observed in late whorl to booting stage (40 – 65 day old crop).

Management: Following are the management options suggested to manage the pest:

General management measures:

- Deep ploughing of the field exposes the FAW larvae and pupae to sunlight and natural enemies
- For synchronous planting sow the crop within the sowing window so that single stage of crop is available.
- Deploy pheromone traps @ 12 traps / ha for monitoring the FAW.
- Collect and destroy egg masses/ larvae during scouting
- Erect bird perches @ 25/ha. soon after sowing as it facilitates movement of insectivorous birds viz., black drongo and swallows which predate on flying moths as well as caterpillars.

Early instars (I – II):

- Treat the millet seed with mixture of Cyantraniliprole 19.8 % + Thiomethoxam 19.8% @ 6 ml/ kg of seed as it protects the crop up to three weeks which in turn helps the crop to establish with good initial plant vigour (Based on results of adhoc trials at IIMR, Hyderabad, Kharif, 2019)
- When incidence is low or at early instar stage (7- 30 day old crop), spray Azadirachtin 1500 ppm @ 5ml/liter or 5% Neem seed Kernel extract (NSKE).
- Spray with fungal pathogen, *Nomurea rileyi* (1 x 10^8 cfu@ 3 grams per liter of water

In case of severe infestation (> 10% damage) as a last resort spray crop with Spinetoram 11.7 % SC @ 0.5 ml/l water or Chlorantraniliprole 18.5 @ 0.3 ml/lit of water. Alternate the chemical in subsequent sprays.

Mid instars III – IV

- Collect egg masses and larvae and destroy
- Apart from insecticides application of mixture of sand (10kg) and lime 50 grams into the whorls harms the larvae protecting the crop. This was observed at farmers field.
- In case of severe infestation (10 – 20 % damaged plants) as a last resort spray crop with Spinetoram 11.7 % SC @ 0.5 ml/l water or Chlorantraniliprole 18.5 @ 0.3 ml/lit of water. Alternate the chemical in subsequent sprays. Spray using high volume sprayer (Knapsack) preferably in the morning or evening with nozzle directed towards the whorls.

Late instarts (V- VI)):

- The late instar larvae are very difficult to manage using chemicals. In case of presence of late instar larvae baiting is suggested with fermented mixture of rice bran (50 kg), jiggery (4 kg), water (8 liters) and Chloropyriphos 20 EC (500 ml)

- Spread 50 kg of rice bran on the floor, to that add 4 kg of jaggery dissolved in two litres of water and sprinkle on the bran evenly.
- The required quantity of insecticide is dissolved in two litres of water and sprinkled on the bran.
- Pour, 4 litres of water into the mixture and mix properly wearing gloves.
- Transfer mixture to a gunny bags and hold for 48 hours for fermentation.
- Thereafter apply the prepared bait as small balls during evening hours into the plant whorls where possible and sprinkle on the ground. The fermenting mixture attracts larvae which in turn feed and succumb.

- In case of severe infestation (> 20% damaged plants) as a last resort spray crop with Spinetoram 11.7 % SC @ 0.5 ml/l or Chlorantraniliprole 18.5 @ 0.3 ml/lit of water. Spray using high volume sprayer, the nozzle directed towards the whorls for better control. The subsequent spray may be taken up after 10 -15 days depending on the intensity of infestation avoiding the previously sprayed chemical.

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Management of Insect pests of maize

Lavakumar Reddy, M.[1], Lakshmi Soujanya, P.[2], Sekhar J.C.[2], Sreelatha, D.[1], Bhadru, D.[1], and Anuradha, G.[1]
[1]MRC, PJTSAU, ARI, Rajendranagar, Hyderabad-30
[2]Winter Nursery Centre, IIMR, Hyderabad-30

Maize is popularly known as "Queen" of cereals because of its highest yield potential. Globally, it is leading cereal in terms of area (over 183 m ha), production (over 717 m tonnes) and average productivity (over 5.0 t/ha). It can play a vital role in ensuing food and nutritional security for India and world as a whole. Maize accounts for 15% of world's proteins and 19% of the calories derived from food crops. In India, maize is cultivated in 9.38 m ha with production and productivity of 28.75 m t & 3.07 t/ha. Maize is used in diversified ways *i.e.*, for human consumption (24%), as poultry feed (52%), as animal feed (11%), as raw material in many industries (11%), as seed (1%) and for brewery (1%). Major maize growing season is *Kharif*, which accounts for about 85% of total maize area whereas *Rabi* maize contributes >25% of annual production with <10% of total maize growing area in the country.

Pest scenario over the years:

About 250 species of insects and mites are reported in maize crop, among all the insect pests of maize, stalk borers, *Chilo partellus* (Swinhoe) during *Kharif* and *Sesamia inferens* (Walker) during *Rabi* are the most serious pests in our state and causes yield loss of 25-80% during severe conditions. Fall armyworm *Spodoptera frugiperda* an invasive pest was first reported in India during *Kharif*, 2018 and caused havoc. Among sucking pests, incidence of aphids is observed in maize particularly in sweet corn.

Various pests, causes damage to leaves, stem, tassel, and cob and reported to cause significant yield losses. These pests not only affect quantify of the produce but also quality of the produce. Maize pests broadly classified in to stalk borers, sucking pest, leaf feeders, root feeders and cob borers. The major stalk borers are spotted or striped stem borer and pink stem borer, which causes economic yield losses due to dead hearts if unnoticed. Now and then aphids also reported to cause considerable damage in seed production plots due to infestation of tassel. In recent years, often termites causing severe damage by lodging crop, particularly in light soils under rainfed situation. Some times *Spodoptera litura/ S. exigua* is causing severe damage to maize seedlings during *rabi* season. Cob borer damage is reported in sweet corn by *Helicoverpa armigera*, however its incidence on commercial crop is 1-2 % only. Recently silk cutter (Euproctis) incidence is increasing in *Kharif* maize. Often *Chiloloba* beetles are observed on tassel, feeding on anthers as results grain formation may be affected.

Stalk borers / Stem borers:

1. Spotted /striped stem borer (*Chilo partellus*):

Moths are medium sized and in straw colour. 20-25 creamy white oval scale like eggs are laid in clusters at night. Fecundity is around 250-300 eggs. Dirty greyish white larva has black head and four longitudinal stripes on the back. Larval period ranges from 14-28 days. Pupation occurs inside the stem. Moth emerges through the exit hole made on the stem by the larva. Total life cycle is completed in 4-6 weeks. There are 5-6 overlapping generations in a year. In peninsular India, it remains active throughout the year.

Symptoms of damage:

Immediately after hatching, larvae crawl over the leaf for about 15-30 minutes and then feed on the surface of tender leaves, bore downwards through the whorl and reach the growing point of the plant. As the whorl opens, pin holes or shot holes (occur in a parallel fashion) are seen on the leaf surface. The larvae cut the growing point resulting in drying up of the central shoot and subsequent formation of "**dead heart"** which on pulling comes out easily. Larvae feed on the tissues (pith) inside the stem and tunnels are formed due to which not only plant vigour is lost but also reduction in grain yield. With slight wind, plant collapses and dries. Caterpillars also damage by boring into immature cobs and tassels. Losses in yield vary from 26.7 to 80.4% and are attributed to early attack (10-20 days old crop) on the growing plant (Narsimha Reddy *et al.*, 2012).

Dead heart

Parallel holes on leaf blade

2. Pink stem borer (*Sesamia inferens*):

Straw coloured adults have coppery shining scales. Fore wings have a mid longitudinal brown triangular streak. Round pearl like 80-300 white eggs are laid in 2-3 longitudinal rows within the sheaths of bottom leaves of young plants (2-3- weeks old). Eggs become pinkish before hatching. Larva is stout, purplish pink on the dorsal side with reddish brown head. Larval period is 3-4 weeks. Life cycle is completed in 6-7 weeks and there are 4-5 generations in a year (Lavakumar Reddy, 2001).

Symptoms of damage:

Young larvae feed on the epidermal layer of leaf sheath and later bore into central shoot resulting in drying up of growing point and formation of **dead hearts**. Grown up plants show many oval elongated holes on leaf blades. Tunnels formed in the stem are filled with excreta and exit holes are seen. Bottom internodes show circular ring like cuts due to larval feeding. Severe damage causes the stem to break. Larvae also feed on immature cobs and tassels. Larvae have migrating tendency and may attack a number of plants. In peninsular India, it is more serious during *Rabi* season. Losses caused by this varied from 25.7 to 78.9%.

Management of Stem borers:

- Farm sanitation: Removal of infested plants, ploughing the field soon after harvest and collection and burning of stubbles to kill the hibernating larvae and pupae.
- Growing stem borer tolerant hybrids (DHM 117).

- Adjusting the sowing time to avoid peak activity of the borers to coincide with critical stage of the plant (10-12 days old).
- Maintaining optimum plant density in the field (33,000 plants/ac).
- Intercropping with legumes such as cowpea, soybean, redgram and green gram in 2:1 ratio encourages the buildup of natural enemy population.
- Trap crop: Sorghum is the preferred host for *C. partellus*. Sowing 2-3 rows of trap crop on all sides of maize and uprooting it after 45 days.
- Clipping of lower leaves of maize on which most of the eggs are laid.
- Crop rotation with non-host crops destroys the buildup of pest due to non-availability of host.
- Release of egg parasitoid, *Trichogramma chilonis* @ 8 cards per ha twice *i.e.*, at 12 and 22 days after germination.
- *Cotesia flavipes* is the dominant and most widely distributed larval parasitoid.
- Use of recommended dose of fertilizers, avoiding excessive use of nitrogen that increases pest attack.
- Prophylactic spray of Chlorantriniliprole 20 SC @ 0.3 ml/l of water at 10-15 DAG followed by Carbofuran 3G @ 7.5 kg/ha in plant whorls in case of severity.

II. Sucking insects

1. Aphid (*Rhopalosiphum maidis*): Small soft bodied, greenish blue, pear shaped aphids are found in colonies on top leaves, whorls, tassels and on cob husks. Aphids attack the plants at the end of mid whorl stage. It is in serious form during drought years. Colony gets a whitish appearance with the exuviae shed by the developing aphids. Aphids secrete honey dew on which black sooty mould develops.

Symptoms of damage:

- Both nymphs and adults suck sap from plants causing yellowing and stunting.
- Tassel emergence is prevented and pollen shed is reduced when emerging tassels and the leaves surrounding the tassels are covered with aphids.
- Ear and shoots are also infested and seed set may be affected.

Aphid colony on tassel and leaf

2. Shoot bug (*Peregrinus maidis*): Yellowish to dark brown adults and yellowish nymphs suck sap from leaves, inner side of leaf sheaths and leaf whorls resulting in stunted yellow plants. Leaf midrib turns red due to laying of cigar shaped eggs in rows. Ants are attracted and black sooty mould is formed for the honey dew secreted by the bugs. It is a vector of stripe disease. Life cycle ranges between 18-31 days.

Management:

- The natural enemies will take care of the sucking insects in field conditions.
- Spraying Dimethoate 30 EC @ 2 ml/l or Monocrotophos 36 SC @ 1.6 ml/l of water.

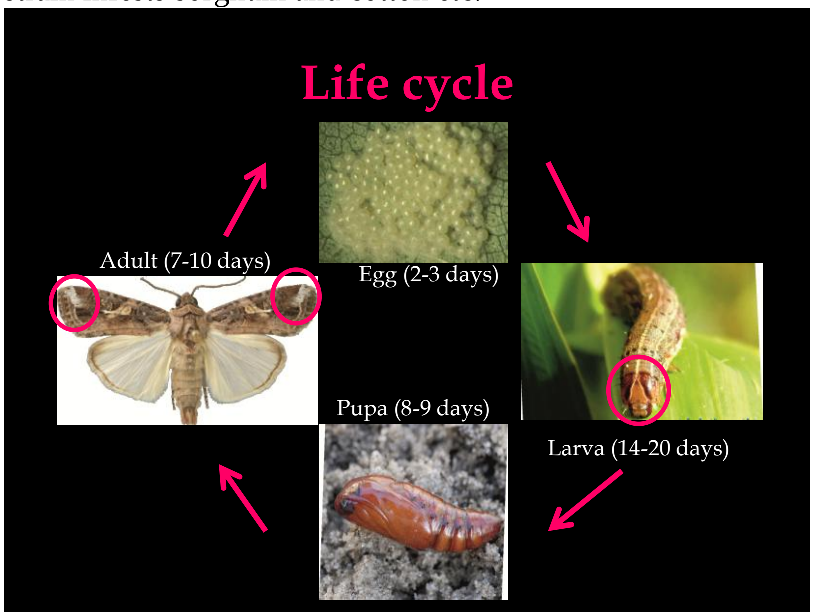
 

Shoot bug nymphs & adults sucking sap

III. Leaf feeders:

Fall Army Worm (*Spodoptera frugiperda)*:

It is polyphagus pest. Prefers grasses, field corn, sweet corn, Sorghum, Grass weed, *Digitaria* spp, Alfalfa, Barley, Buck wheat, Cotton, millet, Peanut, Rice, Sugercane, Soybean, Tobacco, Wheat, Amaranthus spp and vegetables etc., Fall armyworm *Spodoptera frugiperda* (FAW) is reported to have two strains, one is corn Strain and other one is Rice Strain. Corn strain infests sorghum and cotton etc.



Life cycle is competed in 31-40 days and may be prolonged in winter. Number of generations may vary from region to region based on weather and 4-6 generations per annum were reported. No diapause is recorded in FAW. Egg mass (100-200) laid on either side of the leaf and each female lays 1500-2000 eggs after emergence up to 10 days. Size of the egg is 0.3 to 0.4 mm and dome shaped. Incubation period is 2-3 days. Six instars were observed during summer. Young larvae are greenish with black head. Later on, the grownup larva becomes brownish with reddish brown head. A full grown larva has marked with a white inverted 'Y' shaped suture. Four black dots will be observed on last segment of the larvae. The larval period is 14-20 days. The full grown larval size is 34.2 mm. Pupation takes place in soil at a depth of 2-8 cm in cocoon. Cocoon is oval shaped and measures 20-30mm.Pupa is reddish brown in color and measures 14-18 mm in length and 4.5 mm width. Pupal period is 8-9 days. Adult is grey and brown in color. Hind wings are silvery white with a narrow dark marking on edges. It is nocturnal and active during warm and humid evenings. Life span is 10 days with a range of 7-10 days.

Symptoms of damage:

- Young larvae initially feed on leaf tissues from one side leaving the opposite epidermal layer intact (window pane).
- 2nd and 3rd instars larvae feeds and makes holes on leaves and also eat from the edge of the leave inward.
- Feeding in the whorls often produces a row of perforations (holes) in the leaves
- Older larvae cause extensive defoliation often leaving only the ribs and stalks of corn plants or a ragged appearance
- It also burrows through the husk into the ear feeding on kernels.
- In sweet corn 0.2 to 0.8 larvae / plant in late whorl stage cause yield loss by 5 to 20%.

Management:

- Avoid staggered sowing of maize particularly sweet corn..
- Treat the seed with Cyantraniliprole 19.8% + Thiamethoxam 19.8% @ 4 ml per kg seed
- Installation of pheromone traps @8-10 per acre.
- Clean cultivation to avoid alternate hosts.
- Balanced application of fertilizers helps to reduce the incidence of fall armyworm, because of vigor of the plant (enhances immunity).
- Intercropped maize with suitable crops is less preferred over pure maize crop. FAW avoids egg laying on intercropped maize and it also helps to build natural enemies.
- Erection of bird perches @10/acre in early stage of the crop helps to reduce the population.
- Use of trap crops like napier grass which attracts egg laying.
- Desmodium act as a repellant in case of FAW.

- Release of *Telenomus remus* or *Trichogramma pretiosum* @ 50,000/ac at weekly intervals (soon after observation of egg masses in the field).
- Whorl application of *Metarhizium* or *Beauveria* or *Nomuraea* @ 5 g/liter for control of early instars is recommended.
- Application of Sand+lime (9:1 ratio) in whorl @ 10 kg /acre
- Whorl application of Neem formulation (Azadirachtin, 1500ppm) @ 5 ml /l or one lit/acre (to avoid egg laying and to kill the eggs / early instar larvae).
- For management of 2nd and 3rd instars, whorl application of Emamectin benzoate 5 SG 0.4 g per liter or 80 g/acre or Spinetoram 0.5 ml/l or 100 ml/acre (when 5-10%, leaf damage is observed).
- If incidence is very high (>20%) whorl application of Chlorantraniliprole 18.5% SC @ 0.4 ml/l or 80 ml/ac.
- Application of poison bait in whorls for the control of grownup larvae.

  Preparation of poison bait: 10 kg rice bran + 2 kg jiggery and add 2-3 l of water then mix thoroughly and keep 24 hours for fermentation, later on mix 100 g of thiodicarb in the rice bran mixture before 30 minutes of application.

Tobacco caterpillar : *Spodoptera litura* (F.)
Spodoptera exigua (Hubner)

Moth is dark brownish with wavy markings on forewings and whitish hind wings. Egg mass (200 to 300 numbers) is laid on underside of the leaves and covered with brown hairs. First instar larvae are gregarious. Mature larvae are cylindrical, pale greenish brown with rows of dark spots. Pupate in a small cell in the soil. Total life cycle is completed in 30-40 days. Nocturnal larvae defoliate the leaves.

***Spodoptera* adult**

Larva feeding on cob

Symptoms of damage:

On hatching, larvae feed on tender leaves in groups. They scrape the surface but do not actually perforate it, creating a window pane effect. Under severe infestation, the entire young plant may be consumed. Later on they migrate and feed on the leaves which give thin papery appearance. The pest activity is observed in *Rabi* season**.**

Management

- Hand picking and destruction of larvae.
- Installation of pheromone traps @ 10/ ha for monitoring purpose.
- Release of egg parasitoid *Telenomus remus* @ 1,25,000/ha for 4 times at 7-10 days interval.
- Application of NPV solution at 250 LE/ha.
- Spraying 5% NSKE or Neem formulation @ 5 ml/l or Monocrotophos @ 1.6 ml/l or Thiodicarb @ 1.5 g/l of water for the management of early instar larvae.
- Application of poison bait (5 kg rice bran + 500 g jaggery + 500 ml Monocrotophos or Quinalphos mixed with sufficient amount of water) on fields during evening times to control later instar larvae.

IV. Cob borer *Helicoverpa armigera* (Hubner):

This pest is polyphagous and feeds on Cotton, sorghum, soybean, groundnut, tobacco, many legumes and vegetables crops.

Moths are large sized with grey forewings and a crescent mark on hind wings. Round eggs are laid on the silks. Newly hatched larvae are light grey with conspicuous small dark hairs, larval colour varies from red/brown to green with striped appearance. Large reddish brown pupae are found on ears/fallen leaves/earthen cocoon.

***Helicoverpa* adult**

Larva feeding on sweet corn cob

Symptoms of damage:

- When fresh silk is available the eggs are laid on the silk
- The larvae first feed on the leaves or bore directly into the silk and the kernels at the tip of the ear are eaten down to the cob.
- The damage reduce the market price of green cob.

Management

- Hand picking and destruction of larvae.
- Installation of pheromone traps @ 10/ ha for monitoring purpose.
- Release of *Trichogramma chilonis* @ 8 cards/ha.
- Natural enemies present in maize ecosystem will control *Helicoverpa* population (*Trichogramma*, *Braconids* and *Tachinids*).

- Spraying of HNPV @ 500 LE/ha
- Spraying of Neem based products @ 5 ml/l or Bt. formulations (Dipel) @ 2 g/l of water at cob formation stage with boom sprayer.
- Spraying Spinosad (45 SC) @ 0.3 ml/l of water at cob formation stage with boom sprayer (Ranga Reddy *et al.*, 2015).

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Stored grain pests of maize and their management

P. Lakshmi Soujanya[1], J. C. Sekhar[1], S. B. Suby[2], M. LavaKumar Reddy[3] and Sujay Rakshit[4]

[1] Winter Nursery Centre, ICAR-Indian Institute of Maize Research, Rajendranagar, Hyderabad-500030, India

[2] ICAR-Indian Institute of Maize Research, Pusa Campus, New Delhi-110 012, India

[3] Maize Research Centre, PJTSAU, Rajendranagar, Hyderabad-500030, India

[4] ICAR-Indian Institute of Maize Research, PAU Campus, Ludhiana, Punjab-141004, India

Introduction

Maize is the most important cereal crop grown in diverse range of environments providing food for human, poultry, live stock and have great nutritional, industrial values. Over the last 6 decades, even though the production of maize has been increasing from 1.73 million tonnes (mt) to 28.75 mt in 2017-18, the productivity remains low. Biotic factors including insect pests are one of the reasons for low productivity of maize in India. Over 130 insect pests, have been reported causing varying degree of damage attacking from seedling to maturity stage and some pests destroy stored products in godowns, bins, storage structures and packages causing huge amount of loss to the stored food and also deterioration of food quality. In India, according to recent estimate by Ministry of Food Processing, agricultural produce worth 580 billion Rupees gets lost every year during storage. Management of post-harvest losses is challenging in tropical and sub tropical regions because of the prevalent climatic conditions. In India, post-harvest losses of food grains are estimated to be around 10 per cent from farm to market level (Fig. 1). In case of maize at farm level, the losses were estimated to be around 3.02 kg/ quintal at various operations (Basappa *et al*. 2007). Maximum losses were observed (2.55) during storage particularly due to insect pests. The most economically important storage pests of maize are rice weevil, (*Sitophilus oryzae* L. Coleoptera: curculionidae), angoumois grain moth, (*Sitotroga cerealella* (Oliv.) Lepidoptera: Gelechidae), rice moth, (*Corcyra cephalonica* Stainton Lepidoptera: Pyralidae), lesser grain borer, (*Rhizopertha dominica* Bostrichidae: Coleoptera) and red flour beetle (*Tribolium castaneum* (Herbst.) Lepidoptera: Tenebrionidae). Among them, *S. oryzae* is the most destructive pest causing both quantitative (weight loss, economic loss) and qualitative (chemical changes, seed viability, contamination, nutritional deterioration) losses by feeding on the kernels. This weevil can infest crop at maturing stage in the field itself or during storage as well. The per cent damage of 53.30 and weight loss of 14% is observed due to *S. oryzae* attack within four months storage (LakshmiSoujanya et al. 2013). Though, post-harvest losses can be reduced by the use of synthetic insecticides during storage these are not recommended due to chances of food contamination, development of insecticide resistance, environmental hazards, chemical residues in food and side effects on non-target organisms.

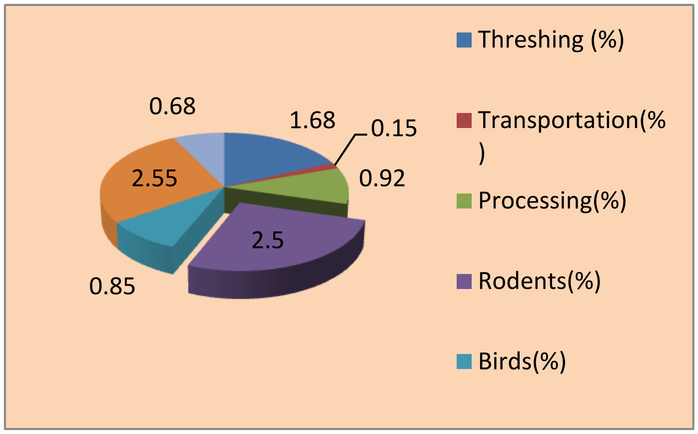

Fig1: Post Harvest losses of food grains in India

1. Rice weevil *Sitophilus oryzae* L. (Coleoptera: Curculionidae)

This pest is widely distributed in tropical and sub tropical regions of the world. The alternate hosts are paddy, wheat, sorghum and barley. The adult is tiny weevil about 2.5 mm long, dark brown or reddish brown in colour. Females lay about 150-300 eggs and hatches in about 3 days. The grub is short, stout "C" shaped that is creamy-white, curved, translucent, yellow or brown head with biting jaws. The larvae feed inside the grain kernel for 18–20 days. The pupa is naked and the pupal stage lasts for 6-7 days. Adults live for 4-5 months. The new adult will remain in the seed for 3 to 4 days while it hardens and matures. The lifecycle is completed in 40–45 days. As it is an internal feeder, both adults and larvae attack the grains and feed voraciously. In case of heavy infestation only pericarp of the kernel is left behind, while rest of the mass is eaten up. The insect can infest crop at maturing stage in the field.

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Fig 1. Egg

Fig 2. Grub

Fig 3. Adult

Fig 4. Egg plugs laid by *S. oryzae*

Fig 5. *S. oryzae* feeding on maize kernel

2. Angoumois grain moth *Sitotroga cerealella* (Olivier) (Lepidoptera: Gelechidae)

The alternate hosts are paddy, wheat, sorghum and bajra. Eggs are cylindrical, cigar-shaped laid singly or in small clusters on the surface of the grain which look white at an early stage but later changes to bright red. Caterpillar is white in colour with yellow head. Larva undergoes 4 instars after about six days each at optimum temperature. The adult moth measures 8-10 mm with buff coloured front wings. Hind wings are margined with long hairs, their tips are elongated. The life cycle is completed in 30-32 days.

Fig. 6. Eggs

Fig 7. Adult

Fig 8. Damage symptoms

Only larvae damage grains, adults being harmless. The larva after hatching, begins to feed on endosperm. As a result, grains are hollowed out resulting into loss of viability. On damaged grains, a circular hole with a characteristic flap or trap door appears. Pest attack is both in fields and stores. In stored bulk grain, infestation remains confined to upper 30 cms depth only.

3. Rice moth *Corcyra cephalonica* Stainton (Lepidoptera: Pyralidae)

Rice moth is known to infest severely in unhygienic storage situations. The alternate hosts are rice, jowar, barley, millets, soybean and oil seeds. Adult has a wingspan of 12-15 mm, with greyish brown forewings. The female lays up to 150 eggs within a few days of emergence. The young larva is creamy white with prominent light brownish yellow head. The adults live for 1-2 weeks and drop their eggs in the produce. At maturity, they construct white silken cocoons for pupation. The pupal period lasts for 7-9 days. The adult lives for 7-15 days. Young larva feeds on the broken grains make webbings resulting in grain pollution with large quantities of frass and silken cocoons.

Fig 9. Larva

Fig 10. Adult

Fig 11. Larva feeding on broken grains

4. Red flour beetle *Tribolium castaneum* (Herbst) (Coleoptera: Tenebrionidae)

The alternate hosts are cereals, millets, flour, starchy material, nuts and prepared cereal foods. Adults are flat brown, 5-6 mm in length and reddish brown in colour. Eggs are whitish colour, sticky and are laid on the grain/ debris of grains. They are small, cylindrical in shape, rounded at both ends. The larvae are very active, cylindrical and pupate after 3-4 weeks. The pupal stage lasts for 5-9 days. The adult has 4-5 months longevity and feeds through out the life. The life cycle is completed in 3-4 weeks. It feeds on broken grains resulting in dust formation. Infested flour emits sour and pungent smell which is due to secretions of beetles. The presence of larval stage, dead and live adults and odour represent damaged material.

Fig 12. Larva

Fig 13. Adult

Fig 14. Adult feeding on maize flour

5. Lesser grain borer *Rhyzopertha dominica* (Fab) (Coleoptera: Bostrichidae)

The alternate hosts are wheat and rice. The full grown larva is dirty white with light brown head and curved abdomen covered with tiny hairs. The larval period varies from 25-28 days. The pupal stage lasts for 7-8 days. It completes its life cycle in 6-8 weeks. Heavily attacked grains become hollowed out and only thin shell remains. After severe infestation adults produce frass and spoil more than what they eat. Profuse powdery substance is the characteristic of its damage.

Fig 15. Adult

6. Khapra beetle *Trogoderma granerium* (Everts.) (Coleoptera: Dermestidae)

The alternate hosts are wheat, barley, oats, cotton seed and dry fruits. The larva is brownish white in colour, body covered with bundles of long reddish brown movable and erectile hairs on the posterior segments and forming a sort of tail in the posterior end. The larval period extends up to 20-25 days. Pupal period is for 4-8 days. The life cycle completes in 33-45 days.The grub feeds on internal part of grain. Adults are harmless. Visible mould occurs. Shed skins and faeces can also contaminate grain and cause allergic reactions.

Management strategies for storage pests

- Cleanliness and sanitation is the most important and first step towards prevention of insect infestation. Dusts, grain, and chaffs should be removed from transport system, storage area as well as threshing yard before using them for new produce after harvest.
- The crop should be harvested at the proper time to prevent egg laying by storage pests.
- The moisture content of grain should be less than 10%.
- Newer grains should not be mixed with older ones.
- Seed stored gunny bags should be kept few inches above the ground.
- Walls and floor of the storage area should be painted/ white washed or sprayed with solution of deltamethrin 2.8EC@1.5ml/l of water/100sqm.
- Malathion 50 EC @ 15ml /4.5 litres of water or 5%NSKE should be sprayed as a thin film on bags before use.
- Through mechanical devices monitoring and mass trapping of stored product insects can be done.
- Staggered sun drying with short exposure to sun spread reduces insect infestation
- By modified atmospheric storage, insects can be controlled by decreasing O_2 or increasing Co_2 or N_2.
- Use of plant products such as *Adathoda vasica*, *Azadirachta indica*, *Vitex negundo*, *Catharanthus roseus* @ 2% w/w (20g /kg seed) have been found to be effective against storage pests.
- Storing of maize in double layered bags is advisable. Application of leaf powder of *Tinospora cordifolia* as water-based paste between the layers of double layered storage bags provide protection against *Sitophilus oryzae* for a period of five months (LakshmiSoujanya *et al*.2018).
- Hermatic control (complete air tightness) is a simple, cheap and effective method of insect management. In this method metabolic activities of insects and microflora act as bio generators that alter the oxygen and carbondioxide composition of the intergranular atmosphere so that insects development is arrested.

Conclusions

Right execution of pre-storage activities will help farmers by reducing the risk of insect pests infestation from field to storage. Preventative measures such as right time of harvest, maintaining optimum moisture content, sanitation in storage area, proper storage structures are essential for effective protection of maize under storage conditions. Utilization of botanicals alone and in combination with different packaging materials reduce rice weevil infestation and its associated losses. Also, application of botanicals through novel methods protects the stored grain with out any adverse effects. Implementation of preventative measures and appropriate use of botanicals in hermetic storage help in strengthening food security and higher returns to small scale farmers.

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Vertebrate Pest Management in Maize (*Zea mays*)

Dr. V. Vasudeva Rao
Principal Scientist and Head, AINP on VPM
PJTSAU, Rajendranagar – 500030

Crop damage by wild animals is a severe problem in most of the areas all over India. Field surveys in different locations showed that on an average 36% of the crop was damaged by depredatory birds and wild animals. Damage to agricultural crops by depredatory birds and wild boar was enormous and widespread. They fed on all phenological stages, especially vulnerable stages of the crop. Even though, out of 1364 species recorded in India, only 5% of the available bird species are depredatory in nature, the magnitude of damage caused by them was significant in isolated areas and needs immediate attention. In India, a total of 63 species of birds belonging to 19 families have been identified damaging several crops. The number of bird species that affected various crops was: cereals-52 pulses-14, oilseeds-15 and fruits-24. In case of wild boar damage caused to *Zea mays, Arachis hypogea, Sorghum vulgare, Oryza sativa,* some pulses and vegetables crops were ranged between 10-75%, 5-56%, 5-30%, 10-35%, 5-20%, 10-30%, respectively in Telangana areas. The incident of damage was very high in crop fields adjacent to forest areas.

The damage caused by wild boar is more alarming than their actual feed; in recent times the extent of damage increased significantly resulted into direct conflict between man-animal. This situation has also adversely affected the sustainability of agriculture and conservation principles. To overcome these crop losses and man-animal conflict in the present study suggested several eco friendly, cost effective and potential non chemical methods.

Maize is one of the important food crops in Telangana state. Due to high nutritious value which is used in most of the food products, apart from using as food it is also used as dhana in the poultry industry, fodder for cattle and as raw material in many industries after gaining importance from World Trade Organization (WTO) it got high exporting capacity. It is mainly rain fed crop, every year it is cultivated approximately 2 to 4 lakh hectares in Telangana. Until now, farmers have used many different traditional measures and some physical barriers to reduce damage to cultivated crops by wild boar. Though the physical barriers like Circular razor wire and chain link fence were proved effective in controlling wild boar, it is expensive for the small scale farmers. Keeping in view, alternative cost effective solutions are very much needed to prevent damage by wild boar in maize. We have designed and conducted field experiments in various maize fields, by using castor as border crop around maize against wild boar.

MANAGEMENT METHODS FOR DEPREDATORY BIRDS

Traditional Methods

Machan: A machan is erected amidst the maize crop. A semicircular mat made of bamboo splits is puton the machan to prepare a small hut for the shelter which is locally called *dhagla*. Sometimes, instead of semicircular mat, an umbrella type structure made of leaves of *Butea monosperma* and bamboo sticks (locally called *dengcha)* is placed on machan. Loud calls are made from the *machan* to keep away the birds. Stones are thrown by locally made equipment called *gophana* (sling) to drive away birds (Plate 1 a).

Flagged bamboos and flagged leader shoots: Pieces of plastics and coloured clothes are tied on bamboo sticks which are erected amidst the crop in the field to keep away the birds. Sometimes these are placed at the periphery only. When the crop reaches the milky stage, flags of cloth are tied on leader shoots of some of the tall trees.

Use of 'Owl-rests':

Cushion owl-rests: A coiled mass of *Tectona grandis* leaves is wrapped at one end of a bamboo stick. Dozens of such sticks are erected in the field keeping the leaf mass upward. At night, owls are attracted to these perches and prey on night dwelling rats. This method is generally used in fields of wheat and gram. ***Pole owl-rests:*** Poles of bamboo culms, 0.5 to 1.5 m long, are erected amidst gram, wheat and barley crops to provide perching stations to the owlets during night.

Pitcher-effigy (scare crows): Pitcher-effigies (locally called *byawana* or *taoon)* are prepared by the farmers with locally available material. An old pitcher (terracotta vessel), having black outer surface due to use in kitchen for cooking purpose, is kept upside down on a vertically erected wooden pole of a man's height to symbolize the head of a man having black hair. Sometimes head is made by black cloth also. Then, a horizontal stick is tied to the vertical pole to resemble arms raised to shoulder level. An old shirt (kurta) is put on the wooden structure to make an effigy of a man working in field. These effigies are said to be effective in repelling raiding birds from (Plate 1 b).

Hanging Crows: A hung dead crow is said to be very effective in repelling crows. This method is equally effective in houses as well as in fields.

Calls made by 'ghunku': Ghunku' is a simple device made by locally available material. An earthen pitcher used in Persian wheel (to draw water from wells, locally called ged) is taken and a piece of goat skin having a hole in its centre is tied to the mouth of the pitcher. A tall feather of peacock is inserted in the hole and a knot is made at its lower end. This apparatus is held between the feet and then a massage like action is made on the feather with the thumb and the first finger. To make the action easy, few oil drops are also applied on the feather. A loud call is generated by this apparatus which is said to be effective in frightening nocturnal animals. This is also used during day-time to keep away birds.

Halan: This method is mainly practiced by *Saharias.* A string is tied loosely around or across the fields. Leaves of *Tectona grandis* are tied to the string in a series. This festoon of leaves is connected by another string at the mid-point. A man sitting on a machan pulls the string in jerky motions and dry, hanging leaves produce a typical buzz like sound which keeps away the birds and other animals. This indigenous device is called *halan* (i.e., something which moves). Many variations of this system can be seen in the state. Sometimes bells instead of leaves are also used. Sometimes, single leaf *halan* (locally called *jalra*) made by bamboo pole and striated *Tectona grandis* leaf are also erected amidst the crop to keep away rodents and birds.

Drum beating: Drums are beaten from some elevated places or machans to keep away the flocks of grain eating birds. This method is said to be effective against the raid of locusts also.

Ecofriendly Management Methods For Depredatory Birds

As a part of All India Net Work Project on vertebrate pest management, multi location trials for evaluation of different eco friendly management practices were carried out to determine their efficacy, feasibility and economical viability under different agro climatic zones. These methods were tested all over India, i.e., Himachal Pradesh in the north to Kerala in the south with the varying cropping patterns stretched in different climatic regimes. As a result several eco friendly economical management practices have been evolved for minimizing losses caused by depredatory birds which are elucidated as under:

Wrapping method on maize crop: Covering maize cobs by wrapping adjacent green leaves around them reduced the damage to a negligible level by parakeets and crows, which were the major problem birds. Being hidden camouflaged, the wrapped cobs escape detection by birds and thus the crop is protected. It is a very simple and effective method, which does not involve any material cost and is les laborious than scaring. This method does not have negative impact on the grain yield. All cobs need not be covered. Since parakeet damage is restricted to peripheral rows, covering of 50% cobs at random on outer 3 rows of the field is sufficient to effectively reduce bird damage (Plate 1 c).

Reflective ribbon for bird scaring: Reflective ribbon is a polyester film with a shining metallic coating with red on one side and silver on the other. It is prepared by cutting along continuous polyester sheet in to strips of 1.5 cm width. Such strips, preferably 15 to 20 m long, are fixed parallel to the crop at 0.5 m height above the crop and at 5 m intervals using bamboo poles and strings. For better reflection, the ribbon should be fixed in north to south direction. During sunshine the reflection of sunlight and humming noise produced by the wind scares the birds from the field. The device is effective only for 15-20 days. After that the birds gets used to it. The ribbons do not scare birds under poor light condition and when the crop is grown in isolation. The technique of bird scaring by ribbons is very effective and easily acceptable to the farmers. Birds like rose ringed parakeet, *House crow (Corvus splendens)* and mynas are scared by this devise in maize (Plate 2 a)

Screen crop: Thick planting of sorghum and bajra (fodder) as well as of maize fodder significantly reduced parakeet damage in maize crop grown for grain production. Besides giving better yield, this practice also provided additional fodder.

Automatic mechanical bird scarer or pyrotechnic method: Automatic bird scarer can also be employed. This is a sound producing device which works continuously for a whole day with 1 kg of calcium carbide and water. One-hectare areas can be covered with this method and it is found effective in reducing crop losses by birds. Care must be taken about the frequency of firing and change of positions and directions to avoid bird getting habituated.

Seed treatment for protecting sprouting seeds: Copper-oxychloride 3gm/kg seed is very effective in reducing the seedling losses due to birds in maize.

Bioacoustics

The bioacoustic technology uses only sounds of predators, distress and alarm calls of target and closely related species of target birds. The calls are broadcast in a field by using an electronic platform with sound drives. Bioacoustic tries to convey the message 'this area is dangerous' to the target bird species in their own language. On hearing the sounds, the target bird species start avoiding the area, thus saving the crop form being damaged. The sounds are natural and safe on humans and animals. The equipment should be ideally installed when the bird damage is beginning.

Habitat manipulation: Creating continuous disturbances to the nesting sites of the depredatory breeding birds in and around the cropped areas that will force the birds to leave breeding grounds and shift to another area. For parakeets in addition to manual destruction of nests, closing the entrance of the nests proved effective reducing their population. Planting of some fruit bearing trees like Manila tamarind (*Pithecolobium dulce*), Flame of the forest (*Butea monosperma*) Mulberry (*Morus alba*) and Toothbrush Tree (*Salvadora persica*) in and around cropped areas attract many granivorous birds during fruiting period and reduces the impact at vulnerable stage of the crop (maize) (Plate 2 b).

MANAGEMENT METHODS FOR WILD BOAR

Several ITKs are being employed by the farming community to ward off wild boar in different innovative ways. Some of such effective ways, practiced by local people were scientifically evaluated and validated for efficiency and economic feasibility. The following are the sum of such methods which are being recommended through AINP on Vertebrate Pest Management.

Traditional Methods

Spraying of dung solution of local pigs

Territoriality is very high in wild boars which are being exploited under this method. The dung collected from local pigs will be made into solution and should be sprayed on soil to the width of 1 ft around the maize crop. This will confuse wild boars with a false assumption of entering into the territory of other pigs; there by their movement will be prevented to avoid territorial conflict. For sustained affectivity it is desirable to go 2-3 sprays with 7 days interval between each spray (Plate 3 a).

Human Hair as respiratory deterrent

Wild boar with poorly developed sight and hearing mechanism has to depend on its smell sensory mechanism only for movement as well as locating of food. In this process it moves from one place to other place only by a way of sniffing on the ground there by getting guided in to the desired routes. Spreading of human hair collected from local barber shops is an affective and low cost traditional method being followed by farmers. Technically this indigenous method do have scientific logic which clearly suggest that the human hair in the movement routs of the wild boar gets sucked through nostrils causing severe respiratory irritation. Due to this the wild boar gets totally disturbed and loses its track by making distress calls, which will ward off other wild boars entering into the cropped area. Several farmers are extensively practicing this method in maize and different crops and controlling the damage caused by wild boar to the extent of 70-80% (Plate 3 b).

Fixing of used colored sarees

This method also is a farmer's innovation, which has a behavioural background as far as wild boar is concerned. By arranging used sarees of different colors around the maize crop will make wild boars to assume human presence in the area there by not preferring to enter into such areas. Even though, not feasible in all situations it has some marginal benefit in the areas of human movement. By using this, extent of damage by wild boar can be minimize to the level of 45-60% (Plate 3 c).

Creation of sounds and light through born fire

To scare away the wild boars from damaging their crops farmer's employee methods such as using fire crackers, making sounds through local drums, empty tins, making born fires and shouting. This type of methods proven to affective on community basis in protecting farmers fields from the wild boars.

Use of traditional local dogs for scaring away wild boars

In endemic areas of wild boar attacks farmers do follow using of trained dogs on a community basis to scare away the approaching wild boars. In selected cases this method proved to be affective and sustainable.

ECOFRIENDLY MANAGEMENT METHODS FOR WILD BOAR

Biological barriers

To avoid additional expenditure in the name of physical barriers, extensive studies were undertaken by AINP on Vertebrate Pest Management to utilize naturally occurring shrubs / plants / crops as physical barriers in the name of bio fencing. Bio fences are useful not only protective barriers but are also eco friendly in nature giving additional income to the farmer through their produce.

Four rows of castor around the crop

This method is widely being popularized in maize crop by planting 4-5 rows of castor with close spacing around the maize crop. Wild boars being capable of identifying maize only through smell can't do so owing to the strong odour emitted by the castor successfully masking the odour emitted by the maize crop. Damage in castor by wild boar is also not possible due to the non palatable nature of the plants with high amount of alcholodies and glucoscides. Through this method, farmer is benefitted with additional income through castor. Usage of castor as border crop is practicable in both *Kharif* and *Rabi* seasons (Plate 4 a).

Planting of thorny bushes and xerophytes around the crop

Different xerophytic species like Cacti sp *Euphorbia caducifolia, E. meriifolia* & Opentia sp *Opuntia elatior*, *O. dillenii*, Zizipus sp *Ziziphus oenopolia*, *Z. mauritiana*, and agave sp *Agave americana*, *Caesalpinia cristata* can be planted on the bunds around the maize, which will not allow the wild boars due to their thorny in nature. The wild boars after unsuccessful trail of entry get injuries and making alarming calls, which makes the other animals to flee the scene.

Planting of Karanda around the crop

Planting of karanda (*Carrissa carandus*) around the maize crop as bio fence does prevent effectively the entry of wild boars into the cropped area owing the thorny nature. Using karanda as a border crop gives enormous benefits to the farmer by giving value added products extract of medical important effective alternative to tamarind etc., in addition to fulfilling of basic purpose of wild boar prevention (Plate 4 b).

Spraying off egg solution

By exploiting the habit of the wild boar using smell of the crop as criteria for identification, an extensive level of experiments were carried out to use spray of egg solution either on the border row of the crop or on the wet soil around the crop. The results has given a clear cut indication that spray of egg solution 20 ml/lt of water was capable of successfully making the natural odour of the crop and thereby reducing the wild boar damage.

Coconut ropes coated with Pig oil

Preparation of solution with sufficient quantity of sulphur is mixed with local / domestic Pig oil is done and that mixture should be smeared on the coconut ropes and the ropes should be erected in 1 feet width in three rows around the crop with the help of wooden poles. This mixture generates the typical smell there by repelling wild boars not to enter into the cropped area. For an effective use of this method two such applications should be done with ten days interval in between.

Barbed wire fence:

Erecting of barbed wire around the field in three rows with first row is at the height of 1 foot from the ground. This is highly effective in preventing wild boars from entering into the cropped area. The cost of such barrier has also been calculated (Barbed wire Rs: 6,855 to 7,000; Labor cost Rs: 1,000; total cost per acre Rs: 8,000) and was found economical.

Circular razor fence

The iron wire fixed with sharp razor blades at regular distance is kept 1 ft away from the cropped area as border by farming circular rings (Plate 8a). The blades caused serious damage to the wild boar which tries to enter into the field. This not only prevents the animal to enter into the field but also scares away other animals. The entangled animal makes alarm calls which deter away the other wild boars thereby saving the entire crop without any damage. The cost per acre will be Rs: 19,000 (Rs. 18,000 for the wire + Rs: 1000 labor) involved in fixing this type of physical barrier (Plate 4c).

Chain link fence

It is an easy most effective way of fixing a barrier which is more durable in nature. Chain link meshes of 3 feet height can be fixed around the crop by maintaining a distance of 1 ft away from the crop (Plate 8b). The cost of the chain link fence needed for 1 acre will ranging between Rs: 10,000 - 10,500 and the labor cost for fixing worked out to be Rs: 1,000 per acre (Plate 5 a).

GI wire fence

A simple GI wire can also be use to create physical barrier for wild boars where three rows of GI wire fixed around the crop with the help of poles with a height of 1 feet from the ground level. This method is comparatively simple and economical method as compared to other barriers. The animal by coming in contact with GI wire feels threatened and gets scared away by confusing the GI wires with electric fences. The cost involved per acre is around Rs: 2,000 including the Rs: 1,000 for labor cost.

HDPE Nylon Fish net as physical barrier

The fish nylon net (HDP, UV stabilized, 2'' mesh and 1.5mm thickness) using bamboo or strong wooden poles should be erected around the crop vertically for about 3 – 4 feet height. At every 10 – 15cm nails to be fixed on the poles for better fixing of the net. Insert the nylon rope in between the mesh net and fix horizontally on the ground by using small wooden pegs. This method prevents entry of the animal into the fields and also if by chance animal enters will be entangled and makes alarm calls which deter away the other wild boars (Plate 5 c).

Trenches method

Digging of 2 ft wide and 1 ½ feet deep trench around the cropped area at a distance 1 ft from the crop keeps away the wild boars from the field. This method also helps as an excellent source for water conservation in the rain fed areas despite being effective method for wild boar management. This method gives additional advantage of preventing the damage of the crop by insect pests which are migratory in nature from one field to other field (Plate 5 b).

Bioacoustics

The bioacoustic technology uses only sounds of predators, distress and alarm calls of target and closely related species of target animals. The calls are broadcast in a field by using an electronic platform with sound drives. Bioacoustic tries to convey the message 'this area is dangerous' to the target animals in their own language. On hearing the sounds, the target animals start avoiding the area, thus saving the crop form being damaged. The sounds are natural and safe on humans, birds and animals. The equipment should be ideally installed when the animal damage is beginning (Plate 6).

Conclusion

All the methods listed above are scientifically proved effective in controlling of depredatory birds and wild boar intrusion in different crop fields. Among all traditional and eco friendly methods, reflective ribbon, wrapping in maize, bio acoustics, screen crop, spraying of egg solution and habitat manipulation were proved effective and reduced crop losses by birds to the tune of 60-70%. Where as in case of wild boar, bio acoustics, safflower as border crop around ground nut, castor as border crop around maize and sorghum, circular razor wire fencing are proved effective in reducing the damage to the extent of 70-80%. Hence, large scale demonstrations and awareness to different stakeholders about these methods will certainly enhances the production and productivity of the crops and also minimizes man-animal conflict.

PLATE 1

(a) Using of Machan to scaring the depredatory birds

(b) Pitcher-effigy (Scare crow)

(c) Wrapping in maize

(d) Reflective ribbons on maize crop

(e) Habitat manipulation practices to reduce depredatory bird damage

PLATE 3

(a) Spraying of dung solution of local pigs around crop

(b) Spreading of human hair as thin layer around the crop

(c) Fixing of used coloured sarees as border around the crop

PLATE 4

Castor (four thick rows) around the maize crop

(b) Planting of karanda around the crop

(c) Circular razor fence around the crop

PLATE 5

(a) Chain link fence around the crop

(a) Trenches around the crop

(b) HDPE Nylon net around the crop

Plate 6

Bioacoustics in Maize field

Maize processing and value addition

Shobha, D
Asst. Nuritionist, AICRP on Maize, Farm, Mandya - 571405
Email: shobhafsn@gmail.com

Food grains are a fine example of diversity of nature with many varieties and varied features. They are storable food commodities and lend themselves to numerous processing manipulations. Nutritionally food grains are rich source of almost all known nutrients and several phyto-chemicals. The increasing incidence of metabolic diseases are attributed to unbalanced energy rich diets lacking in fiber and protective bioactive compounds such as micronutrients and phyto-chemicals (Prakash, 2013). Cereals along with pulse combinations constitute an important part of human diet in many parts of the world because of easy availability, low cost, long shelf life and nutritional balance. During recent past, India has made significant progress in improving the food security of its masses. The green revolution of 60's helped the country in achieving the food security by improving the availability and access components. However, Surplus quantity of food produced is not uniformly distributed and the quality component is not addressed properly which has a direct impact on nutrition. In spite of surplus production of food grains still malnutrition persists. However which can suitably be overcome by combining cereals with good quality pulses and other value addition techniques which will go long way in solving the problem of malnutrition

Even though we are producing variety of cereals, pulses and millets, utilization of produced grains to their fullest potential is not happening in our country which holds good for third largest produced grain maize also. The consumption of corn is very less in our country which may be due to the lack of awareness regarding the nutritional benefits, method of processing, cooking and to some extent availability of other foods in refined and processed forms. However, owing to superiority of maize over rice and wheat due to its high fibre, phosphorus, beta carotene and free from gluten lends itself suitable for people who are allergic to gluten.

Several traditional food processing and preparation methods can be used at household level to enhance the bioavailability of micronutrients in maize based diets. These methods include Alkali cooking, thermal processing, mechanical processing, soaking, germination/malting and fermentation. In countries like Central America and Africa, it is converted into food products by grinding, alkali processing, boiling, cooking and fermentation.

Maize is next to rice and wheat in terms of acreage and ranks second in terms of total production and productivity which accounts for approximately nine per cent of total food grain produced in India. Being a potential crop in India, maize occupies an important place as a source of human food (23 %), animal feed (12 %), poultry feed (51 %), industrial products mainly as starch (2 %) and 1 % each in brewery and seed (Parihar *et al.*, 2011). There are many products from maize that have been taken over by industry and manufactured and marketed at commercial scale. Several of these products already mentioned are now industrialized on a small or large scale. In USA over 1000 different items can be found on the shelves of a typical supermarket and they are derived wholly or partially from maize. These products include: tortillas, maize flours (masa) chips and several types of snack, breakfast cereal, thickness, pastes, syrups, sweeteners, grits, maize oil, soft drinks, beer, whisky etc.

Maize also known as corn, an important food grain in India, has many industrial and food applications apart from its use as a feed ingredient. It is rich in starch and bland to taste and hence lends itself as an ingredient in several traditional foods. Like other cereals, maize contains large proportion of carbohydrates (60-65%) and thus provides bulk of energy in the diets based on it. Apart from carbohydrates it is also a good source of protein (10-12%), fat (3.5-5.5%) and crude fiber (2.0-2.5 %). By virtue of its composition it is quite comparable to rice and wheat in its nutritional value (Table 1 and 2).

Table 1.Nutritional quality of maize compared to rice and wheat (per 100g).

Grain	Carbohydrates (g)	Protein (g)	Fat (g)	Crude fiber (g)	Minerals (g)	Calcium (mg)	Phosphorus (mg)	Iron (mg)
Maize	66.2	11.4	4.6	2.7	1.5	10	348	2.3
Rice (milled)	77.6	6.8	0.5	0.2	0.7	10	100	0.7
Wheat	71.2	11.8	1.5	1.2	1.5	41	306	5.3

Table 2. Vitamin and mineral content of maize.

Nutrients	Per 100 g
Magnesium (mg)	139.00
Sodium (mg)	15.90
Potassium (mg)	286.00
Copper (mg)	0.41
Manganese (mg)	0.48
Zinc (mg)	2.80
Chromium (mg)	0.004
Carotene (µg)	90.00
Thiamine (µg)	0.42
Riboflavin (µg)	0.10
Niacin (µg)	1.80

Processing and consumption of maize:

Maize is being processed in various ways in different parts of the world before consumption. However the soaking and nixtamalization are the major pre treatments followed around the world.

Soaked grain:

The grain is soaked and cooked in water or lime solution then ground to make dough which is used as the base for different preparations. Eventually, the soaked and cooked grain is dehulled and the germ is removed partially or totally. This product can be pounded to obtain the grits and then cooked and eaten like boiled rice or can be used to prepare special type of breads such as the *arepas* in Venezuela or the *soaps* in Paraguay. Likewise, maize gruel can be transformed into sweet or sour drinks. Fermented drinks are popular in Africa and Latin America.

Nixtamalized maize or lime treated or alkali treated grain:

This process was developed by Native American Indians. The nixtamalization consists of mixing one third part of whole maize with two third part of lime (calcium hydroxide) solution between 1 to 2 percent of concentration. In general the cooking time may vary from 15 to 45 minutes and the temperature of cooking is held above 68^0 C. The grinding of nixtamalized kernels is carried out by simple pounding with a hand operated or electric kitchen mixer grinder for large scale masa production. This masa is the base for preparing several traditional products such as *tortillas*, *tamales*, etc (FAO, 2003). The dry masa flour is more stable against rancidity and the shelf life can be until one year in comparison with the whole kernel ground maize flour

Maize

↓ After cleaning

Soak 500g grains in 1% lime water for 5 minutes

(10g of lime in 1 liter water)

↓

Give heat treatment at simmering temperature for 30 minutes

↓

Remove the vessel and leave it for overnight

Wash 3 – 4 times to remove lime

↓

Dry in sunlight

(Moisture level should be 9-10 %)

↓

Store in air tight container

Fig 1. Lime treatment of maize grains

Nixtamalization or lime treatment has the following advantages: it facilitates the per carp removal, controls microbial activity, enhance water uptake, increases gelatinization of starch with improvement in nutritional value through an increased availability of niacin. The research conducted at AICRP (maize) Mandya centre, indicated that the lime treated maize flour can be kept up to three months in LDPE covers without affecting flavor and roti making quality (Shobha *et al*.,2014). The process of lime treatment and its advantages has been disseminated through training to maize growers, SHG's and mill owners. The lime treated corn is being used in India for the preparation of various products such as *dhokla,* snack foods such as *sev, muruku* and *laddu* by suitably combing with pulse and other adjuncts.

In India efforts are being made to intensify the production as well as the utilization of maize in order to alleviate pressing demand for rice and wheat. Grains can be processed into a number of products in dry milling process using mini grain mill such as grits, semolina (suji) and flour. These dry milled products are being used in numerous ways. The milling is carried out on roller mills using fluted rolls. The products are sifted on a plan sifter and are aspirated. The mill is divided into a break station, a series of germ and a series of reduction and quality rolls. The break system releases the rest of the germ as well entire particles and cracks the large grits to produce grits of medium size. The finished grits, meal and flour product are dried to 12-14 per cent moisture content on a rotary steam tube driers prepared out of dry milled products such as suji (semolina) and flour.

SPECIALTY CORNS

Recently maize being grown for diverse uses and specialty purposes. Such maize for specialty and value added purposes are collectively called "**specialty corn**". Compared to field corns, specialty corns possess additional characteristic features (tender-ear, biochemical components relating to sweetness, protein, starch and popping traits). Their global spread, increasing demand and premium price make them an attractive option for the farmers in many countries including India.

The major specialty corns which occupied significant portion in food shelves include baby corn, sweet corn, pop corn and Quality Protein Maize (QPM).

BABY CORN

Baby corn (*Zea mays* L.) refers to the young cobs of maize harvested within 1-4 days of silk emergence. Baby corn is highly nutritive and its nutritional quality is at par or even superior to some of the seasonal vegetables. Besides protein, vitamins and iron, I t is one of the richest source of phosphorus. It is a good source of fibrous protein and easy to digest. It is also free from the residual effects of pesticides as the young cobs are wrapped up within the husk and well protected from diseases, insects, fungicides and insecticides.

Processing of Baby corn:

Main processing methods which can be used to improve the shelf life of baby corn are canning, dehydration and freezing.

Canning: The most common method used for processing of baby corns and is normally practiced by dipping corn in brain solution and can be stored for months together and transported to far off places.

Dehydration: One of the oldest methods to increases the shelf life for longer period with less expenditure. Baby corn can be cut into round or 2 cm long pieces and dried in oven or solar dried. Dried baby corn can be packed in polythene pack/vacuum pack/tetra pack and can be stored for longer period. Dehydrated cobs can be rehydrated by soaking in water and can be used in preparation of food products.

Freezing: Cobs can be frozen and stored for long period like other frozen vegetables. They can be used effectively for preparation of food products like salads, curry and soup preparations.

Baby corn may be consumed raw or used as an ingredient in various preparations. Different value added products such as *manchurian, jam, pickle, pakoda, curry, salad, soups, halwa,* canned corns etc. are few examples under wide range of value added products. Recently a process has been standardized at AICRP (Maize) Mandya centre for preparing baby corn candy using 40, 50 and 60^0 brix sugar solution followed by dehydrating the same till the moisture level reaches between 10-12 per cent. Prepared cadies will have a shelf life of six months in MPP pouches. *Baby corn candy, baby corn lollypop, brined baby corn, baby corn murabba, dehydrated baby corn, minimally processed baby corn* etc are standardized and added to package of practice book of UAS, Bengaluru.

SWEET CORN

Sweet corn (*Zea mays saccharata*) is genotypes with specific endosperm mutation like su and sh. In India, sweet corn green ears are being consumed by direct toasting on fire or boiled in water. Sweet corn kernels often have a wrinkled appearance resulting from a sugary gene which retards the normal conversion of sugar to starch during endosperm development. Kernel colors vary sometimes being mixed both white and yellow. The endosperm is composed of sweetish starch and characterized by translucent horny appearance during immature stage and after maturity the kernel becomes wrinkled. Sweet corn cob is harvested around 80-85 days after sowing (milky stage). It contains on an average 25- 30 % sugar; many sweet dishes such as *halva*, *kadabu*, *crunch*, *salad, jam*, *pakoda* and such other products can be prepared using sweet corn by combining with other ingredients.

Table 3. Nutritive value of sweet corn.

Nutrients	**Per 100g**
Energy (K cal)	86.0
Carbohydrates (g)	18.70
Protein (g)	3.27
Fat (g)	1.35
Fiber (g)	2.00
Vitamin A (IU)	187.0
Calcium (mg)	2.00
Iron (mg)	0.52
Zinc (mg)	0.46

POPCORN

Pop corn (*Zea mays var. everata*) has small grains with hard outer layer. It has higher *per cent* of hard starch than flint corn. It is a popular snack throughout the world. Pop corn is an extreme form of flint corn wherein there is a variation in the proportion of hard starch and soft endosperm. The moisture in the soft starch at the central portion of the endosperm on heating is converted to steam and when this steam tries to escape it is confined by the outer layers of hard endosperm. When the steam pressure increases the hard pericarp of the seed bursts into flakes leading to the phenomenon called popping. Its added feature of pop corn is the light, crunchy texture. The ground pop corn in the form of flour or grits can be used in the preparation of many traditional dishes. Popcorns are usually consumed as a snack food with or without salt (regular), sweetened (caramel/chocolate corn) or butter like topping. Popcorn consumption has greatly increased in recent years because of the advent of microwavable popcorn, the proliferation of flavored ready to eat products with good nutrition.

Table 4. Nutritive value of popcorn.

Nutrients	Per 100g
Energy (k cal)	382.0
Carbohydrates (g)	78.0
Dietary fiber (g)	15.0
Fat (g)	4.0
Protein(g)	12.0
Thiamine (vit. B_1)	0.2 mg
Riboflavin (vit. B_2)	0.3 mg
Iron	2.7 mg

Popping is simple and economical processing technique which is traditional and may be adopted easily with improvement in nutritional quality. It is a high temperature short time (HTST) treatment which sterilizes product, gelatinizes its starch and develops a pleasant aroma to form a ready-to-eat food (RTE) at a very low processing cost. Popping process not only retains the actual nutritional profile of grains but also markedly enhances its protein digestibility, bio availability of iron and dietary fiber content due to the development of resistant starch. Popping also reduces some of the anti nutrients viz., phytate, tannins, acid detergent fiber, lignin and cellulose.

Popped Grain: optimally the minimum moisture to preserve crispiness in popped grain should be less than 2 percent. Moisture also affects the texture of pop corn and hence must be consumed at moisture lower than 2 percent (ideally 1.8-1.7%).

Mechanism of Popping: kernel of popcorn contains certain amount of moisture and oil. Unlike most other grains the outer hull of popcorn kernel is strong and impervious to moisture while the starch is of hard and dense type. When the kernels are heated moisture present in the kernel gets converted to pressurized steam as a result the starch inside the kernel gelatinizes, softens and becomes pliable. At a pressure of about 135psi (930 K Pa) and a temperature of 180-232^0 C is ideal for popping.

Types of Popcorn: Popcorn varieties are broadly categorized based on shape, colour of the kernels and shape of the popped corn. Kernels of maize will be of varied colors, but the popped corn is always off yellow or white as it is only the hull (pericarp) that is coated.“**Rice**” type popcorn has a long kernel pointed at both ends while “**Pearl**” type kernels are rounded at the top. Commercial popcorn production has moved mostly to 'pearl' types. Traditionally pearl popcorns were yellow and rice popcorns are white in colour. However variegated colours like black, red are also cultivated in many parts of the world. Commercial production is dominated by white and yellow.

Normally popped kernels (flakes) found in two major shapes that are “**Mushroom**” flakes are more of ball shaped with few wings and “**White Butterfly”** flakes were having protruding wings Butterfly shaped popcorns are regarded as having better mouthful with greater tenderness and less noticeable hulls than the mushroom shaped popcorns. The mushroom flakes have higher bulk density than the butterfly and are generally preferred in the confectionary industry as they are less susceptible to breakage and easier to coat with flavors or syrups. Butterfly-shaped popcorn has a better mouth feel and is preferred for on-premises popping such as theaters.

Popped grains are good in terms of energy, carbohydrate, fat, fiber, protein and iron. Since pop corns are prepared out of whole grains, which are rich in many components including dietary fiber, starch and fat. Fat or lipids consisted primarily of linoleic, oleic and palmitic acids. Apart from this popcorn do contain other nutrients, minerals, vitamins, lignin and phenolic components all of which have been linked to reduced risk of different types of cancer. Most of these protective components are found in the germ and bran which are reduced in almost all the grains due to refining process. However popping is one such technique of grain processing where in the germ and bran portions are retained and it is the most simplest and economical method of processing which imparts a pleasant aroma and flavor that can be enjoyed by all times. Apart from above advantages, popping of grains enhance the acceptability of cereals as well as millets.

Pop corn is used primarily for human consumption as a favorite nutritious snack food and is becoming more and more popular over time. Most of the popcorn is popped in home at domestic levels and the remaining is sold through retail outlets, fast food shops and also by confectionery industry (Yenagi et al., 2004). Since popcorn and its products are cereal based snack foods and always been an important part of life and these products represent an important segment of the food industry worldwide especially in developing countries.

Value addition to popped grains: at AICRP (maize) centre, Mandy, ground popcorn as flour or various sized grits are utilized in the preparation of many traditional as well as fancied dishes including health mixes (sweet and savoury) spicy pop corn, sweetened pop corn, chocolate pop corn, iron rich pop corn pre mix, energy dense pre mix, fibre rich laddu, pop corn lolly pop and others.

QUALITY PROTEIN MAIZE (QPM):

Quality Protein Maize (QPM) contains opaque-2 gene (o2) which makes it different form normal grains. The dull appearance of kernel and other undesirable characters have been overcome with the accumulation of genetic modifiers and extensive selection efforts carried out by scientists at CIMMYT in Mexico. The protein quality in QPM is much better than in normal maize. The “zein” fraction is reduced between 10 to 13 per cent in QPM as against 39 per cent in normal maize. The nutritional and biological superiority of QPM has been demonstrated in the diets of infants, small children and adults, particularly women.

Although maize contains higher proportion of protein (10-12 %) its quality is poor as compared to that of protein in rice due to presence of high concentration of alcohol soluble protein fraction ‘prolamine’ also known as ‘Zein’ in the endosperm. Zein is very low in some essential amino acids, mainly lysine and tryptophan which contribute more than 50% of the total protein. On the other hand, very high amount of leucine & imbalanced proportion of isoleucine contribute to poor quality of protein in normal maize. To overcome such deficiencies, scientists developed Quality Protein Maize (QPM) where in the quality of protein is not only higher than the common maize, but also significantly higher than that of other cereal grains. Lysine and tryptophan in QPM genotypes was increased compared to the normal grain. The balanced proportion of all these essential amino acids in QPM has increased the protein quality and their biological value

TABLE 5: Quality of essential amino acids in normal and QPM maize (mg/ 100 g protein)

Name of the amino acids	Normal maize	Quality protein maize	FAO / WHO Recommended level
Isoleucine	3.77	3.10	4.00
Leucine	10.60	6.62	7.00
Sulphur containing aminoacids	4.62	3.83	3.50
Tryptophan	0.48	1.20	1.00
Valine	5.02	5.46	5.00
Threonine	4.00	4.62	4.00
Lysine	2.73	4.92	5.50

Quality protein maize (QPM) for food and nutritional security:

QPM can be utilized for diversified purposes in food and nutritional security as infant food, health food/ mixes, convenience foods, specialty foods and emergency ration. The nutritious products developed from Quality Protein Maize can replace fancied and highly priced industrial foods with a diversified purposes under food and nutrition security as infant foods, health foods, convenience foods, speciality foods and emergency rations. It is also useful in fulfilling the protein requirements of different sections of the society to prevent malnutrition. The increased consumption of maize will encourage and open up new avenues for processing and marketing by young generation of urban, rural, small and medium entrepreneurs.

Good number of products from QPM was developed at AICRP, Mandya centre and studied their nutritional quality and storage stability and found that QPM products are quite similar to normal maize products in organoleptic and storage quality. However, they are superior in nutritional quality when compared to normal maize products. Some of the popular products such as *maize noodles, maize vermicelli, maize papad, maize ready-to-cook idli mix, maize ready-to-cook vada mix, maize nutri mix, maize nutri laddu and maize upma mix* developed and commercialized under the brand name "**MAIZY**"

Nutritional enrichment or fortification of maize with other cereal / pulse combinations:

Since the need for nutritive food at low cost is in demand, and a majority of the population in different geographical areas depend on cereals for their daily needs, QPM may not be available in all the places, hence the better alternative for this is to combine the maize with good quality pulse such as soybean, green gram, bengal gram, black gram, groundnut, along with wheat, rice, ragi in desired combinations. The concept of multi grains or multigrain flour is more ideal not only for nutritional and cost benefits but also to improve the texture and shelf life of the flour. A number of products can be prepared from this multi grain flour, which can also be included in mid day meal programmes in Schools and Anganawadis to serve balanced food at low cost. Since maize flour is gluten free, it can be recommended for people who are intolerant to gluten *ie.,* it can replace chapathi with roti of maize flour. The unique property of maize dough is its ability to hold more water than other cereal dough (22.89 – 25.64%)is the reason why maize roti has been found to be quite soft and supple.

Use of maize flour, either singly or in combination with the flours of other cereal or legume flours, for making many types of sweet and savoury snack foods has great possibilities in the Indian context. Different types of deep fried products are possible and have been tried. For example, dough strands prepared by the low pressure extrusion using maize flours or a mixture of maize flour with that of gram (chick pea) flour can give excellent, crisp deep fried *sev*. In this respect, maize flour can be a good extender of gram flour (Bengal gram/ Cicer arietinum) for such preparations. A large variety of sweet dishes – *laddu, vada, mysorepak, etc*. can also be prepared from maize flour.

Attempts have been made at AICRP (Maize) centre, ZARS, V. C. Farm, Mandya, Karnataka to increase consumption of maize, through improved processing techniques. Value addition to maize (both Normal and QPM), processing methods, by - product utilization, training and demonstrations to impart the skills to SHG women, is a first step towards creating awareness regarding nutritional benefits, health benefits and advantage as gluten free energy source for celiac patients.

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Role of bio agents and bio pesticides in bio intensive pest management (bipm) approaches in maize

Dr. S. J. Rahman
Principal Scientist & University Head of Entomology
AICRP on Biological Control of Crop Pests
Professor Jayashankar Telangana State Agricultural University
Rajendranagar, Hyderabad – 500 030

In the present WTO regime, quality of the agricultural produce has gained importance apart from quantity produced. The globalization of agriculture necessitated Indian farmer to follow Good Agricultural Practices (GAP) in crop protection through Integrated Pest Management (IPM). The globalized competition led the farmer to adopt Sustainable agriculture approaches to improve the quality of the produce without chemical residues. In agriculture, plant protection is vital area, which considerably influence the yield attributes. An enormous amount of crop losses are caused due to insect pests, diseases and weeds in several of the commonly grown commodities in India ranging from grain crops like cereals, pulses & oilseeds to cash crops like cotton, jute and several of the vegetables and fruits. Till the last decade, pesticidal applications were used to be the prime measures for insect pest and disease control in many of the crops. However, due to several of the disadvantages associated with pesticidal use, such as residues in commodities, resistance development to pesticides in insect and also most importantly the enormous amount of environmental hazards caused by pesticides, the farmer never got the real benefit out of the chemicals what he was using in the name of pestcides. On the other hand, due to indiscriminate use of pesticides several of the non-target beneficial organisms like natural enemies, honeybees and other such useful fauna are adversely affected causing ecological imbalance resulting into unaccountable amounts of deleterious effects on "Mother Nature".

Bio Intensive Pest Management (BIPM): A Suitable Need in Sustainable Agriculture

By keeping in view the above facts, in mind, it becomes imperative to concentrate on alternate methods of pest control without the negative impact of plant protection measures on the ecosystem. Among various approaches adopted in pest control, Biological control based Bio Intensive Pest Management (BIPM) of crop pests is found to be the most important and practically feasible one by considering the present scenario of Indian agriculture in general and Telangana Agriculture in particular. In BIPM, Bio Agents and Bio Pesticides based eco friendly measures of pest management are of vital importance in the era of sustainable agriculture.

Scope and Applicability of Biological Control and non-chemical methods to fit into situations of Sustainable Agriculture:

Several non-insecticidal methods of pest control such as Biological Control, use of Pheromones, Cultural Control and use of botanical insecticides started gaining importance in IPM programmes in different important crops. Validation of these BIPM programmes with biological control as an integral component was done in important crops to work out the economic feasibility of these eco friendly inputs. Application of these biological pest management inputs in Sustainable agriculture is well justified as the basic concept of sustainable agriculture highlights the fact that it envisages the alternate production system which avoids or largely exclude the use of synthetic fertilizers, pesticides and growth regulating hormones. In case of BIPM it proved to be two way process wherein, BIPM acts as a potential tool in Sustainable agriculture while Sustainable agriculture enhance the potentiality of BIPM.

Basic Background of Biological Control agents and their categories

The efforts aimed at increasing the naturally occurring biotic agents against the pest, both qualitatively and quantitatively can be termed as Biological Control and the pest management programmes where these inputs form the core component is designated as Bio Intensive Pest Management (BIPM) (Table.1,2 &3).The most commonly used bio agents in BIPM are:

PARASITOIDS: Due to their high multiplication rates they are of vital importance in the biological control of insect pests. The parasitoids successfully being used in India are:

1. *Trichogramma* egg parasite against eggs of gram pod borer, rice stem borer, maize stem borer, castor semi looper, cabbage diamond black moth etc.
2. *Bracon hebetor* against insect pests of coconut, maize and sugarcane.
3. *Brachymeria* against the pupae of several pests of plantation crops.

PREDATORS: They are external feeders and will be consuming several of the insect pests during their life cycle and hold a key role in minimizing pest population in field conditions. The important predators put to use in biological control are:

1. *Chrysoperla* sps against several of the soft bodied insects such as aphids, leaf hoppers etc.
2. Ladybird beetle against aphids and mealy bugs.
3. Spiders – against a varied number and types of insects especially in rice and maize ecosystems.

MICROBIAL ORGANISMS: The micro organisms exploited in biological control of insect pests are (a) Insect viruses (b) Bacteria (c) Entomo Pathogenic Fungi (d) Entomo Pathogenic Nematodes and other organisms like Protozoans and rickettsia etc. while several antagonistic fungi and bacteria are being successfully used in minimizing the plant disease incidence. Nematode pest management by using biotic agents is also one of the most promising areas and gaining much deserved importance in the current scenario of sustainable agriculture.

(a) Insect Viruses:

Nucleo Polyhedrosis Virus (NPV): Effective against only lepidopteran insects individually in different crops. *Ha* NPV is used for the management of *Helicoverpa armigera* while *Sl* NPV is meant for *Spodoptera litura*. Similarly, castor semi looper is managed by *Ach* NPV and red hairy caterpillar by *Am* NPV.

Granulosis Virus (GV) and **Cyto Plasmic Viruses (CPV):** are being extensively used against insect pests of sugarcane.

(b) Bacteria: Most commonly and widely used bio pesticide in insect control operations is *Bacillus thuringiensis*. This bacterium is highly effective against several insect pests of Lepidoptera. They cause disease due to which insect turns black and die. The bacteria come in several commercial formulations such as Dipel, Delfin, Halt, Spicturin, Biolep, BioAsp etc.

(c) Fungi: : Several fungi such as, *Beauveria bassiana*, *Metarhizlum anisopliae* and *Lecanicillium lecanii* are used against important pests like gram pod borer, tobacco cater pillar and sucking pests like thrips, aphids and mealy bugs. The fungi develop hyphae inside insect system as a result insect dies due to mechanical congestions. This mode of action makes these organisms to perfectly suit to the needs of sustainable agriculture. In certain cases they produce toxins to kill the insect.

(d) Entomopathogenic nematodes: These nematodes harbour certain bacteria which act as toxins to insect systems. Mainly exploited entomo pathogenic nematodes in insect control operations are – *Heterorhabditis* sp, *Steimernema* sp.

Other than these microorganisms protozoans such as *Variomorpha* sp and others were also found to be effective against insect pests and can be effectively be incorporated as tools in sustainable agriculture.

Antagonistic organisms for plant disease management

Biological control of plant diseases is also very important in the eco friendly management of the crop pests. The most commonly and widely used organisms for these purposes are *Trichoderma viride*, *Pseudomonas fluorescens* and *Bacillus subtilis* which are used for controlling the diseases caused by different pathogens *viz*., *Pythium, Phytophthora, Rhizoctonia, Fusarium* etc., These antagonistic organisms certainly give efficient, practical and cost effective plant disease control without causing any abnormal and adverse effect in the ecosystem. In addition to control of plant diseases, several of the disease antagonistic bio control agents play several other important roles such as plant growth promoting (*Pseudomonas fluorescens*), decomposition of crop residues in to organic matter (*Trichoderma viride*) and for extracting certain enzymes and other commercially viable metabolites.

Weed management through Biological Control

Biological control of the weeds through biotic agents is gaining momentum in the recent years as the weed menace in cultivated lands as well as in waste lands posing serious health problems to the mankind besides reducing the yield levels considerably in agriculture. Mexican beetle, *Zygogramma bicolorata* is being used for reducing the menace of Congress grass, *Parthenium hysterophorus*. Water hyacinth is reported to be attacked by *Neochitina bruchi* (weevil) and *Orthogalumna trerbrantis* (mite). Rust fungus, *Puccinia spegazzinii* is exploited for suppression of *Mikania micrantha.*

Case histories and success stories of Biological Control:

Sugarcane Woolly Aphid (SWA), *Ceratovacuna lanigera* emerged as a serious pest in sugarcane growing areas of Telangana in 2004 but was brought down to minimal level by 2009 through effective conservation of two important native predators of the pest, *Dipha aphidivora* and *Micromus igoratus*.

Similarly, Papaya Mealy Bug (PMB), *Paracoccus marginatus* with wide host range, is a potential polyphagous pest which is kept under suppression by inundative releases of imported Hymenopteran parasitoid, *Acerophagous papaya* with better attributes of parasitization than local populations.

Bottlenecks in use of Biological and bio rational methods and possible solutions

Agricultural ecosystem is ever changing and highly dynamic. This situation never does allow any management strategy to be the ultimate answer for pest problems. The techniques last for more time are considered as the techniques of success. In this process the Bio Control is struggling with certain practical problems. They are:

1. Mass production and sources of availability Bio agents and Bio Pesticides
2. Proper Formulation technology and economic feasibility
3. Quality maintenance and monitoring of biological inputs.
4. Shelf life concerns and handling precautions.
5. Lack of awareness in proper application technology among farming community
6. Competition from chemical pesticides.

The possible solutions available

1. Mass production techniques for several parasitoids, predators and bio pesticides have been standardized for commercial scale production.
2. Several Government programs are in progress highlighting importance of Bio Control. Similarly failure of insecticides, compelled the farmers to turn to Biological Control thus providing a good platform to promote the Bio control Technologies.
3. Research efforts to expand the killing spectrum and to improve the environmental stability of microbial bio agents is moving towards fruitful results.
4. In the days to come Bio pesticides are going to substitute for chemical pesticides. This is evident from the fact that several Multinational companies are already in the production of Bio pesticides.

However, despite the growing confidence on Bio Agents and Bio Pesticides among farming community the issues relating to their availability and quality are acting as stumbling blocks for their acceptance by the farmers. The pin pointed constraints in acceptance and adoption of Bio agents and Bio Pesticides are:

- The Bio Agents and Bio Pesticides are not as easily available in market as chemical pesticides
- By taking advantage of awareness generated among farming community, some scrupulous manufacturers are hijacking the same by cheating farmers in the name of so called "Bio Products"

Availability related constraints in usage of Bio Agents & Bio Pesticides and possible solutions:

- Non availability of *Trichogramma* in the shape of Tricho Cards during the critical crop stage for application
- Reluctance of private entrepreneurs for large scale production of Trichogramma due to short shelf life of '*Tricho Card*' and unpredictable requirement schedule from clientele.
- To address the above precarious situation, nine (9) Biological Control Laboratories are being run by State Department of Agriculture under active collaboration and technical guidance from All India Coordinated Research Project on Biological Control at Professor Jayashankar Telangana State Agricultural University (Table.4). These centres cater to the needs of farming community and make the Bio Agents available to them without being dependent on Private Entrepreneurs.

- All India Coordinated Research Project on Biological Control at Professor Jayashankar Telangana State Agricultural University is acting as nodal centre for all these labs and collaborate on technical knowhow and provision of quality inoculums cultures.
- Widely used Bio Pesticides like *Trichoderma viride* (Rs. 100/Kg) and *Pseudomonas florescens* (Rs.150/Kg) are made available on cost basis through these Govt. run labs.

Purchase, storage and usage of Bio Pesticides from market sources - Certain considerations:

After the growing awareness on Organic Farming & Eco friendly agriculture, the demand for alternatives to chemical pesticides is steadily increasing. In addition to *Trichoderma* and *Pseudomonas*, the Bio Insecticides such as *Beauveria bassiana* (for Lepidopteran Pests), *Metarhizium anisopliae* (for root inhabiting pests), *Lecanicillium lecanii* (for sucking pests) and Azadirachtin (as insect repellent) are available in market as an alternative to chemical Pesticides. Vowing to the rising demand from farming community, quality concerns are at its peak which need to be addressed immediately. The farmers should be made aware of the fact that all these Bio based pesticides are covered under Insecticide Act, 1968. By following the below mentioned precautions during purchase, the culprits can be booked under law in case of any quality related issues in the products.

Dos and Don'ts while purchasing Bio Pesticides:

- Ensure the Registration No. issued by Central Insecticide Board & Registration Committee (CIBRC) on packet/bottle
- Check the Manufacturing License issued by the State Government (where the unit is physically located) on Packet /bottle. Manufacturing license is generally valid for two years only from the date of issue subject to renewal.
- Observe the Manufacturing date and expiry date on packet/bottle suiting to the usage period. Generally, the permitted shelf life claim of Bio Pesticides is 6 months to 1 year.
- Demand for proper receipt after purchase of Bio Pesticides duly ensuring the signature of the person selling the Bio Pesticide. This will help to initiate action in case of any quality related anomalies.
- It is mandatory for manufacturers of Bio Pesticides to provide all the information on packet/bottle as per the Act Provisions. Any product without such information is deemed to be spurious and must be avoided.
- Huge numbers of so called "Bio Products" are flooding the market without any permissions and licenses from Government by taking the advantage of not being listed either in I. Act or in FCO. These types of products are un ethically laced with harmful chemical substances and plant growth hormones and being sold with fancy names and false claims. Farmers are advised to not to use any such products which are neither approved nor ever scientifically validated.

Dos and Don'ts while storing & application of Bio Pesticides:

- Do not store Bio Pesticides in wet or humid or places of direct sunlight.
- The packet / bottle should not be opened from original packing till the date of actual usage.
- Nuclear Polyhedrosis Virus (NPV) shall be sprayed during late afternoon or evening hours

- Avoid using combinations/tank mixing of Bio Pesticides with chemical insecticides & fungicides.
- Seed treatment with *Trichoderma* /*Pseudomonas* should be done immediately before sowing.
- Prefer to stick to the recommended dosage and method of application for Bio Pesticides as approved by licensing authorities.

Act related Regulatory Issues pertaining to Bio Pesticides:

- In case of any quality related doubts the samples of Bio Pesticides can be sent by farmer or their representative to Bio Pesticide Quality Testing Laboratory located at SAMETI Campus, Malakpet for quality testing.
- In case of noticing any spurious Bio Pesticide or any case of intentional cheating in the name of Bio Pesticide a written complaint can be lodged with either local MAO or Deputy Director of Agriculture (Plant Protection) against any person or organization involved in such activity.

With the growing awareness about alternate protection technologies among farming community and with positive initiative from Government machinery, the days are not far where in Biological Control and other Eco friendly approaches can offer an effective substitute to chemical pesticides The use of Bio rational ways to control insect pests, diseases and weeds offers good promise relating to ecological safety without causing adverse effects on nature in general and mankind in particular. This certainly suits to the basic concept of sustainable agriculture. The scope of these bio rational methods of pest management as an integral part of sustainable agriculture is evident from the fact that they are practically being used as an effective component of IPM in several major crops grown in India and can be effectively incorporated as a suitable tool in sustainable agriculture.

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Table 1. Certain Bio rational components being practically used in the management of economically important pests of different crops

Crop	Pests	Bio Agent	Dosage
COTTON	Bollworms Aphids *Helicoverpa*	*Trichogramma* *Chrysoperla carnea* *Ha* NPV	1,50,000/ha – 8 times 14,000/ha – 1 time 500LE --3 times
RICE	Stem borer	*Trichogramma*	50,000/ha – 6 releases. Starting at 35 days
CHILLI	*Helicoverpa* *Spodoptera*	*Trichogramma* *SI* NPV	50,000/ha -6 releases 250LE/ha
SUGARCANE	ESB TSB SB/IB	*Trichogramma* *Trichogramma* *Trichogramma*	50,000/ha - 4-6 releases Starting at 45 days 50,000/ha - 4-6 releases Starting at 60 days 50,000/ha - 10 releases Starting at 90 days
MAIZE	Stem borer	*Trichogramma*	50,000/ha - 6 releases Starting at 45 days

ESB: Early shoot borer; TSB: Top shoot borer; SB: Stem borer; IB: Inter node borer

NPV - 100 LE - ½ kg Jaggery – 100 ml teepol / acre
- 250 LE – 1.25 kg Jaggery – 200 ml teepol / ha
- The above dosage is on the basis of 1.5 x 10^{12} POBs/ ha
- In cotton it is 3.0 x 10^{12} POBs /ha

Bt - 1 gm or ml/lt of water (or) kg / ha (or) 400 gm/acre

Neem solution - 10 kg seed
- 200 lt water
- 100 ml teepol
- 12 hours soaking

Trichoderma viride - 8-10 gm /kg seed (Seed Treatment)
- 4-5 kg/100 kg FYM (Soil Application)
- 5 gm /lt (Drenching at plant base)

(This dosage is common for : Red gram Wilt, Cotton wilt and root rot, Chickpea wilt, Charcoal rot in jowar, Groundnut wilt, Damping off in vegetables)

Pseudomonas fluorescens : 5 gm/lt of water for Blast, Sheath rot and Bacterial leaf blight in rice crop

Mass production protocols for important bio pesticides

Dr. S. J. Rahman
Principal Scientist & University Head (Entomology)
AICRP on Biological Control of Crop Pests
Professor Jayashankar Telangana State Agricultural University
Rajendranagar, Hyderabad – 500 030

PRODUCTION PROTOCOLS FOR *Trichoderma viride* and *Pseudomonas fluorescens*

Maintenance of Mother Culture:

- Maintain on specific media (*Trichoderma/Pseudomonas fluorescens* media) in test tubes/ Petri plates.
- Maintain 10-20 mother culture tubes and store them in refrigerator (alternatively store in sterile glycerol)
- For long term storage, fill with sterilized mineral oil and store at -20^{0}C.

Mass multiplication of mother culture:

Trichodema viride

- *Trichodema* is generally mass multiplied on molasses yeast broth medium (30 g molasses; 5g yeast powder;1L distilled water)/ Jaggery/Soy
- Mix the ingredients in distilled water and pour in conical flasks/ horlicks bottles.
- Plug and cover the flask and keep them for sterilization in autoclave for 15 minutes at 121^0 centigrade with 15 lbs pressure.
- Cool them at room temperature.
- Inoculate with mycelial disc of *Trichoderma* from 5-6 day old cultures grown on PDA.
- Incubate the flask containing sterilized molasses yeast broth inoculated with *Trichoderma* by keeping in rotary shaker at 140 rpm for 3-5 days.
- Estimate the population in the Broth for each batch (cfu/ml)

Pseudomonas fluorescens

- *Pseudomonas* requires adequate nutrient supplements and hence King's B medium/ Tryptic soya broth/ nutrient broth should be used.

- Multiply *pseudomonas* using rotary shakers in 5 litre flask by incubating at 25-28^0 C for 48 hrs.
- Ensure that the harvested bacteria are in active phase.
- Do not continue shaking beyond 4 days and do not use Broth incubated for more than 4 days).

Mass multiplication for making talc based formulation:

- Mass multiply the culture in nutrient broth (*Pf*)/PDB or SDB (*Tv*).
- Homogenize the Bio Mass produced in a mixer.
- Sterilize the fermentor along with in nutrient broth (*Pf*)/PDB or SDB (*Tv*)..
- Incubate mass multiplied culture Broth at the rate of 1lit for 35 lit of media Broth (Kings B media Broth/Tryptic Soya Broth/Nutient Broth for *Pseudomonas*)/PDB or SDB (*Tv*).
- Run the fermentor for 4 days.
- Take a sample from the fermentor and retest the cfu.
- Mix the Broth @ 1:3 with talc powder and air dry it.
- Add CMC (Corboxy Methyl Cellulose) or Gum Arabic @ 0.5 % to the formulation
- Use Blender for mixing.
- Store in polythene bags of required sizes.

PRODUCTION TECHNOLOGY FOR PSEUDOMONAS FLUORESCENS

Prepare 200 ml of Kings B broth and sterilize at 121^0 C for 15 min.

↓

Inoculate a loopful of inoculam at luke warm temperature and keep under shaker for 24 hrs at 120 rpm

↓

Check the purity of the culture by following serial dilution and spread plate method

↓

After confirmation of the purity, the 200 ml broth is aseptically transferred to 10 L King's broth and the same procedure for incubation and purity check is followed

↓

The 10 L broth is aseptically transferred to pilot plant Fermenter containing 50 L of Nutrient

↓

broth

The parameter for the pilot plant fermenter are set at temperature = 30^0 C, aeration = 5 to 6 L/hour, pH = 7, stirrer = 150rpm and incubation time up to 24 hrs.

↓

The purity of the culture was checked similarly

↓

500 L of Nutrient broth was prepared and sterilized in large scale fermenter using boiler at 121^0 C for 30 minutes and cooled to room temperature using cooling towers.

↓

50 L of actively grown culture broth was aseptically transferred to large scale fermenter using peristaltic pump.

↓

The growth conditions in fermenter was set as temp = 30^0 C,aeration = 5 to 6 L/hour, pH = 7, stirrer = 150rpm and incubation time up to 36 hrs.

↓

Check the purity.

DOWNSTREAM PROCESS:

Harvest the whole fermented broth after 36 hrs.

↓

Check the viable population in the broth using plate and haemocytometeric methods.
Formulate the broth with Talc powder in a clean and sterile mechanical blender at the ratio of 1:3 (broth: talc).

↓

Ensure uniform mixing.

↓

Allow the formulated culture to cure in the sterile trays in an aseptic room at room temperature.

↓

Sieve the cured formulation in a mechanical siever of 300 mesh size

↓

Transfer the sieved material into the milky white LDPE pouches not less than 20 micron in size.
Store the packed product in cool condition

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Different types of media used for the production of Bio Pesticides & their composition:

1. Kings B medium

Peptone	:	10 g
K_2HPO_4	:	1.5 g
$MgSO_4$	:	1.5 g
Glycerol	:	10ml (15 ml for Seed Culture)
Dis. Water	:	1000 ml
pH	:	7.0

2. Nutrient broth

Peptone	:	5 g
Beef extract	:	2 g
Yeast extract	:	3 g
Nacl	:	5 g
Water	:	1000 ml
pH	:	7.0

3. Potato Dextrose broth

Potato Infusion	:	200g
Dextrose	:	20 g
Dis. Water	:	6.5 g
pH	:	6.5 g

4. SDB

Dextrose	:	40 g
Pepton	:	10 g
Dis. Water	:	1000 ml
pH	:	6.5 g

Molasses/ Jagary	:	30 g
Yeast extract	:	3 g
Dis. Water	:	1000 ml
pH	:	6.5 g

PRODUCTION PROTOCOLS FOR *Ha* NPV and *Sl* NPV

***Spodoptera litura nuclear polyhedrosis* virus (*Sl* NPV)**

- From the stock culture of *S.litura* 90 percent of 7-9 day old larvae (4^{th} instar) are used for *Sl*NPV production and the remaining 10 percent for continuation of laboratory culture. The larvae are collected and starved for 8 hours. *Sl*NPV suspension is prepared in 250 ml of water in a bottle. The larvae are exposed to *Sl*NPV infection by dipping the clean Castor leaves in *Sl*NPV suspension, drying them under shade for 15-20 min and providing them to the larvae for 2 consecutive days. Thereafter, the larvae are fed on healthy (not treated with *Sl*NPV) leaves for the remaining part of their life. Fresh leaves are provided every day for the larvae. The larvae could also be exposed to *Sl*NPLV infection by transferring them on to a semi-synthetic diet treated with *Sl*NPV suspension.

- The virosed larvae show characteristic symptoms with in 4-5 days infection they start dying from the 7^{th} day onwards and are placed @ 300 per container containing drinking water and are allowed to putrify for 3 days. The *Sl*NPV infected larvae could be easily distinguished by the pinkish color on the under surface of their skin which turn to white with the accumulation of POBs (on death of infected larvae).The skin ruptures and the white liquefied body contents ooze out. In that stage, the larvae are ground and filtered through muslin cloth. The virus is allowed to settle in sufficient water for about a week. The supernatant is now carefully removed and the polyhedra are suspended in water. Further purification can be done by centrifugation at 500 rpm for 5-10 min and the pellet containing only tissue debris is discarded. The collected POBs are further purified by high speed centrifugation at 2500rpm 15-20mins. The white preparation of POBs is finally obtained as sediments. The pure POBs suspended in water are counted through modified Neubauer haemocytometer. The count is expressed on larval basis as well as on per unit of larval weight basis. The POBs are dried over Calcium chloride or by Acetone precipitation and formulated by adding permitted spreaders/ wetting agents.

***Helicoverpa armigera nuclear polyhedrosis* virus (*Ha* NPV)**

- For *Ha* NPV production, the diet used for rearing *H.armigera* is poured at 4gm/ cell and the diet surface is uniformly sprayed with virus prepared in distilled sterilized water at $18x10^6$ POBs/ml. 80 percent of the available 5-7 day old larvae are utilized for *Ha* NPV production and the remaining 20 percent are transferred into trays where 6gms diet/larva is provided (for continuation of the host culture).

- The trays are incubated at 26^0C for 7 days. In case of virus infected larval trays, the diseased/dead larvae harvested after 7 days and subsequently macerated in mixtures /blenders in distilled/ sterilized water.

- The other procedure pertaining to harvesting of POBs is same as given in Sl NPV production protocol.

- The product is standardized with regard to the number of POBs per ml in terms of LC_{50} with 95 percent fiducial limits. The POBs can be restored in distilled water and packed in plastic cans/bottles with proper instructions provided on the container. One larval equivalent is equal to $6X10^9$ POBs or their equivalent in activity. The cost of production of one Ha NPV infested larva comes to Re 1 (overheads included) which could be further reduced when the production is increased. Ha NPV can be stored in a cool/dark place at room temperature without exposing to direct sunlight or in an ordinary refrigerator, up to 6 months to 2 years.

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