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A Review of Papaya Black Spot - A Fungal Disease (*Asperisporium caricae*)

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Abstract

Papaya (*Carica papaya* L.) is one of the important table fruit amongst the tropical and subtropical fruits of the world, because of its taste, nutritional importance and medicinal value. Papaya is affected by several major diseases *viz.,* foot rot, anthracnose, powdery mildew, black spot, papaya ring spot, mosaic and leaf curl disease. Among these, black spot disease caused by *Asperisporium caricae* Mable is an emerging disease and it is one of the severe limiting factor for papaya production and the disease is distributed to all the papaya growing countries of the world. The disease also causes severe post-harvest loss, leads to impairing export and Import. Papaya fruits are being used as one of the everyday diet in a new generation era. Morphologically *Asperisporium caricae* produces sporodochia on which densely fasciculate conidiophore and two celled conidia were produced on the spot. Black spot occurs with greatest intensity under conditions of temperatures between 23 to 27 ºC and high rainfall or overhead irrigation. Optimum soil depth, good soil health and ideal soil moisture are the key factors to preserve the resistance character of papaya varieties for longer period. Soil test based fertilizer and micronutrient application, seedling dip treatment and foliar spray of *Trichoderma viride* (5g/l), Fungicides *viz.,* Prior spray of Mancozeb (0.2 %), followed by Difenoconazole (0.1 %) followed by Chlorothalonil (0.2 %) or Propiconazole (0.1 %) and Hexaconazole (0.1 %) at fifteen day intervals during *kharif* months are very effective in managing papaya black spot disease.

Keywords: *Carica papaya,* Black spot, Etiology, Epidemiology, Integrated approach

Papaya (*Carica papaya* L.) is treated as an important fruit amongst the folks of the tropical and subtropical countries because of its taste, nutritional importance and medicinal usage. It belongs to the small family *Caricaceae*. It is a dicotyledonous, polygamous, diploid species consisting of a small genome size with 372 Mbp/1C and it comprises of eighteen chromosomes (Bennett and Leitch, 2005). The origin of papaya is Mexico and Central America (Storey *et al.,* 1986).

The share of papaya cultivation to the global economy is evident by its wide distribution. It was once had a status of home garden crop but then emerged to that of commercial orchards in many tropical countries. This crop is one amongst the highest producer of fruits per hectare (Singh, 1990). It has short-lived perennial growth habit, large palmate leaves, rapid growth, hollow stems, petioles and fruits, and high phenotypic plasticity. Plant produces climacteric fruits throughout the adult plant life. In cultivation papaya trees grow quickly and gives mature fruits within 9-12 months period after planting (Gonsalves, 1998).

Globally, papaya is the third utmost cultivated tropical crop. India and Brazil are principal producers of papaya and is the fourth most traded tropical fruit. It has more importance due to its high palatability, early fruiting, maximum productivity per unit area, multifarious uses such as food, medicine and as an industrial input (Evans and Ballen, 2012).

Amongst common fruits, papaya is in top position regarding the nutritional scales for the percentage of vitamin C, vitamin A, potassium, niacin, folate, thiamine, iron, calcium, fiber and riboflavin (Huerta-Ocampo *et al.,* 2012).

It is consumed as dessert fruit and it is also well-known for good medicinal property in plant parts such as fruits, pulp, seeds, bark, peel, and roots. It is used for medicinal purpose as a source of chemical compounds such as papain, chymopapain and carpaine (Saran and

Choudhary, 2013). Commercially papain production is bound for digestion of protein, primarily in tenderizing the red meat, brewing of beer and treatment of skin (Ming *et al.,* 2012). Roots of papaya plants are utilized to cure piles, and yams, barks and stems can be managed to make ropes. It is used to extract oils with good amino acid and protein sources and also used as a vermifuge (Watson, 1997).

Papaya crop is grown in about 60 countries, with the substance production contributed from developing economies. Major global producers of papaya are India, Brazil, Nigeria, Indonesia, Mexico, Dominican Republic, Democratic Republic of Congo, Philippines, Venezuela and Thailand. Global annual production of papaya accounts for 13.01 million tonnes. India is leading country in papaya cultivation with area of 1.38 lakh hectares and annual outcome of 5.9 million tonnes (Anonymous, 2018). The largest papaya producing states include Andhra Pradesh, Gujarat, Karnataka, West Bengal, Madhya Pradesh and Maharashtra. Major papaya growing districts of Karnataka are Kolar, Chikkaballapura, Bengaluru, Mysuru, Tumkur, Mandya, Hassan, Chitradurga, Koppal, Ballary and Kalburgi. In Karnataka, papaya cultivation covers 8.75 thousand hectares with yearly production of 5.7 lakh tonnes (Anonymous, 2018).

Occurrence of different diseases are major constraints in papaya cultivation. Papaya plant suffers from several diseases such as foot rot, anthracnose, powdery mildew, papaya ring spot, leaf curl and mosaic, brown spot and black spot (Rajukumar *et al.,* 2018).

Papaya fruit is very much prone to diseases caused by many microorganisms especially fungi, for the reason that fruit has a very thin skin, high in moisture and nutrients (Kumar and Rawal, 2009). It is susceptible to more than a dozen fungal pathogens, Phytophthora (*Phytophthora palmivora*) root and fruit rot, anthracnose (*Collectricum gloerosporioides*), powdery mildew (*Oidium caricae*) and black spot (*Asperisporium caricae*) are the most important fungal pathogens (Zhu *et al.,* 2004).

Among the emerging diseases of papaya, black spot disease caused by *A. caricae* is the most lethal. Both leaves and fruits of papaya can be affected by the black spot disease. In addition, it causes the reduction of photosynthetic area and hence the pathogen can affect commercial value of the fruits (Ventura *et al.,* 2008).

Importance

Black spot diseases of papaya, caused by *A. caricae,* is a wide spread fungus disease found in many countries such as the USA, Brazil, South Africa, China, Philippines, Sri Lanka and Taiwan (Desmond and Ronald, 2001).

In India, the disease was observed as early as 1977 on the papaya variety Coorg Honey Dew at Chettali, Karnataka, and in Palani hills on Variety Co 1 (Ullasa and Rao, 1977).

If the disease is not controlled at early stage, leaf function will be damaged and defoliation can occur, thereby reduces fruit sugar content and quality. Black spot is one of the fungal diseases that have expressive consequences in terms of photosynthetic area and recurring damages to production and papaya fruit quality (Cooke *et al.,* 2009).

The pathogen affects the leaf and fruit parts which get attention by producers and consumers in reducing the economic value. The tissue beneath the lesions remains firm, but the value of harvested fruit with these symptoms is reduced (Peterson and Grice, 1999).

Fruits covered with black spot are unmarketable for the more demanding internal and external markets. When it is commercialized for the less demanding consumer, it gets its value depreciated. Thus, markets that look for products with lower rates of pesticide residues request more sustainable cultivation systems (Dianese *et al.,* 2008 ; Martileto *et al.,* 2009; Poltronieri *et al.,* 2017).

Approximately 30 per cent losses in papaya fruit commercialization was reported due to black-spot disease (Santos and Barreto, 2003). Despite of substantial amount of losses caused by the disease in

many parts of the world only few works are available regarding the management of this disease.

Symptomatology

Black pustules on the abaxial surface of the leaf were distinguishing symptom of this disease. The first symptoms were scattered small spots, visible on both surfaces of the leaf. On the upper surface, the lesions were rounded or somewhat angular, 1 to 4 mm in diameter, pale yellow, with dark margins. Later the lesions became necrotic and whitish. On the lower surface, the lesions were covered with masses of fungal spores which appear as dark dots. The pustules covered the whole lesion (Maublanc, 1913).

Peterson *et al*. (1993) described that the initial symptoms of black spot caused by *A. caricae* were small, water-soaked spots which develop on the upper surface of young leaves and later become greyish-white in color. Black conidial masses form on these lesions on the underside of leaves. Affected leaves curl, become necrotic, brittle and subsequently die under severe disease pressure, which results in extensive defoliation. Lesions on fruit begin as small black spots that can enlarge to 2 to 6 mm in diameter. The tissue beneath these lesions remains firm, but the value of harvested fruit with these symptoms is reduced.

The presence of papaya black spot (*A. caricae*) was recorded in Sri Lanka for the first time during early 1992, the mature leaves and fruits of several pawpaw cultivars showed uncommon disease. The disease was diagnosed as black spot caused by *A. caricae* and was confirmed using Koch's postulates. The disease is now widespread in several localities in the Kandy District and affects almost every pawpaw cultivar (Adikaran and Wijepala, 1995).

Ventura (2008) reported that the disease occurs on the leaves and on the fruits. On upper surface of leaves, characteristic symptoms consist of round, light-brown (tan) necrotic spots, encircled by a yellow halo. On the lower surface of the leaves, in the areas corresponding to the spots, the powdery growth of the fungus with gray to black color was observed. In some cases, over these, a pale mycelium produced by a fungal hyper parasite of the pathogen may be observed. When it occurs, coalescence of the lesions was a common cause of leaf senescence and defoliation of the plants. Abundant spotting cause defoliation and over 50 per cent leaf fall occurred. Young leaves generally did not showed symptoms. Initially, the presence of circular areas of watery aspect were observed on fruits, later disease became brown in color, prominent, with pal points, and that may attain 5 mm of diameter. These lesions generally were epidermal and did not reach the pulp of the fruit, causing only a hardening of the skin of the affected part.

Symptoms of the papaya disease were detected, when the plants were still in early phase of growth. The disease occurs both on the leaves and fruits. Symptoms initiate from older leaves progressively to the middle and upper leaves. On upper surface of older leaves symptoms consists of round, light brown necrotic spots, encircled by yellow halo. On the lower surface of leaves, in the areas corresponding to the spots, black colored fungus growth was observed. On fruits, initially symptoms consists of water soaked lesions and later it becomes brown in color. Initially these lesions were epidermal and did not affect the pulp region of the fruit (Shantamma, 2012).

Distribution

Black spot symptoms on the leaf and the fruits of *Carica papaya* due to infection of *Asperisporium caricae* (Speg.) Maubl. has been reported in Florida (Stevens, 1939) and South America (Saldana *et al.,* 1985). The fungus was originally restricted to Central and South America, West Indies and the USA (Ellis and Holliday, 1972). Reports indicated that the disease was wide spread in South Africa (Chambers and Rijkenfurg., 1987) and in Tanzania (Teri and Keswani, 1981).

In 1992, unusual black spotting observed in mature leaves of several papaya cultivars grown in certain areas around Kandy and the examination of diseased leaves revealed that the main causal agent was *Asperisporium caricae.* There were two other fungi

found associated with the disease at different times of the year. These two were identified as *Sclerospora* sp. and *Verticillium* sp. The papaya cultivars were not known by name but all of them were common and popular local cultivars. Later in 1993 the disease rapidly spread to several areas within the Province and is now common in many other cultivars including Solo Hawaii (Adikaran and Wijepala, 1995).

Black spot diseases of papaya, caused by *A. caricae,* is a wide spread fungus disease found in many countries such as the USA, Brazil, South Africa, China, Philippines, Sri Lanka and Taiwan (Desmond and Ronald, 2001). Among the reported diseases of papaya, black spot has been emerging as economically important disease to major papaya producing areas, majorly in the Central rift valley of Ethiopia (Anonymous, 2001). It is also one of the most serious fungal diseases of papaya in Brazil, where papaya is continuously grown throughout the year in a climate conducive to outbreaks of severe epidemics (Ventura *et al.,* 2003).

In Philippines a survey of papaya diseases was conducted in four provinces namely, Batangas, Laguna, Cavite and Quezon. The typical symptoms of black leaf spot of papaya were collected, on variety papaya 'red lady'. Symptoms of this disease and the causal organism were similar to that previously reported by Cumagun and Padilla (2007). The fungus on the infected papaya leaves was identified as *A. caricae* by comparison with the description and illustrations in Ellis and Holliday (1972) and Liberato and Shivas (2006) .

In India, papaya black spot disease was observed as early during 1977 in the papaya variety Coorg Honey dew at Chettali, Karnataka and in Palani hills in Variety Co 1 during cooler months (January to March) (Ullasa and Rao, 1977) and in Chittor of Andhra Pradesh (Reddikumar *et al.,* 2015), the disease did not emerge in a devastating manner thereafter.

A random survey was conducted for occurrence of black spot disease in papaya growing regions of South Karnataka caused by *Asperisporium caricae* during late winter season of 2011 (Shantamma *et al.,* 2014). A maximum severity of 69.5 per cent and 37.33 per cent on leaves and fruits respectively was recorded at Chikkanahalli in Mysore district.

Recently, in Tamil Nadu during October 2014 to March 2015, black leaf spot symptoms caused by *Asperisporium caricae* were observed on matured leaves in papaya varieties *viz.,* Co2, Co8, Red Lady and Sinta at various districts *viz.,* Coimbatore, Erode, Tirupur, Theni and Krishnagiri of Tamil Nadu state. The disease incidence ranged with PDI range of 10.0 to 23.8. Plants of all ages were susceptible and symptoms initiated during cooler weather accompanied with rains and the disease spread continued even after rains (Thiribhuvanamala *et al.,* 2016).

Identification in Relation to Morphological, Numerical and Molecular Characterization

Sporulation of *Asperisporium caricae* was hypophyllous ranging from dark blackish brown to black. Stroma was well developed, erumpent. Conidiophores were olivaceous brown, geniculate, smooth in dense fascicles with several prominent conidial scars at the tip up to 52 µm long × 6 to 9 µm wide. Conidiogenous cells were polyblastic with thickened and darkened scars. Conidia were solitary, ellipsoidal, pyriform or clavate, 1-septate (mature), hyaline to mid pale brown, verrucose, 16 to 32 × 5 to 11 µm in size (Lavoura, 1913).

Sporodochia of *Asperisporium caricae* was hypophyllous, dark blackish brown to black, stroma well developed, erumpent. Conidiophores closely packed together and covering the surface of the stroma, usually unbranched, hyaline to olivaceous brown, with several prominent conidial scars at the apex, up to 45 x 69 µm. Conidia solitary, ellipsoidal, pyriform or clavate, 1-septate, hyaline to mid pale brown, verrucose, 14-26 x 7-10 µm (Maublanc, 1913; Ellis and Holliday, 1972).

Morphological description of *Asperisporium caricae* was found that sporodochia and conidia were produced on the spot. The sporodochia were subcuticular or intra epidermal, olive-brown to dark brown 40 to 120 µm in diameter. Conidiophores were densely fasciculate,

simple, straight or curved, greenish-brown to olive-brown, 1 to 2 septate. Conidia were terminal, elliptic to ovoid, rounded at the top, truncate at the basal end, hyaline and one-celled at first, then turned to greenish-brown and become two celled, 12 to 28 x 7 to 14 µm with many rough warts (Kobayashi *et al.,* 1998).

Minnis *et al.* (2011) reported *A. caricae* comes under the class-Dothideomycetes, order: Capnodiales, family-Mycosphaerellaceae, synonyms *viz., Cercospora caricae, Epiclinium cumminsii, Fusicladium caricae, Pucciniopsis caricae* and *Scolicotrichum caricae* (Ellis and Everh, 1923).

Morphological findings of *Asperisporium minutulum viz.*, mycelium internal, subcuticular to intra epidermal, branched, 2.5 to 5 µm wide, septate, conidiophores numerous, in dense fascicles, arising from stroma, emerging through stroma or erumpent through the cuticle, forming sporodochial conidiomata, erect, straight to slightly flexuous, short cylindrical or conical, unbranched, conidia formed solitary, straight, broadly ellipsoid to subspherical, 10 to 23 x 8 to 13 µm, 0 to 2 septate (Konstanze and Braun, 2005).

Minnis *et al.* (2011) generated DNA sequence data from the ITS region and nLSU of type species of *Asperisporium* and *Pantospora*, analysed phylogenetically, placed into an evolutionary context within *Mycosphaerellaceae* and compared to existing phylogenies. They observed that *Asperisporium caricae,* the type of *Asperisporium* and cause of a leaf and fruit spot disease of papaya, was closely related to several species of *Passalora* including *P. brachycarpa*.

Shantamma *et al.* (2014) observed that *Asperisporium caricae* conidiophores are compact, covered with stroma, hyaline to brown in color. Conidia are elliptic to oviod, rounded at the top, one or two septate, hyaline to brown in color, size of the conidia varied from 27 to 30 µm.

Shreedevasena *et al.* (2019) subjected *Asperisporium caricae* isolate to polymerase chain reaction (PCR) for confirmation of pathogen at genus level using universal primers such as ITS 1 and ITS 4. Molecular confirmation of *Asperisporium caricae* through 18S rRNA gene sequencing gave an amplicon size of 560bp.

The colonies of *Asperisporium caricae* on potato dextrose agar were near dark green to black in color. Mycelium formed a raised mound covered with whitish, short erect hyphae or whitish aerial hyphae. Surface slightly velutinous with scattered black spherical structures. Hyphae are branched with walls smooth, hyaline to brownish, septate, 3 to 6.5 µm diameter. The conidial production on potato dextrose agar was sparsely distributed. Sporulation usually occurred after a month at 24 °C with a 12 h light / dark regimen (Shreedevasena *et al.,* 2019).

PCR amplification of ten isolates of *A. caricae* with ITS 4 and ITS 5 yielded single fragment amplicon of 590 bp. Dendrogram clustering of ten isolates of *A. caricae* grouped them into two clades, where AcG isolate belonged to clade I and AcH (Hassan), AcKa (Kaduru), AcKu (Kushalnagara), AcMa (Madduru), AcMu (Mudbidire), AcMy (Mysuru), AcNa (Nagamangala), AcR (Ramanagara) and AcV (V. C. Farm) belonged to clade II. According to this AcG (GKVK, Bengaluru) isolate was less similar (62 %) to other isolates. AcH and AcKu isolates had highest similarity (85 %) with each other followed by AcMa and AcMu (78.5 %). The similarity between AcH and AcKu evident in some of the cultural characters also (Shetty, 2020).

Epidemiological Factors on Black Spot Fungi

Black spot occurs with greatest intensity under conditions of temperatures between 23 to 27 ºC, with strong winds and high rainfall or overhead irrigation. The incidence is seasonal, and most infection occurs in late winter and spring. These conditions favor development of the lesions and dispersion of spores from older leaves, considered the principal sources of inoculum and where the disease occurs initially, being disseminated subsequently to the younger leaves. The penetration of the fungus is stomatal and macroscopic symptoms are visible between 8-10 days after inoculation (Holliday, 1980). Fruits can be infected when still green and the lesions resulting from the

eruption of the stroma will emerge completely at the beginning of maturation, liberating new spores when the fruit is totally mature.

Black spot disease of papaya can infect papaya plants at any growth stage. Periods of wet weather and severe soil moisture perhaps elevates the progress of the disease (Shantamma, 2012).

Edaphic Factors of Black Spot Fungi

Shetty *et. al.* (2020) studied the correlation between soil edaphic factors and papaya black spot disease severity on leaves and fruits of papaya plant. The results revealed positive correlation coefficients (increase in disease severity) for soil pH (0.13), available nitrogen (0.30), available phosphorus (0.18), exchangeable calcium (0.08), exchangeable magnesium (0.39) and hot water extractable boron with leaf disease severities, whereas, electrical conductivity (-0.03), organic carbon (-0.35), available potassium (-0.06), available sulfur (-0.05), DTPA extractable zinc (-0.33), DTPA extractable manganese (-0.35), DTPA extractable iron (-0.32) and DTPA extractable copper (-0.17) were negatively correlated (disease severity decreased) with disease severities on leaves. Further disease severities on fruits were positively correlated with soil pH (0.06), available N (0.06), available P (0.09), exchangeable Ca (0.16), exchangeable Mg (0.24), DTPA extractable Cu (0.12) and negatively correlated with EC (-0.06), OC (-0.18), available K (-0.02), available S (-0.21), DTPA extractable Zn (-0.17), DTPA extractable Mn (-0.08), DTPA extractable Fe (-0.06), and hot water extractable B (-0.13).

Management of Black Spot Fungi

Host Resistance

Genetic resistance has emerged as a promising and sustainable control alternative for black spot disease of papaya (Vivas *et al.,* 2015). It is essential to be aware of the genetic variability of papaya genotypes to set plans for improvement strategies (Vivas *et al.,* 2016). Evaluated 41 papaya genotypes against black spot and the genotypes that showed better resistance were lines 1, 4, 9, and 19. Lines 4 and 9 and the parent 'SEKATI' generated the best results in all the variables assessed (Stevans, 1939).

Cultural Methods

Infected old leaves hanging from trees should be removed carefully to reduce the number of spores that spread the disease. Wind protection around plantings is important to minimize fruit abrasions which can create an entry for pathogens (Constantinides and McHugh, 2005). Heavily infected leaf blades should be removed by cutting the petiole half way between the leaf blade and the trunk to protect insects and pathogens to enter the wound (Vivas, *et al.,* 2015). Scouting the orchard periodically is very important to decrease infestation level by weeds, reduce the suffocation of the orchard, and fertilize the plantation. Removal of leaves and fruits with symptoms of black spot disease from the orchard reduces the initial inoculum (Suzuki *et al.,* 2017).

Chemical and Biological Management

In Brazil, fungicides are used to control this disease for all papaya plantations produced commercially (Ferreira and Avidos, 1999). It is also reported that high black spot pressure influence the efficacy of mancozeb and tebuconazole fungicides (Peterson and Grice, 1999).

Effect of foliar applications of phosphates with K, Ca, Mg and Cu evaluated indifferent doses on papaya black spot. In both field and greenhouse trials the Phosphite with other nutrients were found to reduce the incidence and severity of black spot disease (Dianese *et al.,* 2008).

Laboratory studies have showed that *A. caricae* was more sensitive to Difenoconazole (EC50 of 2 ppm) then Tebuconazole (EC50 of 14 ppm) (Vawdrey *et al.,* 2008).

Fourth generation fungicides including strobilurins (Pyraclostrobin and Azoxystrobin), Third generation fungicides *viz.*, triazoles (difenoconazole and tebuconazole), Second generation fundicides *viz.,* dithiocarbamates (Propineb, metiram, ziram and mancozeb) and pthalimide (chlorothalonil) were

evaluated in three field experiments at North Queensland and Australia for the control of papaya black spot (Vawdrey *et al.,* 2008). Among these chemicals difenoconazole, pyraclostrobin and chlorothalonil were better than mancozeb and tebuconazole. Efficacy of combi-product fungicides *viz.,* tebuconazole + trifloxystrobin, pyraclostrobin, azoxystrobin and difenoconazole against Asperisporium caricae was observed good control of the fungus (Livia *et al.,* 2011).

Among the different bio agents tested against *A. caricae* under in vitro condition the maximum reduction in colony growth was observed in *Trichoderma viride* (53.33 mm) which was significantly superior over all the bio agents tested. Next best was *Trichoderma virens* (53.00 mm) and *Trichoderma koningi* (52.00 mm) (Taj and Kumar, 2013).

Taj and Kumar (2013) evaluated different plant extracts against black spot of papaya under *in vitro* condition. Among the different botanicals, neem leaf extract at both the concentration of 5 per cent (43.00 %) and 7.5 per cent (47.66 %) was significantly superior over all other plant extracts.

Fungicides *viz.,* Trifloxystrobin, Tebuconazole, Benomyl, Trifloxystrobin + Tebuconazole, Hexaconazole and Chlorothalonil were found effective among seven fungicides evaluated in inhibiting the mycelial growth of *A. caricae* at 0.2 per cent. Least inhibition was observed at 0.05 per cent by Trifloxystrobin (Taj and Kumar, 2013).

Eight fungicides were evaluated under field condition, for their efficacy in controlling the black spot disease. Out of eight fungicides evaluated difenconazole was most effective against pathogen on leaves followed by chlorothalonil. Whereas, bitertanol was least effective. On fruits also difenoconazole was most effective against the pathogen followed by chlorothalonil. (Shantamma *et al.,* 2014).

The effect of different fungicides on spore inhibition of *Asperisporium caricae* was studied (Shantamma, *et al.,* 2014). Among those difenoconazole inhibited 100 per cent spore germination at 150 ppm followed by chlorothalonil and propiconazole.

Reddikumar *et al.* (2015) conducted *in vitro* studies to test efficacy of new fungicides comprised combination of systemic and contact fungicides *viz.,* Tricyclazole +Mancozeb, Carbendazim + Mancozeb, Hexaconazole + Zineb and two systemic fungicides *viz.*, Azoxystrobin, Difenconazole. Among these fungicides tested, combiproduct Hexaconazole + Zineb had shown most effective result *i.e.,* 100 per cent inhibition at 100 ppm under *in vitro* conditions.

It is advisable to look for signs of disease on the new growth since the fungicides protect the new leaves and fruits, but old damage cannot be undone (Constantinides and McHugh, 2005; Thiribhuvanamala *et al.,* 2016).

Application of protective or systemic fungicides when the first symptoms appear is the best option to early manage black spot disease of papaya (Suzuki *et al.,* 2017).

Fungicides *viz.,* Difenoconazole, Chlorothalonil, Propiconazole and Hexaconazole were very effective in managing this pathogen (Shantamma *et al.,* 2018). In-vitro studies by Patel (2019)[28] reported Carbendazim 50 per cent WP. inhibited 100 per cent mycelial growth of *A. caricae.*

Patel (2019) reported that *Allium sativum* was highly effective in maintaining lesser infection percentage (9.87 %) of papaya black spot disease on infected fruits over of *Prosopis juliflora* (11.21 %), *Vitex negunda* (12.06%), *Lawsonia inermis* (13.65%), *Ocimum sanctum* (15.62%) and *Lantana camara* (17.63%). Further *Azadirachta indica* (20.15 %) was reported to be least effective in decreasing the infection percentage when black spot infected fruits of papaya were dipped into aqueous extract of this plant.

Among the seven bio agents evaluated in the experiment by following dual culture technique *T. viride* (72.59 %) exhibited highest mycelial inhibition, followed by *T. asperellum* (70.37%), *T. harzianum* (64.81 %), *Ampelomyces quisqualis* (63.33 %),

antagonistic bacteria *Bacillus subtilis* (9.63 %), *P. fluorescens* (6.67%) whereas, least inhibition was observed by *Bacillus pumilis* (4.44 %). Poison food technique was followed with seven plant extracts to test their efficacy against papaya black spot (*A. caricae*). Excellent mycelial growth inhibition was observed by Allium sativum (27.93 %) which was significantly higher than all other treatments, which was followed by *Zingiber officinale* (24.15 %). Next best inhibition was imparted by *Vinca rosea* (1.77 %) but which was much less effective as compared to *Allium sativum* and *Zingiber officinalis*. Little inhibition was imposed by *Tinospora cordifolia* (1.47 %), *Azardiracta indica* (1.12 %), *Tagetes erecta* (1.07 %) and Seaweed extract (0.67 %) which were on par with each other (Shetty, 2020).

Five contact fungicides, four systemic fungicides and four combiproduct fungicides were evaluated for their effectiveness against *A. caricae* under *in vitro* condition by following poisoned food technique. Among contact fungicide tested Mancozeb 75 % WP (44.35 %) showed maximum and Copper hydroxide 50 % WP (24.03) showed least inhibition of radial mycelial growth. Carbendazim 50 % WP and Propiconazole 25 % EC gave cent percent mycelial inhibition among the four systemic fungicide evaluated under *in vitro* condition whereas, least inhibition was reported on Hexaconazole 5% EC (38.33 %). Among the combiproduct fungicide used in the treatment to evaluate their efficacy against *A. caricae* 100 % inhibition was obtained by (Carbendazim 12 % + Mancozeb 63 %) 75 % WP and Picoxystrobin 7 % + Propiconazole 12 % SC and Metiram 5 % + Pyrachlostrobin 55 % WG (21.60%) imparted minimum mycelial growth inhibition (Shetty, 2020).

Black spot disease of papaya is very lethal and thus both leaves and fruits of papaya can be affected. Severe black spot infections can cause the leaves to curl and die prematurely which affects photosynthesis. The pathogen can cause direct damage by causing spots on the fruit and post-harvest rotting. Knowledge on distribution of the black spot disease in the world, symptomatology, etiology of the parasite and epidemiological factors influencing disease development are the major concern. Further Probing for integrated approaches *viz.,* adopting host plant resistance, enriching soil health, soil moisture management, maintaining plant to plant distancing and following East-West direction planting, subsequent cultural practices, prior spray of extract of plant products and need based spray of fungicides to manage the black spot disease are an important operations for the increased production of Papaya in the country.

Black spot occurs with greatest intensity under conditions of temperatures between 23 to 27 ºC and high rainfall or overhead irrigation. Integrated approaches in managing the black spot disease are one of the vibrant actions to reduce the residual toxicity and adverse effect on consumers. Optimum soil depth, good soil health and ideal soil moisture are the key factors to preserve resistance character of papaya varieties for longer period. Soil test based fertilizer and micronutrient application, seedling dip treatment and foliar spray of *Trichoderma viride* (5g/l), Fungicides *viz.,* Prior spray of Mancozeb (0.2 %), followed by Difenoconazole (0.1 %) followed by Chlorothalonil (0.2 %) or Propiconazole (0.1 %) and Hexaconazole (0.1 %) at fifteen day intervals during of *kharif* months are very effective in managing papaya Black spot disease.

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Effect of Different Levels of Nitrogen and Zinc on Quality and Nutrient Content of Maize in Rural and Peri-Urban Southern Transact of Bengaluru

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ABSTRACT

Field experiments were conducted in farmers field's in rural and peri-urban southern transact of Bengaluru during *kharif* 2019 to assess the effect of different levels of nitrogen and zinc on quality of maize grain, nutrient content and uptake by maize. Experiment was conducted in a factorial randomized complete block design with ten treatments and three replications. Three levels of nitrogen (0, 150 and 200 kg ha^{-1}) and three levels of zinc (0, 2.1 and 4.2 kg ha^{-1}) was applied in combination with recommended dose of phosphorus, potassium along with FYM. Application of 200 kg N ha^{-1} + 4.2 kg Zn ha^{-1} + RDP and K + 10 t ha^{-1} FYM recorded significantly higher oil content (4.07 and 4.04 %) and protein content (9.52 and 9.03 %) in grains of maize grown in rural and peri-urban, respectively. Significantly higher content of nitrogen (1.40 and 0.80 %), phosphorus (0.29 and 0.22 %), potassium (0.57 and 1.13 %) and zinc (30.50 and 21.80 ppm) in grain and strover of maize in rural with application of 200 kg N ha^{-1} + 4.2 kg Zn ha^{-1} along with RDP and K + 10 t ha^{-1} FYM. Same treatment recorded significantly higher total content of nitrogen (1.23 and 0.75 %), phosphorus (0.26 and 0.21 %), potassium (0.46 and 0.89 %) and zinc (25.57 and 11.67 ppm) in grain and stover of peri-urban grown maize. Hence, judicious application of nutrients to correct deficiency can increase nutrient content and finally productivity of the crop.

Keywords : Nutrient uptake, Nitrogen, Zinc, Oil content, Protein

MAIZE (*Zea mays* L.) is one of the important stable food crops grown all over the world under diversified climatic conditions. Maize is called the queen of cereals because of its greater production potential compared to other cereals. Besides being a potential source of food for human being, it is also used for feeding cattle, poultry and industries for production of starch, syrup, alcohol, acetic acid etc. (Kiran and Chennakeshava, 2017). Hence, nutrient content is very much important. However, there are a number of factors which are responsible for the low nutrient content, quality, production and productivity of maize. Among these factors, inappropriate crop nutrition management and poor soil fertility are the most important factors responsible for low yield of maize (Shah *et al*., 2009 and Kumar *et al*., 2020). Nutrient deficiency is one of the major problems constraining the development of an economically successful agriculture.

Nitrogen has long been considered the most influential macronutrient for maize grain yields. It is a key component of enzymes and other proteins essential to all growth functions. Zinc is considered as a fourth most important yield limiting nutrient after major nutrients. It is an essential micronutrient for plant and animals. Higher plants generally absorb zinc as divalent cation, which acts either as the metal components of enzymes or as a functional, structural or a regulatory co-factor of a large number of enzymes and helps in increasing plant growth and yield (Harish and Rame Gowda, 2017).

MATERIAL AND METHODS

The experiment was conducted in farmers' fields of Kaggalahalli and Taralu of rural and peri-urban areas of southern transact of Bengaluru. The total rainfall during 2019 at Kaggalahalli (Rural) was759.7 mm with maximum rainfall during October (368.2 mm) and minimum during December (4.0 mm). Whereas, in Taralu higher rainfall was recorded in September (275.5 mm) and least in December (2.0 mm) with total rainfall of 862.0 mm. The maximum temperature was

29.95 ºC and 30.97 ºC, while minimum temperature was 20.52 ºC and 20.42 ºC in rural and peri-urban, respectively.

Soil samples were collected before initiation of the field experiment and after theharvest of crop, analysed for various parameters by following standard protocol. Initial soil properties of the experimental site indicated that soils were acidic6.8 and 5.8 (Jackson, 1973), normal electrical conductivity of 0.16 and 0.14 dSm^{-1} (Jackson, 1973) with medium organic matter content of 0.72 and 0.55 per cent (Jackson, 1973), low available nitrogen of 234.23 and 210.12 kg ha^{-1} (Subbiah and Asija, 1956), medium available phosphorus of 25.52 and 22.23 kg ha^{-1} (Bray and Kurtz, 1945) and medium available potassium of 225.12 and 192.21 kg ha^{-1} (Jackson, 1973) and deficit in zinc with 0.34 and 0.27 ppm (Lindsay and Norwell, 1978) in soils of rural and peri-urban, respectively. As the nitrogen and zinc was found low, present study was conducted to assess the effect of different levels of nitrogen and zinc on maize grain quality and nutrient content of plant in two selected farmers field in rural and peri-urban of southern transact of Bengaluru.

Field experiment was laid out in a factorial randomized complete block design with three replications and ten treatment combinations *viz*., T_1: Absolute control, T_2: RDP + RDK + 10 t ha^{-1} FYM, T_3: 2.1 kg Zn ha^{-1} + RDP + RDK + 10 t ha^{-1} FYM, T_4: 4.2 kg Zn ha^{-1} + RDP + RDK + 10 t ha^{-1} FYM, T_5: 150 kg N ha^{-1} + RDP + RDK + 10 t ha^{-1} FYM, T_6: 150 kg N ha^{-1} + 2.1 kg Zn ha^{-1} + RDP + RDK + 10 t ha^{-1} FYM, T_7:150 kg N ha^{-1} + 4.2 kg Zn ha^{-1} + RDP + RDK + 10 t ha^{-1} FYM, T_8: 200 kg N ha^{-1} + RDP + RDK + 10 t ha^{-1} FYM, T_9: 200 kg N ha^{-1} + 2.1 kg Zn ha^{-1} + RDP + RDK + 10 t ha^{-1} FYM and T_{10}: 200 kg N ha^{-1} + 4.2 kg Zn ha^{-1} + RDP + RDK + 10 t ha^{-1} FYM. Full dose of phosphorus, potassium, zinc and 1/3 nitrogen were applied at sowing by drilling in the crop rows. The remaining dose of nitrogen was top dressed in two splits at knee high and tasseling stages depending upon the occurrence of rains.Nitrogen in the form of urea, phosphorous in the form of SSP, potassium in the form of muriate of potash (MOP) and zinc in the form of zinc sulphate.

Results and Discussion

In nitrogen and zinc deficit soils, application of higher levels of nitrogen and zinc resulted in improving quality of maize grains. Application of 200 kg N ha^{-1} + 4.2 kg Zn ha^{-1} (T_{10}) resulted in significantly higher protein content in maize (9.52 and 9.03 %) followed by 200 kg N ha^{-1} + 2.1 kg Zn ha^{-1} + RDP and K + FYM (9.42 and 8.90 %) compared to absolute control (4.33 and 3.82 %) in rural and peri-urban, respectively. Protein content continued to increase with increasing N levels indicating that nitrogen being a major constituent of proteins contributed towards increase in protein content (Asif *et al*., 2013). Whereas, zinc is vital for protein and amino acid synthesis (Logeragan *et al*., 1982) in leaves and this leads to accumulation in seeds. The increase in protein concentration of maize grain with nitrogen supply was earlier confirmed by Tsai *et al*. (1992). They expressed that the increase could be due to preferential deposition of zeinover the other endosperm proteins. Besides, exclusion of N, in the experiment, resulted in lower protein content, corroborating with previous finding that nitrogen application is essential for maize plant to synthesize amino acids (Seebauer *et al*., 2004). Nitrogen, being the principle constituent of protein might have substantially increased the protein content of kernel due to increased uptake of nitrogen under higher nutrient level (Keerthi *et al*., 2013).

Significantly higher oil content in maize in rural (4.07 %) and peri-urban (4.04 %) was observed with application of 200 kg N ha^{-1} + 4.2 kg Zn ha^{-1} with RDP and RDK and 10 t ha^{-1} of FYM (T_{10}) compared to absolute control (2.47 and 2.17 %, respectively). Low grain oil content might be due to availability of nitrogen to plant at proper time and in proper proportion because if protein content is more, then oil content is decreases (Waseem *et al*., 2012). These results narrate the findings of Witt and Pasuquin (2007).while grain oil content continues to decrease in maize grain due to dilution (Ray *et al*., 2019). It was also earlier confirmed by Rehman *et al*. (2011).

TABLE 1

Effect of different levels of nitrogen and zinc application on quality parameters of maize in rural and peri-urban

Treatments	Rural		Peri-urban	
	Protein content (%)	Oil content (%)	Protein content (%)	Oil content (%)
T_1 : Absolute control	4.33	2.47	3.82	2.17
T_2 : RDP + RDK + 10 t ha^{-1} FYM	7.32	3.15	6.70	3.08
T_3 : 2.1 kg Zn ha^{-1} + RDP + RDK + 10 t ha^{-1} FYM	7.44	3.38	6.87	3.36
T_4 : 4.2 kg Zn ha^{-1} + RDP + RDK + 10 t ha^{-1} FYM	7.48	3.42	6.94	3.34
T_5 : 150 kg N ha^{-1} + RDP + RDK + 10 t ha^{-1} FYM	7.68	3.69	7.16	3.45
T_6 : 150 kg N ha^{-1}+ 2.1 kg Zn ha^{-1} + RDP+ RDK + 10 t ha^{-1} FYM	7.93	3.50	7.41	3.63
T_7 : 150 kg N ha^{-1}+ 4.2 kg Zn ha^{-1} + RDP + RDK + 10 t ha^{-1} FYM	9.01	3.93	8.49	3.80
T_8 : 200 kg N ha^{-1} + RDP+ RDK + 10 t ha^{-1} FYM	8.38	3.86	7.86	3.85
T_9 : 200 kg N ha^{-1} + 2 .1 kg Zn ha^{-1} + RDP + RDK + 10 t ha^{-1} FYM	9.42	4.05	8.90	3.99
T_{10} : 200 kg N ha^{-1} + 4.2 kg Zn ha^{-1} + RDP + RDK + 10 t ha^{-1} FYM	9.52	4.07	9.03	4.04
S.Em.±	0.36	0.13	0.36	0.15
CD @ 5 %	1.06	0.39	1.06	0.45

The data pertaining to nitrogen, phosphorus, potassium and zinc concentrations as influenced by different levels of nitrogen and zinc in grain and stover are presented in Table 2.

T_{10} treatment which received 200 kg N ha^{-1} + 4.2 kg Zn ha^{-1} + RDP + RDK + 10 t ha^{-1} FYM recorded higher nitrogen concentration in grain (1.40 and 1.23 %) and stover (0.80 and 0.75 %) of maize grown in rural and peri-urban, respectively and least concentration in grain (1.02 and 0.84 %) and stover (0.61 and 0.48 %) was recorded in absolute control (T_1).

Similar was the trend in phosphorus content, application of 200 kg N ha^{-1} + 4.2 kg Zn ha^{-1} + RDP + RDK + 10 t ha^{-1} FYM (T_{10}) resulted in higher grain (0.29 and 0.26 %) and stover (0.22 and 0.21 %) concentration, followed by application of 200 kg N ha^{-1} + 2.1 kg Zn ha^{-1} + RDP + RDK + 10 t ha^{-1} FYM (T_9) in rural and peri-urban, respectively. Least content in grain (0.10 and 0.10 %) and stover (0.06 and 0.03 %) was recorded in absolute control (T_1).

The significantly higher concentration of potassium in grain (0.57 and 0.46 %) and stover (1.13 and 0.89 %) was recorded with application of 200 kg N ha^{-1} + 4.2 kg Zn ha^{-1} RDP + RDK + 10 t ha^{-1} FYM(T_{10}), followed by T_9 (200 kg N ha^{-1} + 2.1 kg Zn ha^{-1} RDP + RDK + 10 t ha^{-1} FYM) over absolute control (T_1) in rural and peri-urban, respectively. Increased application of nitrogen and zinc along with recommended dose of FYM, phosphorus and potassium had resulted in increased availability of nutrients to maize crop and enhance the process of mineralization of nutrients by microorganisms thereby the concentrations of major nutrients in grain and straw has increased. Application of nitrogen significantly affected its concentration of nutrients in plants of maize. This substantial increase can be due to increased N availability enabling plants to take up more nitrogen. Secondly, N application might have increased the root growth which favoured more removal of nitrogen by maize plants. This increase in nitrogen concentration might be attributed to better plant growth

TABLE 2

Effect of different levels of nitrogen and zinc application on N, P, K and Zn content of maize in rural of southern transact of Bengaluru

Treatments	Rural							
	Nitrogen (%)		Phosphorus (%)		Potassium (%)		Zinc (ppm)	
	Grain	Stover	Grain	Stover	Grain	Stover	Grain	Stover
T_1 : Absolute control	1.02	0.61	0.10	0.06	0.32	0.85	15.25	9.98
T_2 : RDP + RDK + 10 t ha^{-1} FYM	1.16	0.63	0.15	0.10	0.39	0.90	17.05	11.05
T_3 : 2.1 kg Zn ha^{-1} + RDP + RDK + 10 t ha^{-1} FYM	1.20	0.65	0.17	0.12	0.42	0.93	21.06	13.55
T_4 : 4.2 kg Zn ha^{-1} + RDP + RDK + 10 t ha^{-1} FYM	1.21	0.67	0.18	0.14	0.43	0.95	24.01	14.43
T_5 : 150 kg N ha^{-1} + RDP + RDK + 10 t ha^{-1} FYM	1.24	0.68	0.19	0.14	0.45	0.97	23.26	13.12
T_6 : 150 kg N ha^{-1} + 2.1 kg Zn ha^{-1} + RDP + RDK + 10 t ha^{-1} FYM	1.27	0.72	0.21	0.16	0.47	1.03	24.66	14.95
T_7 : 150 kg N ha^{-1} + 4.2 kg Zn ha^{-1} + RDP + RDK + 10 t ha^{-1} FYM	1.34	0.74	0.23	0.20	0.50	1.08	26.16	17.20
T_8 : 200 kg N ha^{-1} + RDP + RDK + 10 t ha^{-1} FYM	1.30	0.72	0.22	0.18	0.49	1.03	23.82	15.04
T_9 : 200 kg N ha^{-1} + 2.1 kg Zn ha^{-1} + RDP + RDK + 10 t ha^{-1} FYM	1.36	0.76	0.25	0.21	0.53	1.10	28.05	18.09
T_{10} : 200 kg N ha^{-1} + 4.2 kg Zn ha^{-1} + RDP + RDK + 10 t ha^{-1} FYM	1.40	0.80	0.29	0.22	0.57	1.13	30.50	21.80
S.Em.± 0.04	0.03	0.02	0.01	0.02	0.03	1.68	1.44	
CD @ 5 %	0.11	0.08	0.05	0.03	0.06	0.08	5.00	4.29

TABLE 3

Effect of different levels of nitrogen and zinc application on N, P, K and Zn content of maize in peri-urban of southern transact of Bengaluru

Treatments	Peri - urban							
	Nitrogen (%)		Phosphorus (%)		Potassium (%)		Zinc (ppm)	
	Grain	Stover	Grain	Stover	Grain	Stover	Grain	Stover
T_1 : Absolute control	0.84	0.48	0.10	0.03	0.26	0.59	9.75	4.99
T_2 : RDP + RDK + 10 t ha^{-1} FYM	0.88	0.50	0.13	0.06	0.30	0.67	13.24	6.61
T_3 : 2.1 kg Zn ha^{-1} + RDP + RDK + 10 t ha^{-1} FYM	0.96	0.59	0.14	0.08	0.31	0.70	16.42	7.83
T_4 : 4.2 kg Zn ha^{-1} + RDP + RDK + 10 t ha^{-1} FYM	0.99	0.62	0.16	0.11	0.33	0.72	20.01	8.14
T_5 : 150 kg N ha^{-1} + RDP + RDK + 10 t ha^{-1} FYM	1.06	0.64	0.18	0.14	0.36	0.74	18.59	6.43
T_6 : 150 kg N ha^{-1} + 2.1 kg Zn ha^{-1} + RDP + RDK + 10 t ha^{-1} FYM	1.10	0.66	0.20	0.15	0.37	0.78	20.10	8.45
T_7 : 150 kg N ha^{-1} + 4.2 kg Zn ha^{-1} + RDP + RDK + 10 t ha^{-1} FYM	1.18	0.71	0.22	0.18	0.40	0.85	21.85	9.26
T_8 : 200 kg N ha^{-1} + RDP + RDK+ 10 t ha^{-1} FYM	1.14	0.67	0.21	0.16	0.38	0.82	19.05	8.17
T_9 : 200 kg N ha^{-1} + 2.1 kg Zn ha^{-1} + RDP + RDK + 10 t ha^{-1} FYM	1.20	0.72	0.23	0.19	0.43	0.87	23.44	10.95
T_{10} : 200 kg N ha^{-1} + 4.2 kg Zn ha^{-1} + RDP + RDK + 10 t ha^{-1} FYM	1.23	0.75	0.26	0.21	0.46	0.89	25.57	11.67
S.Em.±	0.04	0.04	0.02	0.01	0.02	0.03	2.02	0.64
CD @ 5 %	0.12	0.12	0.05	0.03	0.07	0.08	6.01	1.91

TABLE 4

Effect of different levels of nitrogen and zinc application on Ca, Mg and S content of maize in rural and peri-urban of southern transact of Bengaluru

Treatments	Rural						Peri - urban					
	Calcium (%)		Magnesium (%)		Sulphur (%)		Calcium (%)		Magnesium (%)		Sulphur (%)	
	Grain	Stover	Grain	Stover	Grain	Stover	Grain	Stover	Grain	Stover	Grain	Stover
T_1 : Absolute control	0.23	0.51	0.10	0.20	0.04	0.06	0.13	0.43	0.06	0.14	0.03	0.06
T_2 : RDP + RDK + 10 t ha^{-1} FYM	0.26	0.61	0.13	0.23	0.09	0.11	0.18	0.48	0.08	0.17	0.06	0.10
T_3 : 2.1 kg Zn ha^{-1} + RDP+ RDK + 10 t ha^{-1} FYM	0.30	0.65	0.15	0.27	0.12	0.15	0.20	0.52	0.10	0.19	0.09	0.13
T_4 : 4.2 kg Zn ha^{-1} + RDP + RDK + 10 t ha^{-1} FYM	0.32	0.70	0.16	0.28	0.11	0.14	0.22	0.54	0.10	0.24	0.08	0.12
T_5 : 150 kg N ha^{-1} + RDP + RDK + 10 t ha^{-1} FYM	0.35	0.73	0.18	0.31	0.10	0.13	0.25	0.56	0.12	0.26	0.07	0.11
T_6 : 150 kg N ha^{-1} + 2.1 kg Zn ha^{-1} + RDP + RDK + 10 t ha^{-1} FYM	0.36	0.75	0.19	0.32	0.12	0.15	0.27	0.58	0.13	0.27	0.09	0.13
T_7 : 150 kg N ha^{-1} + 4.2 kg Zn ha^{-1} + RDP + RDK + 10 t ha^{-1} FYM	0.39	0.76	0.20	0.34	0.16	0.18	0.28	0.60	0.14	0.30	0.12	0.14
T_8 : 200 kg N ha^{-1} + RDP + RDK + 10 t ha^{-1} FYM	0.38	0.76	0.19	0.32	0.11	0.14	0.27	0.59	0.13	0.27	0.08	0.13
T_9 : 200 kg N ha^{-1} + 2.1 kg Zn ha^{-1} + RDP + RDK + 10 t ha^{-1} FYM	0.40	0.78	0.21	0.37	0.13	0.16	0.29	0.62	0.14	0.31	0.10	0.15
T_{10} : 200 kg N ha^{-1} + 4.2 kg Zn ha^{-1} + RDP + RDK + 10 t ha^{-1} FYM	0.42	0.80	0.23	0.39	0.16	0.20	0.33	0.64	0.15	0.35	0.14	0.18
S.Em.± 0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.03	0.01	0.04	0.01	0.01	
CD @ 5 %	0.05	0.07	0.05	0.05	0.04	0.04	0.04	0.08	0.02	0.11	0.04	0.04

as zinc helps in nitrogen absorption due to synergistic relationship between nitrogen and zinc. Similar findings were obtained by Abel-Hady (2007).

Concentration of zinc was found higher with application of higher zinc and nitrogen along with RDP and K in grain (30.50 and 25.57 ppm) and stover (21.80 and 11.67 ppm) of rural and peri-urban grown maize, respectively. It was found to be on par with the treatment T_9 (200 kg N ha^{-1} + 2.1 kg Zn ha^{-1} + RDP + RDK + 10 t ha^{-1} FYM) and least concentration of zinc in grain (15.25 and 9.75 ppm) and stover (9.98 and 4.99 ppm) was recorded in absolute control. The increase in Zn concentration might be due to synergistic effect between nitrogen and zinc as adequate supply of N enhanced the translocation of Zn from roots to other parts of plants. Further better root and shoot growth with the application of N might have led to better utilization of the zinc and other cations from the soil solution. Similar results were reported by Lin *et al*., 2007.

The data pertaining to calcium, magnesium and sulphur concentration as influenced by different levels of nitrogen and zinc in grain and stover are presented in Table 4.

Among treatments, significantly higher concentration in grain (0.42 and 0.33 %) and stover (0.80 and 0.64 %) in rural and peri-urban maize, respectively was recorded with application of 200 kg N ha^{-1} + 4.2 kg Zn ha^{-1} RDP + RDK + 10 t ha^{-1} FYM (T_{10}) which was on par with 200 kg N ha^{-1} + 2.1 kg Zn ha^{-1} RDP + RDK +10 t ha^{-1} FYM (T_9) over control (T_1). Similarly, significantly higher magnesium concentration in grain (0.23 and 0.15 %) and stover (0.39 and 0.35 %) was observed in T_{10} (200 kg N ha^{-1} + 4.2 kg Zn ha^{-1} RDP + RDK + 10 t ha^{-1} FYM) over absolute control (T_1).

Significantly higher concentration of sulphur in grain (0.16 and 0.14 %) and stover (0.20 and 0.18 %) was recorded with application of 200 kg N ha^{-1} + 4.2 kg Zn ha^{-1} RDP + RDK + 10 t ha^{-1} FYM (T_{10}), followed by 200 kg N ha^{-1} + 2.1 kg Zn ha^{-1} RDP + RDK + 10 t ha^{-1} FYM (T_9) over control (T_1) in rural and peri-urban, respectively. The application of higher level of nitrogen and zinc along with recommended dose of phosphorus, potassium and FYM (10 t ha^{-1}) had significantly increased content of secondary nutrients in maize crop, this may be due to synergetic effect of nitrogen and zinc with secondary nutrients.

From the above results it can be concluded that, rural maize crop recorded higher nutrient content compared to peri-urban, due to judicious use of chemical fertilisers and organic manure applications that maintained optimum soil pH and thereby governing the availability of nutrients.

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Phenotyping of Pigeonpea Genotypes Against *Phytophthora cajani* an Incitant of Phytophthora Blight Disease

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Abstract

The use of resistant cultivars is considered to be the best way of controlling the disease. The present investigation was carried to identify pigeonpea genotypes with resistance to *Phytophthora* blight (PB) caused by *Phytophthora cajani*. Artificial screening of 19 pigeonpea genotypes was carried out using stem inoculation method. None of them showed resistance reaction. Nine genotypes showed moderate resistance reaction with less than 20 per cent disease incidence. Phenotyping of 57 pigeonpea entries comprising varieties, hybrids and wild species for resistance to PB under natural disease pressure. Among the genotypes, incidence of disease ranged from 0 to 100 per cent., 38 genotypes showed resistance reaction with an incidence of less than 10 per cent and six genotypes showed moderate resistance reaction**.** The resistant / moderately resistant genotypes identified can be utilized for breeding programme as donors.

Keywords : Phytophthora blight, Pigeonpea, Phenotyping, Resistance source, Screening

In India, pigeonpea is the second most important pulse crop after chickpea. It is cultivated over 5.34 million ha, accounting 4.87 million tonnes of grain (Indiastat, 2017). India alone contributes 72 per cent of the area and two thirds portion of the global pigeonpea production. *Phytophthora* blight (PB) of pigeonpea caused by *Phytophtohra cajani* is an economically important disease particularly in the area where intermittent rainfall followed by warm and humid weather persists. The varieties grown by farmers are no longer resistant to *Phytophthora* blight (PB). Pande *et al*. (2011) observed the occurrence of PB across all cropping system, soil type and cultivars in the Deccan Plateau of India. The most effective way to control *Phytophthora* blight is identification and development of resistant cultivars. Hence, the present study was undertaken to identify the genotypes of pigeonpea with resistance to *Phytophthora* blight.

Material and Methods

Pathogen

The isolation of pathogen was done by tissue segment method (Rangaswamy, 1958) using V8 juice agar media (Himedia, Mumbai, India) amended with PARP antibiotics (pimarcin 400 µL; ampicillin 250 mg; rifampicin 1000 µL; and pentachloronitrobenzine 5 mlL–1 media). Pathogen was identified by cultural and morphological characteristics as described by Erwin and Ribeiro (1996). The fungus was subcultured and maintained on tomato extract agar. Virulence of the pathogen was maintained by transferring the pathogen through susceptible host after every 60 days.

Phenotyping of Pigeonpea Accessories for Resistance to *Phytophthora* Blight under Artificial Inoculation.

Nineteen pigeonpea genotypes were screened at RL-17 field of ICRISAT, Patancheru for resistance to *Phytophthora* blight as described by Nene *et al*. (1981). The pigeonpea genotypes were planted in rows at spacing of 30 cm. Susceptible cultivar ICP 7119 was planted after every two rows. The collar region of 30 days old plants were inoculated with pathogen. The field was flooded immediately after inoculation and further irrigated twice a week, as and when dry weather was noticed. Typical blight symptoms appeared in about 10 days. Plants which did not show

symptoms were re-inoculated after one month. Percentage of blight affected seedlings was calculated based on number of infected plants to total number of plants (Chauhan *et al.,* 2002). Based on disease incidence the pigeonpea accessions categorized into as resistant (0-10 per cent), moderately resistant (11-20 %), moderately susceptible (21-50 %), susceptible (51-80 %) and highly susceptible (81-100 %).

Phenotyping of Pigeonpea Accessions for Resistance to *Phytophthora* Blight under Natural Epiphytic Conditions

A total of 57 pigeonpea entries comprising varieties and hybrids were sown at ICRISAT in demonstration plot during the survey at 25 days after sowing we noticed the incidence of *Phytophthora* blight and then we have recorded the incidence of *Phytophthora* blight at 30, 60, 90 and 130 days after sowing in the demonstration plot. The per cent disease incidence (PDI) was calculated based on total number of plants present and number of plants showing typical PB symptoms in each entry.

Results and Discussion

Sources of resistance to *Phytophthora* blight were mentioned by various researchers *viz.,* Sharma *et al*. (1995). The crop was found susceptible to *Phytophthora cajani* under natural epiphytotic conditions in major pigeonpea growing areas of Deccan Plateau of India (Sharma *et al.,* 2006). This could be due to frequent evolution of new pathotypes and coexistence of more than one pathotype at one location. In this context, 19 pigeonpea genotypes were screened using stem inoculation method. In addition the reaction of improved Pigeonpea breeding lines in a hot spot area for *Phytophthora* blight at research farm of ICRISAT, Patancheru was also studied.

Screening of Pigeonpea Genotypes against *P. cajani*

Nineteen Pigeonpea genotypes were screened in research farm (RL-17) of ICRISAT, Patancheru, using stem inoculation method and the results are presented in Table 1. Among all the genotypes screened ICP 9174 showed the lowest disease incidence (12.2 %), followed by ICP 8863 (14.3 %). Highest incidence was recorded by genotype ICPL 161 (52.5 %). Based on disease reaction, the genotypes were grouped as resistant, moderately resistant, moderately susceptible, susceptible and highly susceptible. Among the 19 Pigeonpea genotypes (Table 2), nine genotypes (ICP 9174, ICP 8863, JA-4, ICP 11302, ICP 11290, BDN 2, Bahar, KPBR 80 2 1, ICP 2376) showed moderately resistant reaction, eight genotypes (ICPL 288, ICP 4135, ICP 87119, ICP 580, ICP 113, ICP 11304, UPAS 120, ICP 339) showed moderately susceptible reaction and two genotypes (ICPL 161 and ICP 7119) showed susceptible reaction. None of the genotypes showed resistant reaction.

Table 1

Reaction of pigeonpea entries against *Phytophthora cajani* under artificial inoculation

Genotypes	PDI	Reaction
ICP 9174	12.2	MR
ICP 8863	14.3	MR
KPBR 80 2 1	15.6	MR
JA-4	16.3	MR
ICP 87119	16.6	MR
Bahar	16.8	MR
ICP 11302	19.1	MR
BDN 2	19.7	MR
ICP 2376	19.7	MR
ICPL 288	21.0	MS
ICP 4135	25.5	MS
ICP 580	26.7	MS
ICP 11290	27.8	MS
ICP 113	28.7	MS
UPAS 120	35.0	MS
ICP 11304	36.3	MS
ICP 339	36.3	MS
ICP 7119	52.3	S
ICPL 161	52.5	S

TABLE 2

Classification of pigeonpea genotypes based on disease reaction against *Phytophthora cajani*

Disease reaction	Scale	Breeding lines/ germplasm	Number
Resistant	0-10	Nil	0
Moderately resistant	10.1-20	ICP 9174, ICP 8863, KPBR 80-2-1, JA-4, ICP 87119, Bahar, ICP 11302, BDN 2 and ICP 2376	9
Moderately susceptible	20.1-50	ICPL 288, ICP 4135, ICP 580, ICP 11290, ICP 113, UPAS 120, ICP 11304 and ICP 339	8
Susceptible	50.1-80	ICP 7119 and ICPL 161	2
Highly susceptible	80.1-100	Nil	0

Reaction of Pigeonpea Genotypes to *Phytophthora* Blight under Natural Disease Incidence

Reaction of 57 pigeonpea genotypes was assessed at research farm (BP - 14A) of ICRISAT, Patancheru under natural environmental condition. The disease incidence ranged from 0.0 to 100 per cent (Table 3). Among the 57 genotypes, 38 (ICPL 20338 DT, ICPL 20326 NDT, MN 1, MN 5, MN 8, ICPL 87051, 88034, 96053, 6058, 96061, 98008, 92016, 87154, 84023, ICPA 2209, 2043, 2047, 2048, 2092, 2199, ICPH 2363, 2671, 2740, 3461, 3933, 3762, 3477, 3492, 4503, ICP 5028, Maruti, Asha, Lakshmi, Abhaya, Sarita, Durga, Jagriti, Prasada) showed resistant reaction, six genotypes (ICPA 2039, 2089, ICPH 2438, 2364, ICPL 20340 DT, ICPL 85030) showed moderately resistant reaction and 10 genotypes (ICPH 2433, 2751, ICPL 20325 NDT, ICPL 87091, 88039, 97250, 99004,UPAS 120, Pragati, *Cajanus cajanifolius*) showed moderately susceptible reaction. The genotypes ICPL 20092, Kamika and *Cajanus scarabeiodes* showed highly susceptible reaction (Table 4). Preliminary investigations suggest that phenolic constituents of

TABLE 3

Severity of *Phytophthora* blight on pigeonpea genotypes under natural ecosystems

Genotype	PDI at different days after sowing				Disease reaction
	30	60	90	130	
ICPA 2039	0.7	15.11	18.4	17.8	MR
ICPA 2089	1.1	9.7	15.0	16.0	MR
ICPH 2438	0.0	12.8	13.5	14.3	MR
ICPH 2363	1.0	2.5	4.5	4.5	R
ICPH 2364	3.6	8.1	13.9	16.5	MR
ICPH 2433	7.6	29.3	37.6	40.0	MS
ICPL 20338 DT	0.0	4.7	4.7	4.7	R
ICPL 20340 DT	0.0	11.6	12.6	14.5	MR
ICPL 20325 NDT	3.2	26.8	31.6	32.9	MS
ICPL 20326 NDT	0.0	4.6	4.6	4.6	R
MN 1	0.0	1.7	1.8	1.8	R
MN 5	0.0	0.0	0.0	0.0	R
MN 8	2.9	2.9	2.9	2.9	R
Sarita	0.0	0.0	0.0	0.0	R
Pragati	0.0	22.0	22.0	26.1	MS
Durga	0.0	2.0	2.0	2.0	R
Jagriti	0.0	4.0	4.0	4.0	R
ICPL 87091	0.0	15.8	17.7	23.8	MS
ICPL 88039	12.6	13.5	25.6	26.9	MS
ICPL 88034	0.0	2.0	2.0	3.1	R
ICPL 98008	1.9	1.9	1.9	1.9	R
Prasada	0.0	0.0	0.0	0.0	R
ICPL 92016	0.0	0.0	0.0	0.0	R
ICPL 87154	0.0	0.0	0.0	0.0	R
ICPL 85030	0.0	8.3	8.3	10.6	MR
ICPL 84023	0.0	7.0	7.0	7.5	R
ICPA 2209	0.0	1.8	1.8	1.8	R
ICPA 2043	0.0	0.0	0.0	0.0	R
ICPA 2047	0.0	0.0	0.0	0.0	R
ICPA 2048	0.0	0.0	0.0	0.0	R
ICPA 2092	0.0	0.0	0.0	0.0	R
ICPA 2199	0.0	0.0	0.0	0.0	R
ICPH 2671	2.6	3.0	4.8	5.3	R

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Genotype	PDI at different days after sowing				Disease reaction
	30	60	90	130	
ICPH 2740	0.0	0.0	0.0	0.0	R
ICPH 2751	0.0	18.3	18.3	23.9	MS
ICPH 3461	0.0	0.0	0.0	0.0	R
ICPH 3933	0.0	0.0	0.0	0.0	R
ICPH 3762	0.0	0.0	0.0	0.0	R
ICPH 3477	0.0	0.0	0.0	0.0	R
ICPH 3492	0.0	0.0	0.0	0.0	R
ICPH 4503	0.0	0.0	0.0	0.0	R
Maruti	0.0	0.0	0.0	0.0	R
Asha	0.0	0.0	0.0	0.0	R
Lakshmi	1.7	1.7	1.7	1.7	R
Abhaya	0.0	0.0	0.0	0.0	R
ICP 5028	3.6	3.6	3.6	5.4	R
ICPL 96058	0.0	1.7	1.7	1.7	R
ICPL 96061	0.0	1.9	1.9	1.9	R
ICPL 96053	2.3	2.3	4.5	4.5	R
ICPL 87051	2.4	4.9	7.3	7.3	R
ICPL 97250	0.0	29.8	29.8	39.7	MS
ICPL 99004	0.0	18.3	18.3	25.0	MS
Kamika	25.0	59.4	83.7	100.0	HS
ICPL 20092	11.2	44.8	74.8	100.0	HS
Cajanus cajanifolius	6.0	21.2	33.6	43.4	MS
UPAS 120	13.2	19.8	32.9	33.0	MS
Cajanus scarabeiodes	21.7	38.6	64.6	82.1	HS

leaves and stems increased after inoculation in resistant varieties while, they decreased in the *Phytophthora* blight susceptible variety of pigeonpea (Pal and Grewal, 1975). It appears that there may be stimulation of host defense reaction due to infection in the resistant variety while such mechanism may be absent in the susceptible one. Resistance identified so far needs to be reconfirmed under epidemiologically sound disease development environment and with the emergence of new pathotypes of *P. cajani*.

TABLE 4

Classification of pigeonpea genotypes based on reaction against *Phytophthora* blight disease

Disease reaction	Scale	Breeding lines/ germplasm	Number
Resistant	0-10	MN-5, Sarita, Prasada, ICPL 92016, ICPL 87154, ICPA 2043, ICPA 2047, ICPA 2048, ICPA 2092, ICPA 2199, ICPH 2740, ICPH 3461, ICPH 3933, ICPH 3762, ICPH 3477, ICPH 3492, ICPH 4503, Maruti, Asha, Abhaya, Lakshmi, ICPL 96058, MN 1, ICPA 2209, ICPL 98008, ICPL 96061, Durga, MN 8, ICPL 88034, Jagriti, ICPH 2363, ICPL 96053, ICPL 20326 NDT, ICPL 20338 DT, ICPH 2671, ICP 5028, ICPL 87051 and ICPL 84023	38
Moderately resistant	10.1-20	ICPL 85030, ICPH 2438, ICPL 20340 DT, ICPA 2089, ICPH 2364 and ICPA 2039	6
Moderately susceptible	20.1-50	ICPL 87091, ICPH 2751, ICPL 99004, Pragati, ICPL 88039, ICPL 20325 DT, UPAS 120, ICPL 97250, ICPH 2433 and *Cajanuscaj anifolius*	10
Susceptible	50.1-80	Nil	0
Highly susceptible	80.1-100	*Cajanusscarabeiodes,* Kamika and ICPL 20092	3

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Agrobacterium tumefaciens Mediated Transformation of *Nicotiana tabacum* Plant with PRSV Coat Protein Gene

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ABSTRACT

Papaya ringspot virus is a major limiting factor for the cultivation of papaya in tropical and subtropical areas throughout the world. The present investigation was undertaken with the aim of incorporating coat protein gene of the virus to impart pathogen derived resistance through genetic engineering. Attempts were made to incorporate *PRSV CP* gene in the model plant *Nicotiana tabacum* through *Agrobacterium* mediated approach. The viral RNA was isolated and converted to cDNA by Reverse transcription polymerase chain reaction and amplified with *PRSV CP* gene specific primers to obtain an amplicon size of ~900bp. This amplicon was further cloned into pTZ57R/T vector, transformed into *E. coli* DH5α and sequenced to confirm its identity as CP. The CP gene was further sub-cloned into binary vector pBI121 and transformed to *N. tabacum* through *Agrobacterium* mediated approach, regenerated on selective media with 100 mg L^{-1} kanamycin and 200 mg L^{-1} cefatoxime, confirmed by polymerase chain reaction and serological approaches like Dot Blot.

Keywords : Coat protein, cDNA, Amplicon, Nicotiana

PAPAYA (*Carica papaya* L.) is an important fruit crop of tropical and subtropical regions of the world belonging to the family *Caricaceae* and has both economical and nutritional value. It is infested by an important viral disease Papaya Ring Spot Virus (PRSV) which causes ringspot on fruits and stems. The disease was reported for the first time in the island of Ohau in Hawaii (Parris, 1938), which was sap transmissible and later named as 'Wailu' disease (Lindner *et al.,* 1945) and shown to be of viral nature by Jensen (1949) from Kailu, island of Ohau in Hawaii.

The virus is ssRNA belonging to the family potyviridae and transmitted by numerous species of aphids in a non-persistent manner with limited host range (Anonymous, 2004 and Hema & Prasad, 2004). The conventional methods are not very effective in controlling the disease, as traditional genetic sources of virus resistance are rare and the resistance is frequently broken under field conditions (Lecoq *et al.,* 2004). In the 1990s, the Papaya industry on Hawaii suffered a 50 per cent decline in production due to an outbreak of the potyvirus, PRSV (Gonsalves, 1998). Virus resistance was obtained in a high-yielding papaya hybrid using the viral coat protein sequence as the transgene which led to development of Rainbow and Sunup (Gonsalves, 2004).

A similar approach has been successfully applied in US cucurbit production, although the situation has been more complicated due to the presence of several different viruses (Fuchs *et al.,* 1997 and Fuchs & Gonsalves, 2007). The results obtained repeatedly in laboratory and field studies demonstrate that transgenic strategies for virus resistance works effectively.

The genetically engineered resistance is referred as pathogen-derived resistance (PDR) (Sanford & Johnston, 1985), classified as RNA and protein mediated. RNA-silencing is a sequence specific RNA degradation or silencing mechanism, operates as a natural antiviral defense system and provides promising potential for viral resistance (Eamens *et al.,* 2008) and followed by protein mediated resistance, where the transformation cassette is designed to be translated and expressed into the plant leading to interference of viral assembly (Ritzenthaler, 2005).

Controlling plant viruses by genetic engineering, including the globally important PRSV, mainly involves coat protein (CP) gene mediated resistance *via* post-transcriptional gene silencing (PTGS). Although the CP gene of PRSV has been transferred into papaya by particle bombardment and transgenic lines with high resistance to Hawaii strains have been obtained, they are susceptible to PRSV isolates outside Hawaii. This strain-specific resistance limits the application of the transgenic lines in other areas of the world (Bau *et al*., 2002). The study involves development of a transgenic *N. tabacum* a model plant, where *PRSV CP* gene of south Indian isolate (Hosakote strain) is transferred and expressed in T_0 plants through *Agrobacterium* mediated transformation and confirmed by molecular studies.

Material and Methods

RNA Isolation and cDNA Synthesis of *PRSV* CP Gene

Field infected PRSV plant leaf sample was collected and used for the isolation of total RNA using Lithium chloride method (LiCl) (Yang *et al*., 2008). The isolated RNA was used as template for the synthesis of cDNA by MMuLV-RT enzyme (Fermentas). The synthesized cDNA was amplified by sense and antisense coat protein gene specific primers (CP gene specific FP: CCATGGCCAAAAATGAAGCTGTGGATAC and CP gene specific RP : AGATCTATACCCAGGAGA GAGTGCATGT).

Plasmid Constructs

The PCR product was purified and cloned in pTZ57RT cloning vector (InsTAclone™ PCR cloning kit, Fermentas, USA), pTZ57RT+*PRSV* CP gene was transformed into competent *E. coli* DH5α cells following standard protocols (Sambrook and Russell, 2001). The positive recombinant clones were identified by blue-white screening, confirmed by gene specific PCR amplification using gene specific primers and by restriction analysis. For PCR confirmation of clones, the template DNA from plasmid was isolated following the alkaline lysis protocol of Brimbion and Dolly (1979) and restriction analysis was done using BamHI-HF and SacI-HF restriction enzymes. The PRSV CP gene cloned into pTZ57R/T was sequenced using M13 forward and reverse primers. The sequence was analyzed using BLAST algorithm (https://www.ncbi.nlm.nih.gov/). Confirmed clone of *PRSV* CP gene was sub-cloned into a binary vector pBI121, using the same restriction enzymes, BamHI-HF and SacI-HF where *GUS* gene was removed from pB121 and *PRSV CP* gene was cloned in between right and left borders of T-DNA region, driven by CaMV35s promoter, with a selectable *neomycin/kanamycin* gene and nos terminator sequence (Fig. 1). The construct of pBI121+*PRSV CP* gene was transformed into competent *E. coli* DH5α cells. The transformants were confirmed by colony PCR, plasmid PCR amplification and restriction analysis was done using the same restriction enzymes mentioned above.

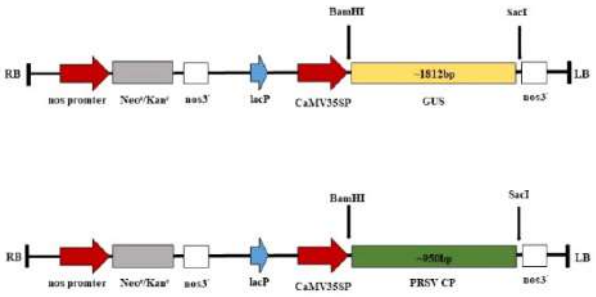

Fig. 1: The construct of pBI121+*PRSV CP*

Agrobacterium Mediated Transformation of *N. tabacum*

The confirmed clones were further transferred in to *Agrobacterium tumefaciens* strain LBA4404 by freeze thaw method (Jyothishwaran *et al*., 2007). Transformed Agrobacterium were confirmed by colony PCR and plasmid PCR with gene specific primers. The positive colonies of transformed *Agrobacterium* with the construct of pBI121+*PRSV* CP gene were used for co-cultivation of *N. tabacum*, which were grown in YEP medium with rifamycin 100mgL^{-1} and 50mgL^{-1} kanamycin at 28^{0}C for 48 hours. Bacterial cells were pelleted at a speed of 3500 rpm for 10 min and re-suspended in half MS solution plant culture medium at a density of 10^9 cells per ml (OD560=1) with 100mM of acetosyrinzone. This infection solution

was used for co-cultivation of tobacco explants (leaf discs of 1 cm^2), which were tap dried and kept in dark for 48 hours (Jyothishwaran *et al*., 2007).

The co-cultivated explants from dark were transferred to a fresh MS medium with 2 mgL^{-1} Kinetin, 1 mgL^{-1} IAA for multiple shoot regeneration. Explants with multiple shoots were subjected to selection media containing 100 mgL^{-1} kanamycin for transformed plant confirmation and 200 mgL^{-1} cefatoxime to kill the excess growth of *Agrobacterium.* Further they were transformed into rooting media consisting of half strength MS media. Rooted plants were hardened at *in vitro* condition for about 15 days and later transferred to greenhouse conditions.

Confirmation Studies

The T_0 plants were confirmed for integration of the *PRSV CP* gene by molecular PCR amplification using gene specific primers Every PCR reactions were performed in eppendrof tubes containing 20 µl of reaction solution having, 10X reaction buffer, 2 mM dNTPs, 100 ng of DNA, 10pmol/µl of forward and reverse primers each and 3U/il of TaqDNA polymerase, Fermentas. The PCR amplification of DNA was performed using a thermal cycler (Bio-Rad), under the given conditions of temperature: 94 °C for 3 min followed by 35 cycles of 94 °C for 45 seconds, 60°C for 1:30 min, 72 °C for 1 min and final extension reaction at 72°C for 30 min. Amplified DNA fragments were then analyzed by electrophoresis using agarose gel 1 per cent and visualized through ethidium bromide staining (Sambrook *et al*., 1989) under ultraviolet light.

The expression of the gene was confirmed by serological technique, Indirect Dot Immuno-Binding Assay (DIBA) which was conventionally performed on nitrocellulose membrane with antibodies specific to PRSV CP. The DNA isolated from transformed and non-transformed plants was denatured by heating on a temperature 95 °C for five min. and cooled rapidly on ice. Dots of DNA were made with the help of a micropipette on nylon membrane. The membrane was allowed to dry at 37 °C overnight and then hybridized with the antibodies specific to PRSV CP followed by washing. Secondary antibody with the conjugated enzyme was hybridized and substrate was added to detect the color.

Results and Discussion

Isolation of *PRSV CP* Gene

RNA isolated from PRSV infected leaf samples was subjected to RT-PCR for the synthesis of cDNA, which was used as template for PCR amplification of *PRSV CP* gene specific primers. The obtained amplicon was run on 1 per cent agarose gel and the size obtained was approximately 950bp (Fig. 2). Various study report suggests several sizes of *PRSV CP* gene and it has a conserved region of ~534 bp (Byadgi, 2008 and Krubphachaya *et al*., 2007). The PCR amplification of cDNA using the PRSV-CP gene specific primers deduced from the blast search, resulted in a ~900bp fragment (Quemada *et al*., 1990; Wang and Yeh, 1992 and Silva-Rosales *et al*., 2000). Kunklikar and Byadgi (2004) reported that the PRSV isolate Type-P from India showed 715 bp long nucleotide sequence.

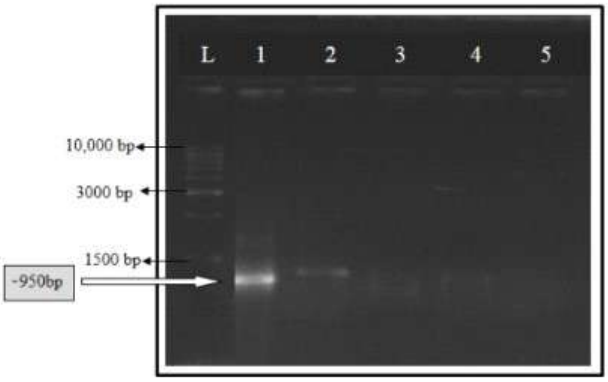

Fig. 2: Amplification of PRSV coat protein gene from the infected papaya leaf samples

Yap *et al*., (2009) reported that the CP gene obtained from transformed papaya revealed a size of 800bp. Hema and Prasad (2004), reported molecular characterization of the coat protein (CP) gene of a South Indian strain (INP-UAS) of PRSV-P and revealed an open reading frame of 849 bp. Size differences resulted from the differences in the number of lysine and glutamate (KE) repeats in the amino terminal region (Jain *et al*., 2004). NCBI database information on PRSV CP gene also supports this,

which probably is due to the fact that various groups have reported partial sequence of the CP gene. Genome structure of PRSV reveals that the CP gene exist polycistrionically with the NIb gene of PRSV and it may be difficult to separate the two and hence difference in the reported size of PRSV could exist.

Amplicon of PRSV CP gene was cloned into pTZ57R/T vector and the ligated product was transformed into *E.coli* DH5α cells by heat shock method. After incubation at 37^{0}C overnight, transformed colonies were observed. Transformed colonies were observed and selection was done based on blue-white screening (Fig. 3a). CP gene of PRSV- Hyderabad strain was cloned in to pTZ57R vector of 2.88kb size with T overhang. The vector was transformed into *E. coli* strain DH5α, multiplied and transformation finally confirmed (Kunkalikar, 2003). Hema and Prasad, (2004) amplified the PRSV CP gene, gel-eluted it by using the freeze-thaw method, cloned into pTZ57R and using an InstT/A PCR cloning kit transformed into *E. coli* strain XL1-Blue MRF' cells.

Cloning of PRSV CP Gene in Binary Vector

The plasmid DNA (pTZ57RT+*PRSV CP* gene) from the transformed *E. coli* DH5α cell was isolated and the pTZ57R/T plasmid containing CP gene was confirmed by using the CP gene specific primers. The PCR amplification showed the presence of ~ 950 bp *PRSV-CP* gene amplicon when it was run on 1 per cent agarose gel and by restriction analysis 950 bp *PRSV-CP* gene was released (Fig. 3b and 3c).

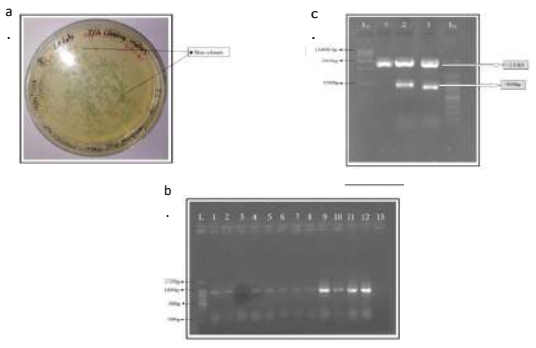

Fig. 3: (a). Transfromed *E. coli* DH5α cells with pTZ57RT + *PRSV CP* gene, (b). Colony PCR for confirmation of recombinant clones and (c). Restriction analysis of the positive transformed colonies

The plasmid DNA isolated from the transformed *E.coli* DH5α cell was sequenced using M13 primers. The sequences obtained from the automated sequencing was analyzed using NCBI-BLAST to find possible matches with the papaya ring spot virus coat protein gene reported throughout the world in order to confirm that it was *PRSV CP* gene.

According to the sequencing results, the gene was inserted in the proper orientation in into pTZ57R/T vector. Therefore, the restriction enzymes BamHI and SacI were used to cleave the insert from the pTZ57RT+*PRSV CP* gene construct, simultaneously binary vector pBI121 was also digested with same enzymes. The release of *PRSV CP* gene and cleaved pBI121 were eluted and ligated to develop a construct of pBI121+*PRSV CP* gene, which was transformed into *E. coli* DH5α cells by heat shock method. After incubation at 37^{0}C overnight, transformed colonies were observed (Fig. 4a). Yepes *et al*. (1996) cloned the sense coat protein gene of tomato ringspot nepovirus into pBI121 binary vector.

A binary vector containing the coat protein gene under the control of a 35S promoter, was constructed and transformed into somatic embryos of papaya cultivar Khak Dum by micro projectile bombardment (Kertbundit *et al*., 2007). Chon-Seng *et al*. (2007) cloned and sequenced a 927bp CP gene of PRSV. Subsequently the gene was sub-cloned into bacterial

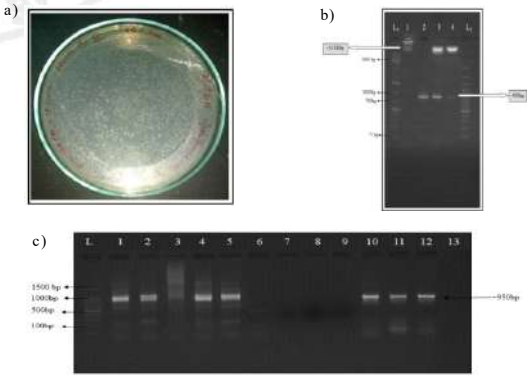

Fig. 4: (a). Transfromed *E. coli* DH5α cells with pBI121 + *PRSV CP* gene, (b). Colony PCR for confirmation of recombinant clones (L1- 1kb ladder; Lane 1, 2, 4, 5, 10, 11 and 12 positive transformed colonies) and (c). Restriction analysis of the positive transformed colonies (L1- 1kb ladder, L2- 100bp ladder, Lane 1 is isolated pBI121 + PRSV CP construct; Lane 2- PRSV CP; Lane 3 and 4- restriction digestion)

expression vector pRSET, to form pRSET:PRSVCP and expressed in *E. coli* BL21(DE3) strain.

The plasmid DNA (pBI121+*PRSV CP* gene) from the transformed *E.coli* DH5α cell was isolated and the pBI121 plasmid containing CP gene was confirmed by using the CP gene specific primers. The PCR amplification showed the presence of ~ 950 bp *PRSV-CP* gene amplicon when it was run on 1 per cent agarose gel and by restriction analysis 950 bp *PRSV-CP* gene was released (Fig. 4b and 4c).

Transformation of *Agrobacterium* with Recombinant pBI121 Vector

The plasmid DNA (pBI121+*PRSV CP* gene) was isolated from *E. coli* DH5α cells and was confirmed with CP gene specific primers. Then it was mobilized to *Agrobacterium* strain LBA4404. The transformants from *Agrobacterium* strain LBA4404 were streaked onto YEP media containing 50mg L^{-1} kanamycin and 100mg L^{-1} rifamycin, after incubation for 48 hours at 28 ^{0}C transformed colonies were observed (Fig. 5a).

The transformed *Agrobacterium* colonies were confirmed by performing colony PCR using *PRSV CP* gene specific primers which showed ~ 950bp CP gene from the pBI121 vector backbone on 1 per cent agarose gel (Fig. 5b). This confirmed the recombinant nature of the transformed colonies. The sense coat protein gene of tomato ringspot nepovirus was cloned into binary vector and transformed into *Agrobacterium* (Yepes *et al*., 1996).

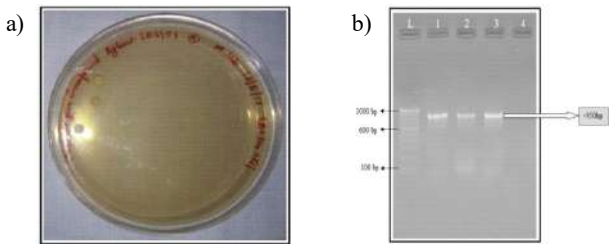

Fig. 5 : (a) Transformed *Agrobacterium* cells with pBI121 + *PRSV CP* gene and (b) Colony PCR for confirmation of recombinant clones

Transformation of pBI121+*PRSV CP* Gene Construct into *N. tabacum*

N. tabacum leaf discs were co-cultivated with the confirmed *Agrobacterium* colonies with pBI121+*PRSV CP* gene construct and were incubated for 48 hours in dark conditions for co-cultivation. *N. benthamiana* and *N. tabacum* transformed by *Agrobacterium* mediated transformation (Yepes *et al*., 1996). The co-cultivated explants were washed with cefataxime, tap dried and sub-cultured in shooting media containing 100mgL^{-1} kanamycin for transformed plant confirmation and 200mgL^{-1} cefatoxime to kill the bacteria. Transformed explants survived and response like curling of disc end was observed after 7-10days. Multiple shoots were observed after 20-25 days of inoculation and they were transformed to rooting media (Fig 6).

Fig. 6: Regeneration of *N. tabacum* on selection media after *Agrobacterium* mediated transformation, shoot emergence, multiple shooting and transferred to rooting media

PCR and Dot Blot Analysis/ Molecular confirmation of Transgenic Plants

Before transferring to the rooting media the DNA was isolated from the transformed shoots, which was used for PCR amplification with *PRSV CP* gene specific primers (Fig. 7a). Among the T_0 plants in two, there was amplification and the band size of ~ 950 bp was observed on 1 per cent agarose gel. Further to confirm the gene expression, protein dot blot analysis was conducted using PRSV CP antibody at different

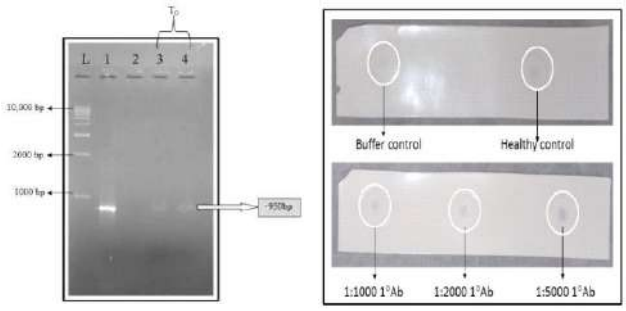

Fig. 7: (a). Colony PCR for confirmation of transgenic *N. tabacum* plants and (b). Indirect Dot Immuno-Binding Assay for confirmation of protein expression

concentrations, there was no color development in buffer control and healthy controls. Color was observed in transgenic plants, which confirmed the expression of protein in the transformed T_0 plants. The plants will be further advanced to T_1 generation and bioassay studies will be done.

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Effect of Watermelon *(Citrullus lanatus)* Rind Flour Incorporation on Nutritional and Organoleptic Attributes of Cakes

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Abstract

Bakery products have become popular among different cross-sections of the population in India in recent years due to increased demand for convenient foods. The sponge cakes and fruit cakes were prepared by replacing only refined wheat flour with different levels of watermelon rind flour (WRF). WRF has a moisture of 12.17 per cent, protein 10.18 g, fat 2.37 g, crude fibre 17.44 g, ash 11.82 g and carbohydrates 46.02 g, respectively. Three variations of sponge cakes and fruit cakes were prepared by incorporating WRF at 10, 20 and 30 per cent levels, respectively. Among sponge cakes, T_1 (10 % incorporation) was found to be most accepted with scores for appearance 8.57, colour 8.42, texture 8.09, aroma 8.33, taste 8.54 and overall acceptability 8.23. The nutritional value of sponge cake indicated fibre (2.70 g), fat (3.73 g), calcium (47.68 mg), iron (1.98 mg) and phosphorus (87.07 mg), respectively. The sensory scores of fruit cake with 10 per cent WRF incorporation (T_1) was found to be best accepted with values for appearance 8.19, colour 8.26, texture 8.07, flavour 8.33, taste 8.19 and overall acceptability 8.09. The nutritional composition indicated fibre (2.76 g), fat (11.49 g), calcium (46.36 mg), iron (1.90 mg) and phosphorus (149.90 mg), respectively which is higher than that of control. Therefore, it can be observed that cakes enriched with watermelon rind flour increased the nutrient composition especially fat, fibre and mineral content of the cakes. Hence, watermelon rind flour, the byproduct of watermelon can be utilized effectively for enhancing the nutritional composition of cakes.

Keywords : Bakery products, Byproduct utilisation, Fruit cake, Sponge cake, Watermelon rind

Fruits and vegetables being perishable in nature undergo spoilage at various stages of their harvesting, handling, transport, storage, marketing, processing. The spoilt produce is not fit for marketing and is a virtual loss. Some fruits do not find much suitability for processing and are mostly used for direct consumption, one such fruit is watermelon (Bhatnagar, 1991). Red coloured watermelon pulp is used normally discarding the watermelon rind that has protein, fat, carbohydrates, crude fiber and ash content decently (Koocheki *et al*., 2007). The nutrient composition of watermelon rind flour has a moisture of 12.17 per cent, protein 10.18 g, fat 2.37 g, crude fibre 17.44 g, ash 11.82 g and carbohydrates 46.02 g, respectively (Ashoka,–2019). Some work on the utilization of watermelon peel in preparation of value-added products is done but there is scope for trying out some more products with this material (Bhatnagar, 1991). Currently, the food sector has to deal with a high rate of food waste produced by industrial fruit processing of various products such as jams, wines, juices, ice cream, sweets and others. The use of waste from the industrial processing of fruits is an important new step for the food industry (Bertagnolli *et al.,* 2014). The bakery industries are one of the largest organized food industries all over the world and particularly cakes are one of the most popular products (Sindhuja *et al.,* 2005). Bakery products are generally used as a source for the incorporation of different nutritionally rich ingredients for their diversification (Sudha *et al.,* 2007).

Numerous studies have been carried out to replace wheat flour with the flour from the fruit residues in the preparation of bakery products such as biscuits and cookies because of the economic constraints, business requirements, new consumption trends, and specific eating habits (Aquino *et al.,* 2010 and Perez

& Germani, 2007). Fruit residues can be important sources of nutrients and to satisfy consumer demand for healthier products, many food industries are finding ways to add functional ingredients to their products (Assis *et al.,* 2009).

The cake is one of the relished and palatable baked products prepared from flour, sugar, shortening, baking powder, egg and essence as principal ingredients. The variation in these constituents causes changes in the textural properties of cakes. Cakes are highly popular among the large segment of the population in urban and rural places and their demand and consumption are increasing day by day [Hoque and Iqbal (2015)]. The present investigation was carried out at the Department of Food Science and Nutrition, University of Agricultural Sciences, Bangalore with the objective of the effect of watermelon *(citrullus lanatus)* rind flour incorporation on nutritional and organoleptic attributes of cakes.

Material and Methods

Selection and Collection of Sample

The fresh and matured watermelon fruits were procured from the local market of Bengaluru, Karnataka, India.

Processing and Dehydration

The watermelon fruits were washed under running tap water and they were wiped with using a clean dry cloth. All the watermelon fruits were peeled separately by using a peeler and the pulp was separated from the watermelon rind by using a knife and the remaining portion of seeds was separated by cutting the pulp into small cubes. After weighing the watermelon rind, the pieces were kept for dehydration at 60 °C until they dried properly. The dried rind was ground into powder by using an electric grinder and sieved through a scientific sieve (mesh size 60). Then, the dehydrated powder was packed and used for further purposes.

Formulation of Watermelon Rind Sponge Cake

The sponge cakes and fruit cakes were prepared by replacing refined wheat flour with different levels of watermelon rind flour in the basic formulation of cakes. The replacement of refined wheat flour by watermelon rind powder was at 10 , 20 and 30 per cent substitutional levels and they were compared with control. The procedure for preparation has been mentioned in Fig. 1 and 2.

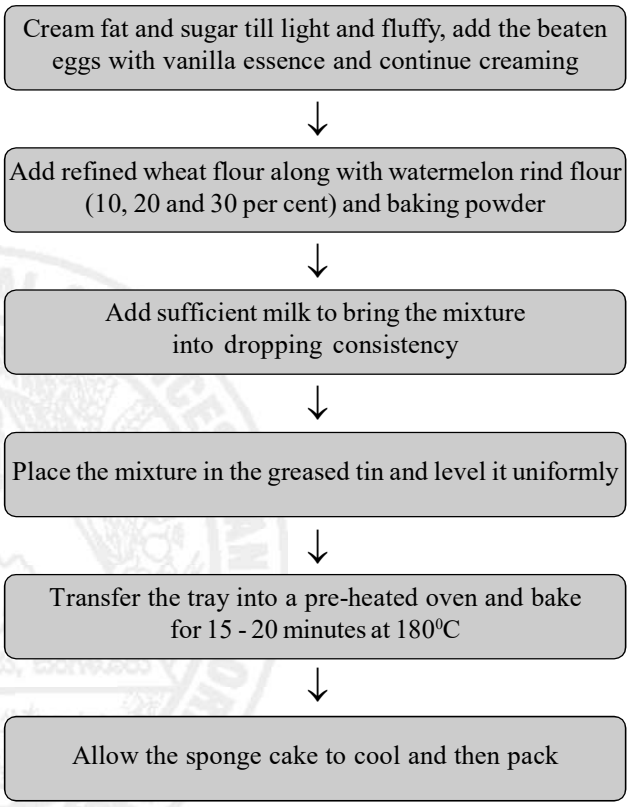

Fig. 1: Procedure for preparation of watermelon rind flour Sponge cake

Organoleptic Evaluation of the Developed Products

The products were subjected to sensory evaluation. Sensory quality attributes were evaluated by a semi-trained panel of 21 members using a nine-point hedonic scale [Amerine *et al.* (1965)].

Computation of Nutritional Composition for Best-Accepted Cookies

The nutrient composition for the best-accepted products was computed by using the Indian food composition table [Longvah *et al*. (2017).

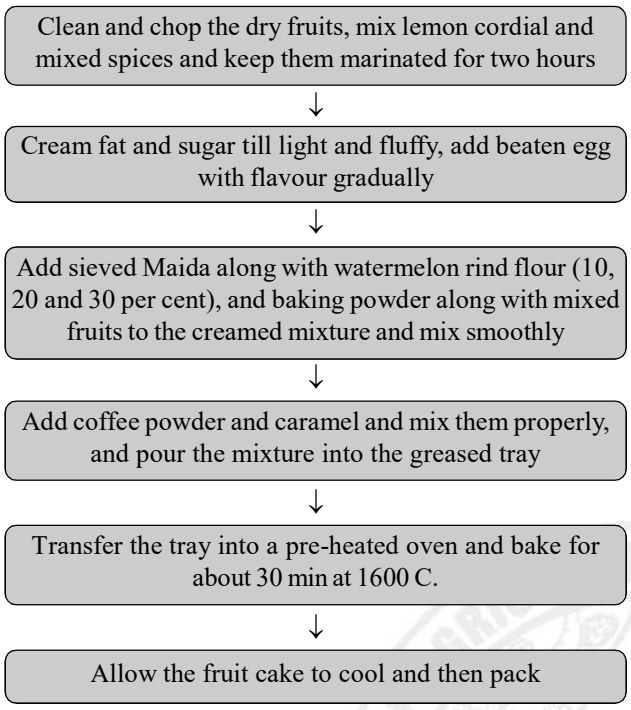

Fig. 2: Procedure for preparation of fruit cake with watermelon rind flour

Statistical Analysis

The data were subjected to analysis of variance (ANOVA) for testing the significance of variation of sensory evaluation of developed products by using software Statistical Package for Social Sciences (SPSS) version 12.0 (Sabine and Brian, 2004).

Results and Discussion

Sensory Evaluation of the Sponge Cake

Sponge cake formulated with different levels of incorporation of watermelon rind flour and subjected to sensory evaluation and mean scores are presented in Table 1. It shows appearance, colour, and taste had highly significant differences whereas texture and overall acceptability were non-significant. Control had high scores for all sensory attributes when compared to sponge cake prepared from different variations of WRF. Wherein sponge cake with 30 per cent incorporation *i.e.,* (T_3) had a comparatively lower score for appearance (7.80), colour (7.78), flavour

Table 1

Sensory evaluation of watermelon rind flour sponge cake and fruit cake

	Variation	Appearance	Texture	Colour	Flavour	Taste	OA
WRF Sponge cake	C	8.23 ± 0.88	8.38 ± 0.58	8.19 ± 0.67	8.21 ± 0.60	8.35 ± 0.57	8.30 ± 0.55
	T_1	8.57 ± 0.59	8.09 ± 0.60	8.42 ± 0.65	8.33 ± 0.65	8.54 ± 0.58	8.23 ± 0.53
	T_2	8.04 ± 0.58	7.94 ± 0.59	7.76 ± 0.53	7.88 ± 0.54	7.88 ± 0.63	8.11 ± 0.49
	T_3	7.80 ± 0.87	8.07 ± 0.84	7.78 ± 0.78	7.76 ± 0.88	7.88 ± 0.89	7.92 ± 0.92
	Mean ± SD	8.16 ± 0.78	8.12 ± 0.67	8.04 ± 0.71	8.04 ± 0.71	8.16 ± 0.73	8.14 ± 0.65
	F value	*	NS	*	*	*	NS
	CD	0.46	-	0.41	0.42	0.42	-
	SEM	0.16	0.14	0.14	0.14	0.14	0.14
WRF Fruit cake	C	8.23 ± 0.53	8.38 ± 0.58	8.19 ± 0.67	8.21 ± 0.60	8.35 ± 0.57	8.30 ± 0.55
	T 1	8.19 ± 0.66	8.07 ± 0.59	8.26 ± 0.73	8.33 ± 0.65	8.19 ± 0.74	8.09 ± 0.53
	T_2	8.00 ± 0.63	7.97 ± 0.55	7.80 ± 0.51	7.80 ± 0.60	7.80 ± 0.60	7.95 ± 0.49
	T_3	7.85 ± 0.79	7.90 ± 0.76	7.80 ± 0.74	7.80 ± 0.87	7.80 ± 0.87	7.85 ± 0.85
	Mean ± SD	8.07 ± 0.66	8.08 ± 0.64	8.01 ± 0.69	8.04 ± 0.72	8.04 ± 0.73	8.05 ± 0.64
	F value	NS	NS	NS	*	*	NS
	CD	-	-	-	0.42	0.43	-
	SEM	0.14	0.13	0.14	0.15	0.15	0.13

Note : C- Plain or control cookies, T_1 = 10% WRF, T_2 = 20%WRF, T_3 = 30%WRF
OA-Overall acceptability, NS-Non significant, *-Significant

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(7.76), taste (7.88) and overall acceptability (7.92). However, the overall acceptability of sponge cake revealed that control was best when compared to all (8.30) followed by 10 percent incorporation *i.e.*, (T_1) (8.2) and 20 per cent incorporation *i.e.,* (T_2) (8.11). A statistical decrease in scores was observed when compared to control.

The results obtained from the present study were similar to that recorded by Hoque *et al.* (2015) about the incorporation of watermelon rind flour with refined wheat flour to develop cakes and the results revealed that overall acceptability of the cake sample incorporating 10 per cent watermelon rinds flour *i.e.,* (T_1) was more accepted than 20 per cent (T_2) and 30 per cent (T_3). As the substitutional level of rind flour increased the acceptability level decreased however, T_1 was accepted among all variations.

Sensory Evaluation of the Fruit Cake

The mean sensory scores of fruit cake prepared with different levels of incorporation of watermelon rind flour are indicated in Table 1. It revealed that flavour and taste differed significantly whereas appearance, texture, colour and overall acceptability were non-significant. The results from Table 1 showed that in the sensory evaluation, there was a decrease in the appearance, texture, colour, flavour and overall acceptability of the fruit cake with the gradual increase in the watermelon rind flour. The fruit cake incorporated with 10 per cent supplementation of watermelon rind flour is the most acceptable among experimental variations when compared with the control. It could be concluded that WF can be supplemented (up to 10 %) during the preparation of cakes.

Nutrient Composition of Best Accepted Watermelon Rind Flour-Based Baked Products (per 100g)

The nutrient composition for the best-accepted products was computed by using the Indian food composition table [Longvah *et al*. (2017)]. The nutrient composition of best-accepted WRF cookies, sponge cake, and fruit cake are represented in Table 2.

Moisture, protein, fat, crude fibre, total ash, carbohydrates, ascorbic acid, and mineral composition of control and 10 per cent WRF incorporated sponge cake was analyzed and results revealed that, except protein (5.61g) and carbohydrate (42.20 g), 10 per cent WRF incorporated sponge cake had a higher amount of moisture (26.20 %), fat (3.73 g), ash (1.42 g), crude fibre (2.70 g), calcium (47.68 mg), iron (1.98 mg) and phosphorous (87.07 mg) per 100g. While control sponge cake had moisture (26.11 %), protein (5.63 g), fat (3.57 g), ash (0.28 g), crude fibre (2.70 g), carbohydrate (45.03 g), calcium (24.29 mg), iron (0.88 mg) and phosphorous (71.25 mg) per 100g.

Also, similar results were detected by Al-Sayed and Ahmed (2013) where they noticed that proximate analysis of cake containing substituted flour with different levels of watermelon rind powder and results revealed that 27.04 per cent, 13.40 g, 1.48 g, 9.49 g, and 48.58 g (control) and 25.24 per cent, 13.49 g, 2.11

TABLE 2

Nutrient composition of best-accepted watermelon rind flour-based baked products (per 100g)

Products	Moisture (%)	Protein (g)	Fat (g)	Ash (g)	Crude fibre (g)	CHO (g)	Ca (mg)	Fe (mg)	P (mg)
Control	26.11	5.63	3.57	0.28	1.23	45.03	24.29	0.88	71.25
Experimental (10% WRF)	26.20	5.61	3.73	1.42	2.70	42.20	47.68	1.98	87.07
Control	20.59	7.82	11.45	0.66	2.39	42.04	40.51	1.62	145.95
Experimental (10% WRF)	20.66	7.81	11.49	0.94	2.76	41.33	46.36	1.90	149.90

g, 7.50 g and 51.64 g (7.5 % WRP) of moisture, fat, ash, protein and total carbohydrates, respectively which was higher than the control. Similarly, the moisture, fat, ash, crude fibre, and minerals were increased in the present study whereas, carbohydrates and proteins were decreased.

Ten per cent WRF fruit cake had higher amount of moisture (20.66 %), protein (7.81g), fat (11.49g), total ash (0.94g), crude fibre (2.76g), carbohydrate (41.33g), calcium (46.36mg), iron (1.90mg) and phosphorous (149.90mg) compared to control fruit cake *i.e.,* it had moisture (20.59 %), protein (7.82g), fat (11.45g), total ash (0.66), crude fibre (2.39g), carbohydrate (42.04g), calcium (40.51mg),iron (1.62mg) and phosphorous (145.95mg). As watermelon rind flour was added to the product the nutrient composition was increased because the rind flour contained more amount of minerals and other macronutrients like fibre.

Watermelon rind which is usually a waste after the consumption of the pulp has good functional and nutritional properties and thus the dehydrated watermelon rind flour can be used for food formulations. The cakes enriched with the watermelon rind flour indicated adequate increase in protein, fibre and minerals like calcium, iron and phosphorous with also a slight increase in fat. Hence it can be a good option for incorporating WRF in bakery products like cakes that are very popular snack item so as to enhance the nutritional composition.

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An Opinion Study about Online Learning Method Conducted during COVID-19 Pandemic among Agricultural Students

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Abstract

Online learning is an educational process which takes place over the internet as a form of distance education where the learners and the instructors are not in the same place. Due to COVID-19 pandemic circumstances, online learning played an indispensable role in education programs, where most of the educational institute shifted towards online learning platform to up keep the academic activities. For a developing country like India, the use of ICT in education process still poses many challenges and it is not clear about its effectiveness. The research study focuses on agricultural students' opinion about online learning method which was conducted using social distancing during COVID-19 pandemic situation. For the purpose, an online survey was conducted among 60 randomly selected undergraduate students who had attended the online classes. The results indicated that majority of the students (91.70 %) preferred to use smart phone for online learning. Most of them viewed that live classes with quiz at the end of each class helps in effective learning. Majority of the students opined that more interaction during online classes makes it interesting, whereas network connectivity related issues in rural areas makes it a challenge for students to make use of online learning initiatives. However, in agricultural education system, many courses are practical oriented, conducting practical classes in online mode may not be possible. Hence, there is a need to device a hybrid mode of learning. The results of the study can be helpful in making online learning more effective.

Keywords: Online education, Opinion study, COVID-19 pandemic, Preferences

Online learning is an educational process which takes place over the Internet as a form of distance education where the learners and the instructors are not in the same place. In the wake of COVID-19 pandemic, the Government of India imposed a nation-wide lockdown on 25th March 2020 to control the spread of the disease and lockdown continued for months. Lockdown and staying home strategies have been put in place as the needed action to flatten the curve and control the transmission of the disease (Sintema, 2020). Most of the educational institutes made transition from classroom education to digital online education through the use of online educational platforms like Google Classroom, Microsoft Teams, Zoom, Cisco WebEx, Google Meet, Skype etc. An unexpected shift from face-to-face classroom learning to online created some difficulties among students and teachers. With the increase in use of online modalities during COVID-19, it is necessary to assess their effectiveness with regards to teaching and learning from various stakeholders (Schwartz *et al.,* 2020). Assessing student readiness for online learning is an issue facing many education and training providers as more learning opportunities are made available online in varying formats (Smith, 2005).

Communication in e-learning is considered to be an important concept and divided into three categories *viz.,* learner–instructor, learner–learner, and learner–content interactions (Moore, 1989). Satisfaction and retention in e-learning can be accomplished with the coordination of online resources, activities and communication tools in online courses. Inadequate interaction in e-learning leads to ineffective learning, and this may lead to lack of retentions and dropouts of online learners (Anderson, 2003). The Ministry of Human Resources Development and its associated institutions have also promoted digital education with

equity and developed online resources during the COVID-19 pandemic situation (Anonymous, 2020). In this backdrop, a study was conducted to identify the opinion about online learning method conducted during covid-19 pandemic among agricultural students with the following specific objectives:

1. To identify the preferences of students for the online classes
2. To analyze the perception of students towards online learning
3. To find out the factors influencing success and failure of online classes and
4. To know the benefits and problems faced by the students in online learning

Material and Methods

Ex-post facto research design was used in this study by considering the objective and type of information needed. Agricultural graduates were chosen as the respondents for this study. Agriculture is the most diverse subject that includes subjects ranging from life sciences to social sciences where students work from lab to land. The participants were 60 randomly selected undergraduate students from second year, third year and final year since they had attended the online classes. About 20 students from each year was selected randomly. Among them, 34 were boys and 26 were girls. The data were collected through online survey by using a well–structured interview schedule. Pre-testing was done with ten students who had attended the online classes and their feedback was considered for designing the final questionnaire. The link for Google form was sent to the students through WhatsApp and e-mail. Data were collected on demographic features, followed by learners' preferences, perception, factors influencing online learning, benefits and constraints. The analysis was carried out by applying statistical tools such as frequency, percentage analysis, cumulative frequency and garret ranking technique.

Results and Discussion

Demographic Details of Respondents

The data regarding the demographic variables (gender and native place) of the respondents are presented in Table 1.

Table 1

Demographic details of respondents

(n = 60)

Characteristic	Category	Respondents	
		Frequency	Per cent
Gender	Female	34	56.70
Male		26	43.30
Native place	Rural	23	38.30
Semi-urban		15	25.00
Urban		22	36.70

From Table 1, it is evident that more than half of the respondents were female students (56.70 %) and the remaining respondents were male students (43.30 %). A larger number of the respondents were from rural area (38.30 %) whereas other major group of the respondents belonging to urban area (36.70 %) and only one-fourth of the respondents were from semi urban area (25.00 %). Similar findings were reported by Muthuprasad *et al.* (2021)

Basic Information Regarding Online Classes

The basic information regarding online classes of the respondents are presented in Table 2.

From Table 2, it is apparent that majority of the respondents (61.67 %) attend online classes and 38.33 per cent did not attend online classes prior to the online learning followed during COVID-19 pandemic. Whereas most of them (95.00 %) suggested the education institute to provide assignments and reading materials as well as to concise the curriculum (75.00 %) to cope up with the situation. The reasons behind the responses may be the impotence to focus on curriculum due to the pandemic fear or technological constraints faced during online learning. The constraints faced by the students are analyzed in later part.

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TABLE 2

Demographic details of respondents

(n = 60)

Characteristic	Category	Respondents	
		Frequency	Per cent
Earlier experience with online course	Yes	37	61.67
	No	23	38.33
Education institute have to provided assignments and reading materials during COVID-19 situation	Yes	57	95.00
	No	3	5.00
Education institute have to concise the curriculum	Yes	45	75.00
	No	15	25.00

Technical Modalities for Online Learning of The Respondents

The information related to the technical modalities for online learning of the respondents are presented in Table 3.

It could be inferred from the results depicted in Table 3 that majority of the respondents used WhatsApp (85.00 %) and email (80.00 %) as best way for communi-cating class updates, while most of the respondents used Smartphones (91.70 %) followed by laptop (65.00 %) which was felt compatible for attending online classes. A vast majority of the respondents preferred power point presentations (95.00 %) , more than half of the respondents (51.70 %) preferred oral presentation of the content and only a few respondents (10.00 %) preferred whiteboard mode of teaching for online classes. Majority of the respondents used mobile data pack (90.00 %) as source of internet, while the remaining (10.00 %) used Wi-Fi connection. A larger proportion of the respondents preferred live classes (80.00 %) as it gives synchronised learning experience, whereas nearly half of the respondents (45.00 %) preferred sending of reading materials, 28.30 per cent preferred live classes which can be recorded because it gives flexibility in learning, and only a few respondents (8.30 %) preferred pre-recorded video classes as the format of online class. As for the nature of course material preferred for reading, majority of them (73.30 %) preferred sending reading materials supplemented with video content for quick understanding, 21.70 per cent preferred reading material alone and only a few respondents (5.00 %) preferred video content alone as course material for their online classes.

TABLE 3

Technical necessity for online learning of the respondents

(n = 60)

Characteristic	Category	Respondents	
		Frequency	Per cent
Way of communication used for communicating class updates	Posting in university websites	2	3.30
	Text messages	9	15.00
	E-mail	48	80.00
	WhatsApp	51	85.00
	Others	7	11.70
Device used for online classes	Laptop	39	65.00
	Desktop	2	3.30
	Smartphone	55	91.70
	Tablet	2	3.30
Mode of teaching preferred for online classes	Power point	57	95.00
	Whiteboard	10	6.70
	Oral presentation	31	51.70
Source of internet used	Mobile data pack	54	90.00
	Wi-Fi	6	10.00
Preferred format of online class	Live class	48	80.00
	Live classes that can be recorded	17	28.30
	Pre recorded video class	5	8.30
	Sending reading materials	27	45.00
Nature of course material preferred for reading	Reading material	13	21.70
	Video content	3	5.00
	Both	44	73.30

* Multiple responses were obtained

Repetition and Length of Online Classes for Online Learning

The data related to the repetition and length of online classes for online learning preferred by the respondents are presented in Table 4.

TABLE 4
Recurrence and span of online classes for online learning

(n = 60)

Characteristic	Category	Respondents	
		Frequency	Per cent
Anticipated frequency of classes conducted by the course teacher	According to the time table	37	61.70
	Daily	4	6.70
	Alternate days	15	25.00
	Weekly twice	4	6.70
Duration like to spend in a day for an online class (per class)	30 minutes	11	18.34
	1 hour to 45 minutes	47	78.33
	> 1 hour	2	3.33
Duration of break preferred between two online classes	< 10 minutes	3	5.00
	10 minutes	3	5.00
	15 minutes	31	51.70
	> 15 minutes	23	38.30
Total duration like to spend in a day for online classes	< 2 hours	10	16.70
	2 to 4 hours	34	56.70
	4 to 6 hours	16	26.70

* Multiple responses were obtained

The results in Table 4 revealed that more than half of the respondents (61.70 %) expected the course teachers to conduct the classes according to the timetable whereas one-fourth (25.00 %) of the respondents expected on alternate days, 6.70 per cent each expected daily classes as well as weekly two classes by the course teacher. Regarding the preferable duration for an online class, 18.34 per cenr preferred 30 minutes, 78.30 per cent preferred one hour to 45 minutes and only 3.30 per cent preferred more than an hour. The respondents needed a break for 15 minutes between two online classes (51.70 %) while 38.30 per cent needed more than 15 minutes, 5.00 per cent each needed less than 10 minutes and 10 minutes as break and would like to spend 2 to 4 hours a day for online classes (56.70 %) to enhance the productivity of learning.

Addressing Queries and Assessment for Online Class

Table 5 presents the data on the information regarding addressing queries, plans and models for assessment of online learning as preferred by the respondents.

TABLE 5
Addressing queries, plan and models for assessment of online learning

(n = 60)

Characteristic	Category	Respondents	
		Frequency	Per cent
Ways liked to use for explaining questions	Email	27	45.00
	Live chat	41	68.30
	Platform for queries	19	31.70
	Tele communication	11	18.30
	Others	1	1.70
Anticipated time preferred for explaining the questions by the instructors	Within few hours	10	16.70
	Within a day	20	33.33
	Within next class	20	33.33
	Within 2-3 days	5	8.30
	Within a week	5	8.30
Preference to attend quiz at the end of each class	Yes	56	93.30
	No	4	6.70
Preference to have assignments at the end of each class	Yes	42	70.00
	No	18	30.00
Deadline for presenting the assignments	1 day	2	3.30
	2 - 3 days	8	13.30
	1 week	36	60.00
	Prior to next class	14	23.30
Preference to attend online exams	Yes	54	90.00
	No	6	10.00
Preference in the nature of online assignment	Objective	30	50.00
	Subjective	2	3.40
	Both	28	46.70

* Multiple responses

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Majority of the respondents (68.30 %) preferred live chat for addressing their queries spontaneously, whereas one-third of the respondents (33.33 % each) wishes their queries much be cleared within a day and by next class for better understanding of the classes. Majority of the respondents liked to have quiz (93.30 %) and assignments (70.00 %) at the end of each class for enhancing their learning experience with a week (60.00 %) as deadline for presenting the assignments which they felt as adequate time to complete. As high as 90.00 per cent of the respondents liked to have online examination, whereas the nature of the online assessment was preferred by half of the respondents was objective type (50.00 %) which can be attended even through mobile phones. Less than half of the respondents preferred both objective and subjective type online assessment (46.70 %) whereas less number of respondents preferred subjective type of online assessments (3.40 %) as it requires more time.

Perception of Students Towards Online Learning

Table 6 presents the information with respect to the students perception towards online learning.

The results in Table 6 reveals that more than half of the respondents (56.66 %) agreed that online courses are moderately structured in comparison with face-to-face courses, 52.50 per cent accepted that online classes are moderately effective in comprehending the course material and 43.84 per cent opined that the online environment makes communication moderately easier. Whereas, 40.83 per cent opined that it is less effective. In case of responding to questions comfortably, 35.83 per cent of the respondents perceived that online classes are moderately effective, whereas 35.00 per cent of the respondents perceived online classes are less effective. Regarding technical skills, 47.50 per cent agreed that online classes are much more effective in improving their technical abilities. Online classes are opined as moderately effective for spending time on home work by 56.66 per cent of the respondents in comparison with classroom learning. In case of the instructors' ability to comprehend the virtual climate and make the platform simpler to learn 52.00 per cent agreed online classes are moderately effective in contrast with face-face classes.

TABLE 6

Students perception towards online learning

(n = 60)

Statements	Less effective (%)	Moderately effective (%)	Much more effective (%)
Online courses are well structured with set due dates similar to face-to-face courses	36.67	56.66	6.67
Online classes help me comprehend the course materials compared to classroom learning	37.50	52.50	10.00
Online environment makes it easier for me to communicate with my instructor than classroom environment	40.83	43.84	15.32
I am more comfortable responding to questions by email than orally	35.00	35.83	29.17
My technical skills (email/internet apps) has increased after attending online classes	14.17	38.33	47.50
I spend more time on my homework / assignment in comparison with regular classroom learning	26.67	56.66	16.67
Instructor comprehend the online climate and makes it simple to learn through continuums	24.70	52.00	23.30

Friedman Rank Test Analysis

In order to check the presence of pattern in data, Friedman test was applied. The positioning given by the respondents can be random without any pattern and just contrasting them dependent on mean position can be erroneous. In this way, mean positions can measure up solely after ensuring that there is a pattern in the evaluations given by the respondents. The analysis uncovered that there is a pattern in the data as the friedman test statistics turned out to be significant. Mean value for every statement was

utilized to rank the statements related to the perceived effectiveness of online classes in examination with classroom teaching. The results of the friedman analysis was presented in the Table 7.

Friedman rank test mean rank results mentioned in the Table 7, shows that improvement in technical skills; instructors ability to comprehend the virtual climate and making the platform simpler to learn and spending more time on assignments in comparison to classroom environment were ranked first, second and third, respectively whereas, fourth rank was given for comfortable responding to questions through email than orally, fifth rank for comprehending the course material, sixth rank for making the environment easier to communicate with instructors and last rank was given in case of online courses structured with set due dates similar to face-to-face courses. Friedman rank test analysis reveals that the differences were highly significant with the chi-square value 41.67 at 6 degrees of freedom.

TABLE 7

Friedman rank test

Statements	Mean Rank	Rank given
Technical skills (usage of email/internet apps) has increased after attending online classes	5.33	1
Instructors' ability to comprehend the virtual climate and make the platform simpler to learn	4.23	2
Spending more time on assignments in comparison with regular classroom learning	4.06	3
More comfortable responding to questions by email than orally.	4.02	4
Online classes help me comprehend the course materials compared to classroom learning	3.52	5
Online environment makes it easier for me to communicate with my instructor than classroom environment	3.48	6
Online courses are well structured with set due dates similar to face-to-face courses	3.35	7

Factors Influencing Online Learning

Factors influencing the success and failure of online learning are presented in the Table 8 and 9.

From Table 8, it could be inferred that flexibility of online learning that is learning can takes place from anywhere and at anytime was the majorly (95.00 %) agreed statement followed by which basic knowledge of computer and internet (90.00 %), accessible and understandable content (83.33 %), relevancy of content (80.00 %); three-fourth of the respondents (75.00 %) agreed with the statements interactive content as well as user friendly software/hardware as factor for success of online class. 71.67 per cent of the respondents agreed that motivation which is self-learning interest; 61.67 per cent of the respondents agreed that communication skills as factor for success. It is also evident that there is a partial agreement with the statements that clarity in audio/video which is used for online learning (53.33 %) and ability to avoid distractions (50.00 %) also opinioned as the factors which influence the success of online classes.

TABLE 8

Factors influencing the success of online classes

(n = 60)

Factors	Respondents	
	Yes (%)	No (%)
Accessible and understandable content	83.33	16.67
Interactive content	75.00	25.00
Flexibility (Study anywhere at any time)	95.00	5.00
Relevancy of content	80.00	20.00
Basic knowledge of computer & internet	90.00	10.00
User friendly Software / Hardware	75.00	25.00
Communication skills	61.67	38.33
Motivation (Self-learning interest)	71.67	28.33
Focus (Ability to avoid distractions)	50.00	50.00
Clarity in audio/video	53.33	46.67

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TABLE 9

Factors influencing the failure of online classes

(n = 60)

Factors	Respondents	
	Yes (%)	No (%)
Interactive content	75.00	25.00
Digital divide	95.00	5.00
Non- recordable videos	73.33	26.67
Technical issues	95.00	5.00
Virtual presence only	76.67	23.33
Noise	81.67	18.33
Poor learning skills	80.00	20.00
No follow-up	76.67	23.33
Feedback/queries unanswered	60.00	40.00
Unmotivated	78.33	21.67
Strain due to harmful radiations	88.33	11.67

From Table 9, it is evident that digital divide the gap between those who can access and those who cannot access the digital e-resource as well as technical issues faced while attending the online classes (95.00 %) are the major constrains which inherent factors that influence failure of online classes followed by which strains due to harmful radiations by using gadgets for online classes (88.33 %), noise the unwanted disturbances / information's which is transferred along with the communicated message from the instructors (81.67 %), poor learning skills (80.00 %), unmotivated nature of learners towards online classes (78.33 %), no regular follow-up by students and instructors as well as no face to face interaction between learners and instructors (76.67 %), online classes that cannot be recorded or downloaded (73.33 %) and feedback/ queries which is felt unanswered for a period of time being are opinioned as the factors which influence the failure of online classes.

Benefits of Online Learning

The data regarding the benefits of online learning were analyzed using Garret ranking technique and the results are presented in Table 10.

From Table 10, the study results shows that the statement adaptability and comfort to use was positioned as the significant advantages of the online learning. Henceforth, adaptability and comfort are significant drivers behind the interest for online training. Effective way for delivering lessons, self- discipline and responsibility, affordability, more interaction and greater ability to concentrate and suits a variety of learning styles were positioned two, three, four, five and six, respectively.

TABLE 10

Benefits of online learning

(n = 60)

Benefits	Total Score	No. of respondents	Average score	Rank
Adaptability and comfort to use	3914	60	65.23	1
Efficient way for delivering lessons	3732	60	62.20	2
Self-discipline and responsibility	3711	60	61.85	3
Affordability	3702	60	61.70	4
More interaction and greater ability to concentrate	3606	60	60.10	5
Suits a variety of learning styles	3460	60	57.67	6

Problems in Online Learning

The data regarding the problems in online learning were analyzed using Garret ranking technique and the results are presented in Table 11.

From Table 11, the study results shows that lack of connectivity such as network problem, data speed etc. was the major hindrance in online learning. The results shows that digital divide and lack of equity in access to the internet being a major issue to large number of students particularly for the students from remote areas the situation was even worse. Followed by which lack of devices, poor learning environment, inability to focus on screens, little/ no face to face interaction and fear of using new technologies were positioned two, three, four, five and six respectively.

With endeavours to prevent the spread of corona virus, education system are changing from face-to-face to

TABLE 11

Problems in online learning

(n = 60)

Problems	Total score	No. of respondents	Average score	Rank
Lack of connectivity (Network, data speed etc)	4082	60	68.03	1
Lack of device	3635	60	60.58	2
Poor learning environment	3586	60	59.77	3
Inability to focus on screens	3450	60	57.50	4
Little / no face to face interaction	3444	60	57.40	5
Technophobia (Fear of new technology)	3316	60	55.27	6

online which was becoming the primary framework of instruction as it is essential to follow isolation and social distancing. Many educational institutes and universities are shifting towards online platform to follow up with the designed curriculum. The results of the study indicates that majority of the students showed a positive opinion towards online classes in the wake of corona. The online learning was discovered to be worthwhile as it gave adaptability further more comfort for the students. Students opinioned to send reading materials supplemented with video content as course material for their online classes and to concise the curriculum. They also indicated the requirement for interactive sessions with quizzes and assignments at the end of each class to upgrade the learning experience. However, most students also revealed that online classes could be more difficult than conventional classroom learning because of technological constrains, inability to handle Information and Communication Technologies effectively, improper follow-up and delayed feedback. The usage of online learning platforms like Google classroom, Microsoft teams etc is radically changing the way by which education has been traditionally delivered. It is conceivable that when the COVID-19 pandemic settles down, there is a continued increase in education systems using online platforms for study aids as it can be used in hybrid mode with regular classes. The findings of the study can be helpful in making online learning more effective by understanding the opinion of students.

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Swarna Sub-1 as a Suitable Climate Resilient Variety : A Boon for Increasing Paddy Productivity in Flood Prone Areas

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Abstract

Flash flood or submergence is a frequent incident in Paddy growing rainfed lowland areas in Barak Valley Zone of Assam, causing wide extends of damage to paddy crop growing during *kharif*. Therefore, Krishi Vigyan Kendra, Cachar has introduced submergence tolerant paddy variety Swarna sub-1 through frontline demonstration during *kharif* 2018 and 2019 at different locations in the district. The FLDs include scientific cultivation practices with line transplanting. The field was submerged after transplanting for a period of six days and four days during 2018 and 2019, respectively. The paddy productivity and economic returns under improved technologies were calculated and compared with the prevailing farmers' practice. The results revealed that swarna sub-1 variety under improved practices recorded higher yield of 17.67 and 21.05 per cent during 2018 and 2019 and the recommended practice gave higher net returns of Rs .27,400 and 30,625 per ha and B:C ratio of 1.58:1and 1.65:1, respectively as compared to farmer's practice.

Keywords: Flash floods, Barak valley zone, Submergence tolerant, Variety

Climatic vulnerability in North-East India has already been documented in terms of rainfall variability, including increased frequency of high intensity rains leading to flash flooding, a reduced number of rainy days and occurrence of mid season / terminal dry spells (Chauhan, 2011). The Barak basin receives average rainfall of 3204.6 mm with a standard deviation of 419.6 mm (Chauhan, 2011). Paddy crop holds the key for food security of Assam as well as the country. In Assam, presently the crop is grown on 2.43 million hectare areas with a production of 5.28 million tones (Deka *et al.,* 2013). Mostly the farmers of this region are going for cultivation of medium to long duration (140-160 days) Paddy varieties as rainfed crop. Among the various submergence tolerant Paddy varieties, *Swarna Sub-1* (Parent variety: Swarna*3/ IR 49830-7-1-2-2) has submergence tolerance up to two weeks. This variety is widely grown in flood prone ecologies of Odisha, West Bengal, Bihar, Assam and other eastern states of India (DE&S, 2018). Keeping this in view, Krishi Vigyan Kendra, Cachar has taken up frontline demonstrations to introduce and popularize Swarna sub-1 variety of paddy in the prevailing low-lying rainfed Paddy growing areas of the district.

Material and Methods

Frontline demonstrations (FLDs) in submergence tolerant paddy variety *Swarna Sub-1* were conducted during *kharif* 2018 and 2019 by Krishi Vigyan Kendra, Cachar at the farmers' fields in different locations. Total 33 frontline demonstrations were conducted in the selected villages by covering 12 ha of area. The seed was procured from Regional Agricultural Research Station, Titabar, Assam Agricultural University and National Seed Corporation, Guwahati for demonstration purpose. The whole package approach demonstrated to farmers through FLDs included components such as improved variety, line transplanting, recommended seed rate, seed treatment, weed and water management, fertilizers and plant protection measures (Table 1). In the demonstration plots, critical inputs in the form of certified seed of *Swarna Sub-1*, chemical fertilizers and plant protection chemicals were provided to the farmers. In the case of local check plots, farmers have adopted their traditional practices. The Subject Matter Specialists from KVK facilitated the participating farmers in performing proper field operations like timely sowing at nursery bed and transplanting in the

TABLE 1

Improved practices and farmers practices of paddy under FLD

Technology	Improved practice	Farmer's practice	GAP (%)
Variety	*Swarna Sub -1* (HYV)	*Balam* (Traditional)	100
Land preparation	Ploughing, Harrowing and puddling	Ploughing, Harrowing and puddling	50
Seed rate	40 Kg/ha	60 Kg/ha	50
Seed treatment	Carbendazim @ 2.5 g/kg of seed	No Application	100
Transplanting method	Line transplanting	Random transplanting	100
Herbicide application	Pretilachlor @ 0.75 kg/ha	No Application	100
Fertilizer dose	60-20-40 (N-P_2O_5-K_2O)	Indiscriminate application	50
Plant protection	IPM	Indiscriminate application	50

main field, application of balanced fertilizers, spraying of herbicides/plant protection chemicals and harvesting. Various extension activities like farmers' trainings, diagnostic visits, field days, etc. were carried out during the crop-growing period for the benefits of the farmers. Crop yield data were recorded by twenty-five-meter square observation method randomly from three to four places from an FLD plot. The yield data was collected from both the demonstrations and farmers' fields and analyzed using simple statistical tools. The technology gap, extension gap and technology indexes (PoP, 2019) were calculated using the following equation:

Technological Gap: Potential yield – demonstration yield

Extension Gap: Demonstration yield – yield under farmer practice

Technology index (%): (Potential yield - demonstration yield / potential yield) x 100

TABLE 2

Grain yield performances of FLDs and farmers practice

Year	No. of Demons-trations	Area (ha)	Demo yield (q/ha)	Farmers' practice (q/ha)	Yield increase (%)
2018	6	2.00	49.60	42.15	17.67
2019	27	10.00	51.75	42.75	21.05
Mean	16.5	6.00	50.68	42.45	19.36

RESULTS AND DISCUSSION

The selection of suitable crop varieties also comes under good agronomic practices, which can eliminate chances of biotic and abiotic stress (Samui *et al.,* 2000). Paddy yield recorded under demonstration was 49.60 and 51.75 q/ha during *kharif* 2018 and 2019, respectively (Table 2). Even though, after transplanting the crop was submerged in the early stage for a period of six days andfour days during 2018 and 2019, respectively, the yield enhancement due to the improved practices was to the height of 17.67 and 21.05 per cent over farmers' practice.

Extension gap of 7.45 q/ha and 9.00 q/ha was observed during *kharif* 2018 and 2019, respectively. It implies the need to bringing consciousness among the farmers for adoption of submergence tolerant varieties along

TABLE 3

Yield attributes of paddy under FLD and farmers' practice

Yield attributes	Demons-tration	Farmers' practice
Avg. plant Height	113 cm	122 cm
Avg. no. of effective tillers/ hill	18	15
Avg. length of panicle	24 cm	20.5 cm
Avg. no. of total grains/panicle	209	188
Avg. no. of filled grain/panicle	191	162
Avg. days to 50% flowering	128 days	122 days

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TABLE 4

Economical comparison of paddy cultivation between FLD and farmers' practice

Year	Demonstration				Farmers' practice				% increase in Net return
	Gross cost (Rs/ha)	Gross return (Rs/ha)	Net return (Rs/ha)	B:C ratio	Gross cost (Rs/ha)	Gross return (Rs/ha)	Net return (Rs/ha)	B:C ratio	
2018	47000	74400	27400	1.58	44500	63225	18725	1.42	46.33
2019	47000	77625	30625	1.65	44500	64125	19625	1.44	56.05

with improved production technologies and to revert the inclination of wide extension gap.

A technological gap between the improved technology and farmers' practice of 10.40 and 8.25 q/ha during *kharif* 2018 and 2019, respectively has been observed. Difference in soil fertility status and agricultural practices can be the major factors for such a deviation and may be rectified by following better management practices.

The technology index indicates the feasibility of the evolved technology at the farmers' fields. Lower the values of technology index more is the feasibility of the technology demonstrated (Singh *et al.,* 2012). The technology index in this study was 17.33 and 13.75 per cent showing the effectiveness of the technical interventions. The feasibility of the technology demonstrated has been well indicated by reduction in the technology index from 17.33 per cent in the first year to 13.75 per cent in the second year (Table 5).

The economical aspect of the improved technology indicates that the cost of production in FLD was higher than that of the local practice (Table 4). A net return of Rs.18,725 and Rs.19,625 was achieved in the farmers' practice, while improved technology fetched a higher net return of Rs.27,400 and Rs.30,625 per ha, which is 46.33 and 56.05 per cent higher than the existing farmers' practice. A similar pattern has been observed in B:C ratio which is 1.58 and 1.65 during both the years in improved technology as compared to 1.42 and 1.44 under farmers' practice. A higher net return of Rs.27,400 and Rs.30,625 per ha was recorded during both the years as compared to Rs.18,725 and Rs.19,625 achieved as net returns in the farmers' practice. The benefit-cost ratio of paddy cultivation under improved cultivation practices was 1.58 and 1.65 during both the years as compared to 1.42 and 1.44 under farmers' practice. This may be due to higher yield obtained under improved technologies as compared to farmer's practice.

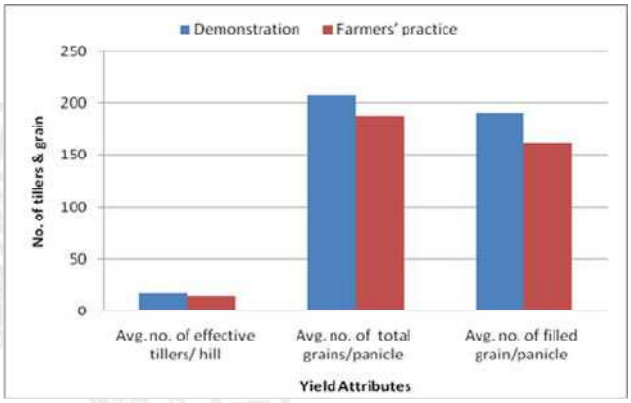

Fig. 1 : Comparison of yield attributes of *Swarna Sub-1*

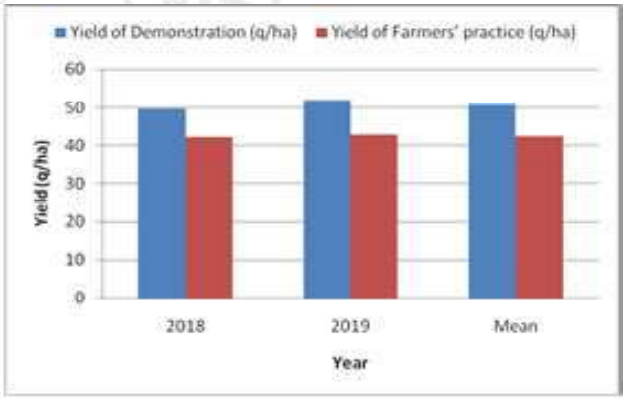

Fig. 2 : Yield performance of demonstration and farmers' practice of 2018 & 2019

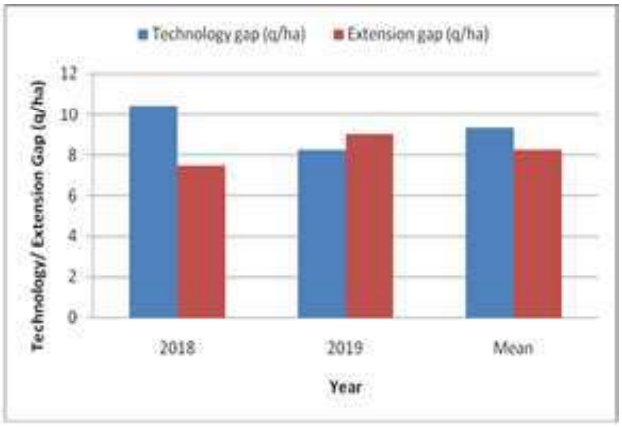

Fig. 3 : Technology gap and extension gap of 2018 & 2019

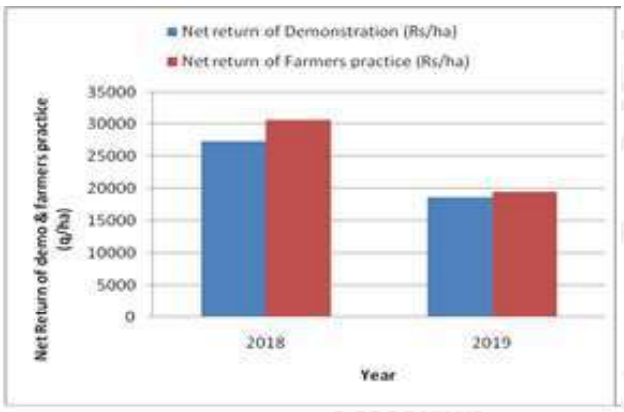

Fig. 4 : Comparative net return of demo and farmers' practice during 2018 & 2019

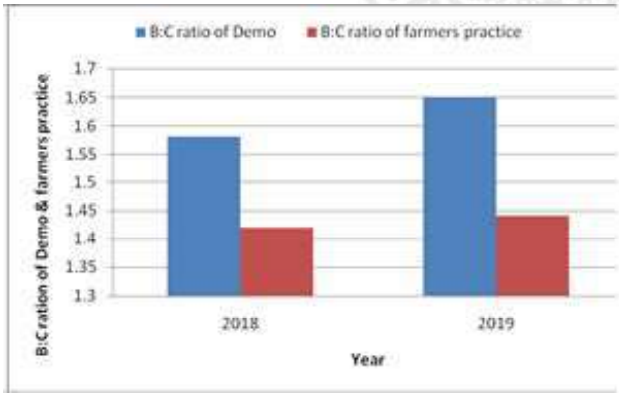

Fig. 5 : Comparative B:C ratio of demo and farmers' practice during 2018 & 2019

The yield attributes of improved technology indicates that the average plant height and average length of panicle were 113 cm and 24 cm against 122 cm and 20.5 cm in farmers' practice. It revealed that plant height is more in case of farmers practice as compared to demonstration. Further, average number of effective tillers/ hills, average number of total grains/panicle and average number of filled grain/panicle were 18, 209 and 191 in improved technology and 15, 188 and 162 in farmers' practice, respectively. It revealed that average no. of effective tillers / hill, average no. of total grains / panicle and average no. of filled grain / panicle were more than that of farmer's practice. On further observation it was found that *Swarna sub-1* required 128 days to attain the stage of 50 per cent flowering while the farmer's variety *Balam* required 122 days.

Table 5

Impact of paddy var. Swarna sub-1 on technology gap, extension gap and technological index under FLDs

Year	Technology gap (q/ha)	Extension gap (q/ha)	Technology index (%)
2018	10.4	7.45	17.33
2019	8.25	9.00	13.75
Mean	9.33	8.23	15.54

The productivity gain under frontline demonstration over existing practices of paddy cultivation created greater awareness and motivated the other farmers to adopt suitable production technology of submergence tolerant paddy in the district. This variety of paddy (*Swarna sub-1*) gained a momentum in upscaling the paddy productivity, which created a positive impact on farming community.

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Evaluation of Various Agricultural Biomass for Cellulase Production by *Trichoderma* spp. under Solid State Fermentation (SSF)

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ABSTRACT

The proximate and compositional analysis of fifteen agricultural biomass was done to evaluate their biotechnological potential. The analysis of ash, moisture, carbohydrate, crude protein and crude fibre along with cellulose, hemicellulose, and lignin content of selected local agro-lignocellulosic wastes was performed by using standard procedures. The ash content was found to be highest in rice husk (20.2 ± 0.02 %) and lowest in corn cob (2.52 ± 0.04 %). Moisture content was maximum in pea pod waste (8.67 ± 0.05 %) and minimum in groundnut shell (1.67 ± 0.05 %). The carbohydrate content was found maximum in the cotton stalk (58.12 ± 0.06 %) and minimum in soybean husk (1.12 ± 0.02 %). The maximum crude protein content was found in the green gram shell (12.64 ± 0.06 %) and the minimum in coconut coir (0.98 ± 0.02 %). Sugarcane bagasse (57.5 ± 0.80 %) showed the highest crude fibre whereas the lowest was reported in soybean stalk (7 ± 0.23 %). All the agro-residues showed a good amount of cellulose, hemicellulose and lignin. The highest cellulose and hemicellulose were seen in sugarcane bagasse (57.28 ± 1.2 %) and wheat straw (24.8 ± 0.01 %), respectively while both are reported as lowest in rice husk. The maximum lignin content was noted in rice husk (41.0 ± 0.09 %) and minimum in soybean husk (2.8 ± 0.08 %). Further, five agro-residues (banana peel, corn cob, groundnut shell, sugarcane bagasse and pigeon pea stalk) were used as substrates to produce cellulase by *Trichoderma harzianum* and *T. viride* under SSF. The results demonstrated that the assessed agro-residues can serve as an inexpensive feedstock for cellulase production.

Keywords: Lignocellulosic biomass, Solid state fermentation, Fungal cellulase, FPase, CMCase

In the twenty-first century, fossil fuel-based energy is non-feasible due to its cost, limited availability, and negative impact on the environment, which led to the exploration of economical and renewable energy sources (Caraschi *et al*., 2019). Amongst the several renewable choices, lignocellulosic biomass-derived biofuel has come up as the best substitute to fossil fuel since, these are cost-effective, abundantly available, and environmentally friendly (Yahya *et al*., 2015). However, the cost of cellulase enzyme needed for the biological transformation of these substrates into bioethanol which is one of the major impediments in the commercialization of bioethanol production from lignocellulosic biomass (Chovau *et al.,* 2013). In this context, utilizing lignocellulosic substrates for the production of cellulase enzyme can considerably lower the overall process cost. Several microorganisms are capable of producing the cellulases that can break the most abundant lignocellulosic compound, cellulose (Pachauri, *et al*., 2017).

Lignocellulosic biomass encompasses all vegetation including agricultural wastes, municipal residues, wood residues, and other residue materials (Ayeni *et al*., 2013). Cellulose, hemicellulose, and lignin cover the major chunk of lignocellulosic biomass. They are held together by various bonds and forces establishing a complex structure that contributes to the recalcitrance of the lignocellulosic biomass to enzymatic hydrolysis and insolubility in water (Menon and Rao, 2012). Apart from these major components, lignocellulosic biomass also contains other compounds such as water (moisture), a small amount of proteins, ash, organic acids, and minerals. High variability and uncertainty among lignocellulosic materials exist as their compositional characteristics vary (Kang and Tan, 2016).

The proximate analysis methods are used to determine the moisture content, total solids, volatile matter, ash, and the fixed carbon content of the substrate (Garcia *et al*., 2013). The compositional analysis of the lignocellulosic quantifies the structural components such as cellulose, hemicellulose, and lignin. Typically, the lignocellulosic biomass is made up of cellulose (40-50 %), hemicellulose (23-32 %), and lignin (15-25 %) (Sun *et al*., 2016). However, this composition of the lignocellulosic residues varies with the type and location of biomass, climate, and the nature of soil where they propagate (Yengkhom *et al*., 2017). Since the comprehensive and correct characterization of lignocellulosic biomass is a fundamental requirement for any process, it is necessary to characterize the selected local agricultural lignocellulosic biomass through the proximate and compositional analysis for assessing the potential of agro-residues as substrates for the production of cellulases employing Solid State Fermentation (SSF). After proximate and compositional analysis of fifteen agricultural residues, five of them with maximum cellulose content and low lignin content are assessed for their ability to produce cellulase using *Trichoderma harzianum* and *T. viride* employing SSF.

Material and Methods

Biomass Sampling and Preparation of Substrates

The collection of agro-residues was done randomly by taking their availability to the locality into consideration. For the present study, the selected agricultural biomasses are collected from the farms nearby the Parbhani district of the Marathwada region (Maharashtra, India). These agricultural substrates were banana peel, corn cob (maize cob), coconut coir, cotton stalk, cotton boll shell, soybean stalk, green gram shell (mung bean shell), rice husk, corn stalk (maize stalk), groundnut shell (groundnut husk), wheat straw, soybean husk, pea pod waste, sugarcane bagasse, and pigeon pea stalk (tur stalk).

The biomass residues were sun-dried under ambient conditions with utmost care that the samples were not over-exposed to sunlight. The sun-dried samples were powdered to a minimum particle size of 1 mm, sieved and stored in an air-tight container for further study.

Proximate analysis

The selected substrates were analyzed for ash, moisture, carbohydrate, crude protein, and crude fibre content.

Ash

Ash content of the biomass sample is the measure of the solid residue left after the substrate is burned. The oxide form of silica, iron, aluminum, calcium, sodium, potassium, magnesium, and titanium are the principal elements of ash (Vassilev *et al*., 2013). The ash content was determined by the method of Andrew and Agidi (2015) and the percentage of ash content was calculated as:

$$\text{Ash content (\%)} = \frac{W2}{W1} \times 100$$

Where, W_1 is the weight of the oven-dried sample and W_2 is the weight of the ash.

Moisture

Moisture content is the amount of water in biomass, which is expressed as a percentage of the material weight that affects all the processes associated with the substrate including the resultant products (Karunanithy *et al*., 2013). The moisture content (%) was determined by using the following equation (Andrew and Agidi, 2015).

$$\text{Moisture content (\%)} = \frac{(W1-W2)}{W1} \times 100$$

Where, W_1 is the weight of the sample and W_2 is the weight of the oven-dried sample.

Carbohydrate

The carbohydrate contents of samples were calculated by using the method of Hedge and Hofreiter (1962).

Crude protein

The protein content in the substrates was determined by AOAC (2004) method. The percentage of protein

content in the substrate was computed using protein factor 5.7 as follows:

$$\% \text{ Nitrogen} = \frac{(\text{TS-TB}) \times \text{Normality of acid} \times \text{meq. } N_2}{\text{weight of sample}} \times 100$$

Where, TS is the titre value of the sample (ml), TB is thetitre value of the blank (ml), and Meq.N_2 is 0.014

$$\% \text{ protein} = \% \text{ Nitrogen} \times 5.7$$

Crude fibre

The crude fibre determination was made employing the method of Maynard (1970), which was calculated by the following equation:

$$\text{Crude fibre (\%)} = \frac{\text{Loss in weight on ignition (W2-W1) - W3-W1)}}{\text{Sample weight}} \times 100$$

Where, W_1 is the weight of the sample dish, W_2 is the weight of the oven-dried sample, and W_3 is the weight of the ash.

Compositional Analysis

In compositional analysis, cellulose, hemicellulose, and lignin content of the substrates were estimated.

Cellulose

The cellulose content in the sample was estimated according to the method of Gopal and Ranjhan (1980). The percentage cellulose concentration was calculated using the formula:

$$\text{Cellulose (\%)} = \frac{W2 - W3}{W1} \times 100$$

Where, W_1 is the weight of the sample, W_2 is the weight of the oven-dried sample, and W_3 is the weight of the ash.

Hemicellulose

The hemicellulose content (%w/w) of dry biomass is calculated as per the method of Ayeni *et al*. (2013).

Lignin

The lignin content in the sample was measured by the procedure of Gopal and Ranjhan (1980). The percentage of lignin was calculated by the following equation:

$$\text{Lignin (\%)} = \frac{W2}{W1} \times 100$$

Where, W_1 is the weight of the sample and W_2 is the weight of the oven-dried sample.

Solid State Fermentation of Substrates for Cellulase Production

The SSF for cellulase production was carried out in commercial Petri plates by using two fungal cultures *T. harzianum* (MTCC 8230) and *T. viride* (MTCC 800). *Trichoderma* species were used in the present study for cellulase production owing to the fact that they are the most suitable cellulolytic candidates as compared to the other cellulase producing fungi like *Aspergillus* and *Humicola* spp. (Imran *et al*., 2016).

Five agricultural biomass residues *viz.*, Banana Peel (BP), Corn Cob (CC), Groundnut Shell (GH), Sugarcane Bagasse (SB), and Pigeon Pea Stalk (PPS) were chosen as substrates for estimating their potential to produce cellulase enzymes. SSF for cellulase production was carried out by taking five gram of each selected substrate and inoculating it with spore suspensions (10^8 spores/mL-suspension) of *T. harzianum* and *T. viride* at the loading of 0.1 mL per gram dry substrate in the separate sterile petri dish. The moisture content of all the substrates was adjusted to 70 per cent (wet basis) by adding sterile Mandel's media (Mandels and Weber, 1969) of pH five followed by incubation at 30 °C for 6 days under static conditions (Brijwani and Vadlani, 2011).

Cellulase Assay

After the extraction of enzyme as per the method of Brijwani and Vadlani (2011), the supernatant was collected and analyzed for Filter Paper (Total cellulase or FPase) activity and Carboxymethyl Cellulase activity (CMCase) using standard protocols described by Ghose, 1987. FPase activity was determined by mixing 1.0 ml of enzyme with 1.0 ml 50 mM citrate buffer pH 4.8 in a clean test tube. One Whatman filter paper strip (1.0 x 6.0 cm) was placed in the test tube containing the enzyme and buffer. The test tubes were then incubated at 50 °C in an incubator for 60 min. After the incubation,

the released reducing sugar was determined by Dinitrosalicylic Acid (DNS) method (Ghose, 1987).

CMCase activity was determined by mixing 0.5 ml of 2 per cent carboxymethylcellulose (CMC) prepared in 50 mM citrate buffer pH 4.8 with 0.5 ml of the enzyme. The enzyme substrate mixture was incubated at 50 °C for 30 minutes and the reducing sugar produced was determined by DNS method (Ghose, 1987). One unit (U) of FPase and CMCase was defined as the amount of enzyme releasing 1 µmole of glucose from Whatman filter paper and Carboxymethyl Cellulose respectively per minute under standard assay conditions. The enzyme activity is expressed as Unit per mL (U/mL).

Results and Discussion

Biomass Sampling and Preparation of Substrates

The agricultural lignocellulosic biomass used in the study were collected from the local farms and were ground into powder form. The processed agricultural biomass substrates after crushing are shown in Fig. 1.

Fig. 1: Powdered agricultural biomass residues used in the study

Proximate Analysis

The results of proximate analysis of agricultural biomass are presented in Table 1.

Ash

The ash content of the fibrous feedstock is the inorganic elements such as salts of calcium, potassium, magnesium, and silicates present in it (Kumar *et al*., 2017). The maximum ash content of 20.2 ± 0.02 per cent was observed in the rice husk whereas corn cob showed the lowest ash content (2.52 ± 0.04 %) among all the agricultural substrates analyzed. These results slightly vary than those recorded by Cardoen *et al*. (2015) who reported ash content of 22.2 per cent and 1.2 per cent in Paddy husk and Maize cobs, respectively. The results for ash content in the present work conforms to those reported by He *et al*. (2014) who stated that ash is the measure of the total content of dust and inorganic constituents in biomasses, which is expected to be about 10 per cent in lignocellulose biomass. The ash content of BP, CC, GH, SB and PPS used in the present study for cellulase production was found to be 11.4 ± 0.42 per cent, 2.52 ± 0.04 per cent, 3.1 ± 0.21 per cent, 9.1 ± 0.3 per cent and 6.35 ± 0.43 per cent, respectively. These findings can be compared with studies of Pyar and Peh (2018) for BP; Cardoen *et al*. (2015) for Maize cobs, Groundnut shell and Sugarcane bagasse; Telang *et al*. (2010) for Tur straw.

Moisture

Low moisture content in substrates is essential for their enhanced shelf life as it will hamper the undesirable microbial activities in it. The lowest moisture content was observed in groundnut shell (1.67 ± 0.05 per cent) whereas maximum moisture content of 8.67 ± 0.05 is found in pea pod shell. The moisture content of analyzed agricultural substrates varied between 1.67 per cent to 8.67 per cent which showed that all the substrates were dried and stored well.

Carbohydrate

The carbohydrate content of the selected lignocellulosic substrates ranged between 1.12 and 61.2 per cent. Amongst all the substrates analyzed, the cotton stalk showed a maximum (58.12 ± 0.06 %) carbohydrate value while the soybean husk presented the minimum value of 1.12 ± 0.02 per cent. Other results include 23.4 ± 0.02 per cent, 46.18 ± 0.62 per cent, 22.2 ±

TABLE 1

Proximate analysis of agricultural biomass

Substrate	Ash (%)	Moisture (%)	Carbohydrate (%)	Crude Protein (%)	Crude Fibre (%)
Soybean husk	2.86±0.88	1.84±0.28	1.12±0.02	8.8±1.02	28.3±0.22
Cornstalk	8.46±0.32	2.94±0.16	34.88±0.12	3.08±0.12	41.12±0.83
Green gram shell	3.24±0.62	2.08±0.21	42.32±0.10	12.64±0.06	38.84±0.08
Corncob	2.52±0.04	2.96±0.14	46.18±0.62	3.86±0.38	31.52±0.08
Pea pod waste	4.86±0.03	8.67±0.05	51.12±0.06	9.88±0.04	8.14±0.04
Wheat straw	4.16±0.03	1.75±0.10	50±0.09	3.24±0.08	38.14±0.06
Banana peel	11.4±0.42	3.67±0.05	23.4±0.02	7.9±0.11	17.7±0.05
Coconut coir	2.60±0.04	6.93±0.07	46.12±0.09	0.98±0.02	33.12±0.06
Cotton stalk	4.88±0.12	5.2±0.10	58.12±0.06	11.3±0.39	18.7± 0.07
Cotton boll shell	2.9±0.22	2.75±0.10	21.12±0.06	3.5±0.29	48.12±0.83
Groundnut shell	3.1±0.21	1.67±0.05	22.2±0.22	7.3±0.31	33.45±0.13
Sugarcane bagasse	9.1±0.3	3.96±0.14	46.4±0.11	2.8±0.08	57.5±0.80
Soybean stalk	7±0.14	3.82±0.10	24.11±0.11	5.0±0.03	7±0.23
Rice husk	20.2±0.02	8.19±0.06	16.3±0.09	3.0±0.08	40.5±0.33
Pigeon pea stalks	6.35±0.43	5.95±0.06	44.25±0.25	10±0.05	7.65±0.03

Results are mean + SD of triplicate analysis

0.22 per cent, 46.4 ± 0.11per cent and 44.25 ± 0.25 per cent, respectively for BP, CC, GH, SB and PPS. The finding in this research can be compared with the reported result of Pyar and Peh (2018); Abubakar *et al.* (2016); Cardoen *et al*. (2015) and Telang *et al*. (2010).

Crude protein

The crude protein contents of the agricultural biomass varied from 0.98 ± 0.02 per cent for coconut coir to 12.64 ± 0.06 per cent for green gram shell. The protein contents of other selected wastes were 7.9 ± 0.11 per cent, 3.86 ± 0.38 per cent, 7.3 ± 0.31 per cent, 2.8 ± 0.08 per cent and 10 ± 0.05 per cent for BP, CC, GH, SB and PPS, respectively. The obtained data for protein content of BP, CC, GH, SB and PPS showed slight variations with the reports of Cardoen *et al.* (2015).

Crude fibre

The lowest crude fibre content was recorded in soybean stalk *i.e.,* 7 ± 0.23 per cent while the highest *i.e.,* 57.5 ± 0.80 per cent was recorded in sugarcane bagasse. Crude fibres in substrates such as BP, CC, GH, SB, and PPS were found to be 17.7 ± 0.05 per cent, 31.52 ± 0.08 per cent, 33.45 ± 0.13 per cent, 57.5 ± 0.80 per cent and 7.65 ± 0.03 per cent. These values compare favorably with the works of Pyar and Peh (2018) for BP; Abubakar *et al*. (2016) for corn cobs; Abdulrazak *et al*. (2014) for Groundnut shell; Cardoen *et al*. (2015) for Sugarcane bagasse; Telang *et al*. (2010) for Pigeon pea stalk.

Compositional Analysis

The results of compositional analysis of agricultural biomass are presented in Table 2.

Cellulose

Cellulose is the largest portion of most plants that accounts for around 35-50 per cent of the total dry weight of physical plant biomass (Somerville *et al*., 2010). The cellulose content of the agricultural biomass samples ranged from 26 to 57.28 per cent. Rice husk showed lowest cellulose of 12.0 ± 0.26 per cent. The cellulose content of BP, CC, GH, SB and PPS was

found to be 37.9 ± 0.09 per cent, 37.68 ± 1.38 per cent, 35.7 ± 1.41 per cent, 57.28 ± 1.2 per cent and 30 ± 0.34 per cent, respectively. These results are in accordance with the previous studies of Pyar and Peh (2018) for BP; Cardoen *et al.* (2015) for CC, GH and SB; Telang *et al*. (2010) for Pigeon pea stalk. The results showed that the selected agricultural lignocellulosic biomasses are rich in cellulose.

Hemicellulose

Hemicelluloses are heterogeneous polymers that comprise around 15 - 35 per cent of the entire plant material. Taking the complexity in the structure of the cell wall of the plant components into consideration, hemicellulose stands next to cellulose (Althuri *et al.,* 2017). The hemicellulose value of all biomass evaluated in this study was within the range of the stated values. The highest hemicellulose content of 24.8 ± 0.01 per cent was recorded in wheat straw and the lowest in rice husk (7.2 ± 0.33 per cent). These values corroborated with those noted by Cardoen *et al.* (2015) where hemicellulose of 7.2 per cent was reported in paddy husk while wheat straw showed slightly higher hemicellulose content (30 %). Hemicellulose content of BP, CC, GH, SB and PPS used in the present study was 23.9 ± 0.08 per cent, 14.12 ± 0.86 per cent, 18.7 ± 0.88 per cent, 9.28 ± 0.8 per cent and 17 ± 0.16 per cent that can be compared with earlier studies of Cardoen *et al,,* 2015; Mythili and Venkatachalam, 2013.

Lignin

Usually, most of the agricultural biomass contains nearly 10 - 25 per cent lignin (Iqbal *et al.,* 2011). The lignin content of some of the biomass examined in the present investigation shows considerable deviation from the earlier statement. In the present study, soybean husk showed the minimum lignin value (2.8 ± 0.08 per cent), whereas rice husk biomass was found to have the maximum lignin value (41.0 ± 0.09 per cent). These findings can be compared with the lignin content reported by Cardoen *et al.* (2015) who reported the lignin content of 4.9 and 43 per cent, respectively for soybean husk and paddy husk. Amount of lignin content present in BP, CC, GH, SB and PPS used in the study was 9.0 ± 0.55 per cent, 10.62 ± 2.18 per cent, 25 ± 1.03 per cent, 12.20 ± 1.1 per cent and 18.2 ± 0.34 per cent that was lower than those reported in earlier studies of Cardoen *et al.,* 2015 and Mythili & Venkatachalam, 2013.

These variations in the values of agricultural biomass components exists because of the differences among species, tissues, and maturity of the plant, their growing conditions and techniques used for measurement (Barakat *et al.,* 2013).

Evaluation of Selected Agro-residues for Cellulase Production under SSF

Taking results of proximate analysis into consideration, the indigenous agro-residues such as BP, CC, GH, SB and PPS were used as substrates for cellulase production since they were having high cellulose and low lignin content. This is mainly because the substantial amounts of lignin would cover the cellulose portion making it inaccessible for the action of cellulolytic enzymes (Oberoi *et al*., 2010). Thus, although having maximum cellulose, substrates like Cotton stalk (41 ± 0.08 %) was not selected for the cellulase production study because it also showed high lignin content (30.8 ± 0.14 %) compared with the low lignin containing substrates like PPS and GH.

The results of cellulase production by *T. harzianum* and *T. viride* using selected agricultural biomass revealed that all the five agro-residues are potential substrates for induction of cellulolytic enzymes

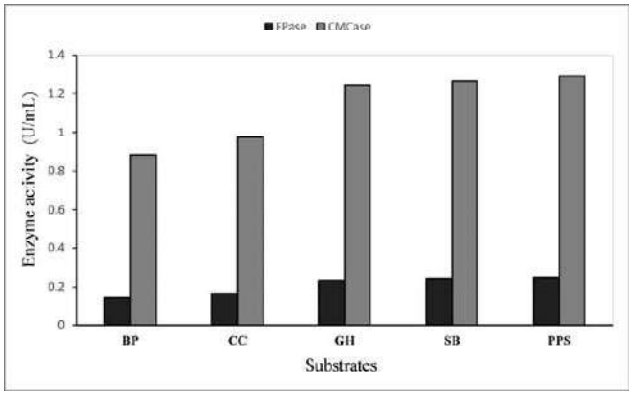

Fig. 2 Cellulase production by *T. harzianum* (MTCC 8230) under SSF of various agricultural biomass

TABLE 2
Compositional analysis of agricultural biomass

Substrate	Cellulose (%)	Hemicellulose (%)	Lignin (%)
Soybean husk	31.64±0.42	11.58±0.14	2.8±0.08
Cornstalk	42.22±0.14	22.36±0.62	11.12±0.82
Green gram shell	26.26±0.46	14.36±0.05	9.21±0.42
Corn cob	37.68±1.38	14.12±0.86	10.62±2.18
Pea Pod waste	26.84±0.08	19.68±0.34	18.06±0.16
Wheat straw	36.8±0.04	24.8±0.01	15.22±0.03
Banana peels	37.9±0.09	23.9±0.08	9.0±0.55
Coconut coir	35.08±0.21	12.28±0.06	29.18±0.18
Cotton stalk	41±0.08	21±0.42	30.8±0.14
Cotton boll shell	48.7±1.38	18.5±0.82	22.3±0.62
Groundnut shell	35.7±1.41	18.7±0.88	25±1.03
Sugarcane bagasse	57.28±1.2	9.28±0.8	12.20±1.1
Soybean stalk	26±0.46	18±0.34	12±0.42
Rice husk	12.0±0.26	7.2±0.33	41.0±0.09
Pigeon pea stalks	30±0.34	17±0.16	18.2±0.34

Results are mean + SD of triplicate analysis

(Fig. 2 and 3). However, the maximum cellulase yield in terms of both FPase and CMCase was induced by Pigeon pea stalk followed by sugarcane bagasse, groundnut shell, corn cob and banana peels. Higher cellulase production with PPS and SB could be attributed due to more cellulose content compared to other three substrates (Table 2).

The results showed that PPS was the most effective substrate for cellulase production with FPase activity of 0.247 U/mL and CMCase activity of 1.291 U/mL by *T. harzianum* and FPase activity of 0.326 U/mL and CMCase activity of 1.586 U/mL by *T. viride.* SB was the next best substrate that showed 0.242 U/mL FPase and 1.267 U/mL CMCase activity by *T. harzianum*.

It is clear from Fig. 3 that after PPS, the second high cellulase production was obtained with SB with FPase of 0.323 U/mL and CMCase of 1.513 U/mL. This is in conformity with the results of Cunha *et al*. (2012) who stated that sugarcane bagasse is the best inducer of cellulase in fungi. The aim of employing these five substrates was to explore their ability to induce cellulase enzyme. From the results, it can be stated that all the five substrates are able to produce cellulolytic enzyme which is in agreement with earlier studies that reported the ability of these agricultural biomass to produce cellulase utilizing Banana peel (Sun *et al*., 2011); corn cobs, carrot peelings, composite,

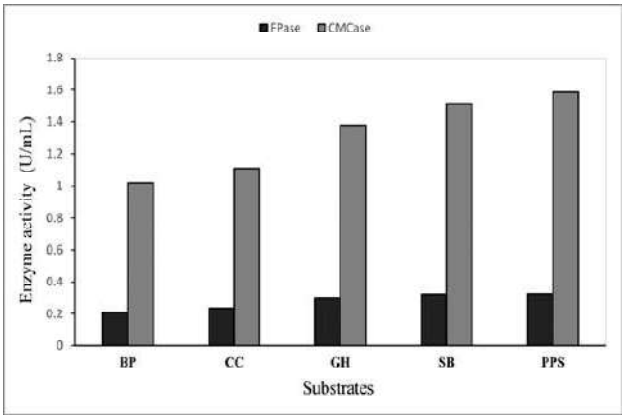

Fig. 3 : Cellulase production by *T. viride* (MTCC 800) under SSF of various agricultural biomass

grass, leaves, orange peelings, pineapple peelings, potato peelings, rice husk, sugarcane bagasse, saw dust, wheat bran, wheat straw (Bansal *et al*., 2012); Groundnut Husk (Salihu *et al*., 2013); Pigeon pea stalk (Kirti *et al*., 2019).

The prime objective of this work was to explore various raw agricultural biomass residues available in the Marathwada region (Maharashtra, India) for the production of cellulase enzymes. The selected lignocellulosic biomasses are highly indigenous to the Marathwada region of Maharashtra (India) and such exploration if added to the database of biomass can help in their utilization for future studies in areas like biofuel production. The resultant data from the proximate and compositional analysis of the selected local agricultural lignocellulosic residue is also an evidence for their potential to serve as a resource for future biofuel production. The present study also showed the potential of utilizing agricultural biomass for the production of cellulase by *T. harzianum* and *T. viride* which can be used to develop an economically viable cellulase production system. However, further studies in optimization of the process parameters for enhanced cellulase production are being considered.

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Response of Identified Thermotolerant Bivoltine Silkworm Breeds for *Beauveria bassiana* (Bals-Criv.) Vuill. Infection : A Source for Thermal and Fungal Dual Stress Resistance

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Abstract

An investigation was conducted using ten different silkworm breeds to assess their performance under two different stress conditions *i.e.,* high temperature treatment (36 ± 1 p C) and *Beauveria bassiana* (Bals-Criv.) Vuill. (LC_{50} 6.86 x 10^4 spore / ml) inoculation. Among the ten, seven (B1, B2, B4, B6, B8, APS12 and APS45) were thermotolerant bivoltine silkworm breeds, two were popular bivoltine (CSR 2 and CSR 4) and one was popular multivoltine (pure Mysore) breed. All the ten breeds were exposed to aforementioned two stress conditions. The results revealed that, the breeds B4, APS45 and B1 performed better under thermal treatment as they exhibited maximum ERR, single cocoon weight, cocoon shell weight, pupal weight and cocoon shell ratio. With respect to *B. bassiana* inoculation, the thermotolerant silkworm breeds B1, B2 and B4 exhibited higher ERR, pupation percentage, single cocoon weight, cocoon shell weight, pupal weight and shell percentage. Further, the breeds B4 and B1 were found to show commonality in exhibiting better survival and quantitative cocoon parameters under both high temperature treatment and *B. bassiana* inoculation. Hence, the breeds B1 and B4 can be used as potential dual stress resistant breeds against high temperature conditions and *B. bassiana* infection.

Keywords : Bivoltine, *Bombyx mori*, Cumulative survival index, Muscardine, Thermotolerance

India occupies the second position in global silk production next only to China. Sericulture in India is being practiced predominantly in tropical regions and to limited extent in temperate region. The existing tropical situation in the country provides scope for the exploitation of multivoltine breeds / hybrids as these breeds show the inherent capacity to perform well under varied and / fluctuating environmental conditions. But the quality of multivoltine silk is low compared to the existing International standards. To meet this standard it is necessary to shift to bivoltine sericulture which assures the production of quantitatively and qualitatively superior cocoons. It is a well established fact that, unlike multivoltine silkworms, bivoltines are more vulnerable to different stresses under tropical condition as these bivoltines have originated from temperate region. It is, therefore, imperative to evolve bivoltine silkworm breeds which can give stable yields under different stress conditions. Keeping this in view, the study was envisaged to know the phenotypic assessment of few thermotolerant bivoltine silkworm breeds under two different stress conditions *i.e.,* high temperature treatment and *Beauveria bassiana* infection. Ten thermotolerant silkworm breeds *viz.,* B1, B2, B3, B4, B5, B6, B8, APS12 and APS45 were evaluated under muscardine infection in our previous study and results revealed that, B4 breed performed better with respect to single cocoon weight, pupal weight, shell weight, cocoon shell ratio, filament length and filament weight, followed by B1 and B8 breeds (Keerthana *et al.,* 2019b).

Material and Methods

Phenotypic performance of ten selected silkworm breeds under high temperature treatment and *Beauveria bassiana* inoculation was studied at the Department of Sericulture, University of Agricultural Sciences, GKVK, Bengaluru during, 2020-2021. Seven thermotolerant silkworm breeds namely, B1, B2, B4, B6 and B8 and APS12 and APS45 were procured from Central Sericultural Research and Training Institute, Mysore and Andhra Pradesh State Sericulture

Research and Development Institute, Hindupur, respectively. Along with these seven breeds, three popular silkworm breeds *viz.,* CSR2 (productive bivoltine), CSR4 (susceptible bivoltine) and Pure Mysore (resistant multivoltine) were also used for investigation. Silkworm rearing was conducted during July to August 2020. Silkworms were reared in bulk up to fourth moult following the standard rearing practices given by Dandin and Giridhar (2014) and V-1 mulberry leaves were fed to silkworm till spinning.

Newly ecdysed fifth instar silkworms (50 silkworms per replication in three replication each) were used to impose the treatment. All the ten breeds were maintained in two sets for two different treatments *i.e.,* high temperature and *B. bassiana* inoculation. One set of all the ten breeds were treated with high temperature *i.e.,* 36 ± 1 p C and 85 ± 5 per cent relative humidity using BOD incubator. The treatment was given for first six days of fifth instar for duration of six hours daily (10.00 to 16.00 hours) (Sudhakara Rao *et al.,* 2006) and the silkworms were fed twice a day using leaf feeding method. Another set of all the breeds were topically inoculated with *B. bassiana* spore suspension with 6.86 x 10^4 spores per ml at the rate of 0.5 ml per silkworm, based on the previous studies conducted at the department (Keerthana *et al.,* 2019a) and silkworms were fed thrice a day using leaf feeding method. Simultaneously, a control batch of all the ten breeds was also maintained.

Observations on fifth instar larval duration, fifth instar larval weight, effective rate of rearing (ERR), per cent pupation, single cocoon weight, cocoon shell weight, cocoon shell ratio and pupal weight were recorded. The data obtained were analysed using completely randomized block design (Sundarraj *et al.,* 1972). Cumulative survival index (CSI) was calculated using the formula :

CSI=[(ERR%/100) x (per cent pupation/100)] x 100

where,

CSI- Cumulative Survival Index

ERR- Effective Rate of Rearing.

Further, the thermotolerant silkworm breeds were ranked utilizing the CSI so obtained and the mean of CSI was employed to identify the superior breeds separately for high temperature treated and *B. bassiana* inoculated batches.

Results and Discussion

Fifth Instar Larval Duration (hrs)

Significant differences were observed among the breeds utilized for the study under both high temperature treatment and *B. bassiana* inoculation with respect to larval duration. The larval duration was determined from first day of fifth instar till spinning.

In high temperature treated batch, APS45 recorded maximum larval duration of 234.67 hr, followed by B2 (223.67 hr) and it was minimum in B8 (197.00 hr) and APS 12 (201.00 hr). At the treated temperature, B2 breed showed increased larval duration of 2.60 per cent over control, whereas the highest reduction in the same was observed in APS45 (2.63 %) (Table 1). In *B. bassiana* inoculated batch, B4 breed showed maximum larval duration of 219.33 hr, followed by B2 and B1 (217.50 hr each) and the same was found to be minimum in Pure Mysore and APS12 (195.00 hr each) and B8 (197 hr). In the pathogen inoculated batch, increased larval duration was observed in B4 breed (0.61 %) and APS45 breed showed the highest reduction (9.96 %) over control (Table 1). In a similar study, four thermotolerant silkworm breeds (B1, B4, B6 and B8) and their hybrids were inoculated with different dilutions (10^{-2}, 10^{-4}, 10^{-6}, 10^{-8}) of *B. bassiana* wherein B6 (10.58 days) breed, B6 x B1 and B6 x B8 (10.50 days each) hybrids showed prolonged larval duration over all the dilutions compared to control (Jayashree *et al.,* 2020).

Fifth instar larval weight (g)

Fifth instar larval weight was affected significantly among all the silkworm breeds due to high temperature treatment and *B. bassiana* inoculation. In thermal treated batch, maximum larval weight was recorded in B2 breed (31.27 g) followed by B4 (30.89 g) and B1 (30.33 g) breeds. The least larval weight was

TABLE 1

Effect of thermal treatment and *B. bassiana* infection on growth and survival of selected thermotolerant bivoltine silkwormbreeds

BREEDS	Larval duration (hrs)			Larval weight (g / 10 larvae)			Effective rate of rearing (%)			Per cent pupation		
	Control	Thermal treated	*B. bassiana* infected	Control	Thermal treated	*B. bassiana* infected	Control	Thermal treated	*B. bassiana* infected	Control	Thermal treated	*B. bassiana* infected
B1	218.50	218.75 (+0.11)	217.50 (-0.46)	36.34	30.33 (-16.54)	18.07 (-50.27)	100.00	83.33 (-16.67)	77.33 (-22.67)	100.00	100.00 (0)	100.00 (0.00)
B2	218.00	223.67 (+2.60)	217.50 (-0.23)	37.03	31.27 (-15.56)	18.59) (-49.81)	100.00	48.00 (-52.00)	84.00 (-16.00)	100.00	100.00 (0)	86.67 (-13.33)
B4	218.00	220.33 (+1.07)	219.33 (+0.61)	34.24	30.89 (-9.79)	16.83 (-50.84)	100.00	90.67 (-9.33)	74.00 (-26.00)	100.00	100.00 (0)	66.67 (-33.33)
B6	217.17	218.75 (+0.73)	215.75 (-0.65)	31.11	24.41 (-21.53)	15.04 (-51.65)	100.00	90.00 (-10.00)	59.33 (-40.67)	100.00	100.00 (0)	56.67 (-43.33)
B8	199.67	197.00 (-1.34)	197.00 (-1.34)	27.12	22.82 (-15.84)	12.92 (-52.36)	100.00	82.22 (-17.78)	64.44 (-35.56)	100.00	100.00 (0)	93.33 (-6.67)
APS12	197.00	201.00 (+2.03)	195.00 (-1.02)	31.83	26.15 (-17.83)	15.50 (-51.31)	100.00	90.00 (-10.00)	48.89 (-51.11)	100.00	100.00 (0)	76.67 (-23.33)
APS45	241.00	234.67 (-2.63)	217.00 (-9.96)	30.42	30.22 (-0.66)	14.56 (-52.13)	100.00	86.67 (-13.33)	54.67 (-45.33)	100.00	100.00 (0)	73.33 (-26.67)
CSR2	218.50	218.75 (+0.11)	216.00 (-1.14)	36.12	29.01 (-19.69)	15.32 (-57.59)	100.00	91.11 (-8.89)	70.83 (-29.17)	100.00	100.00 (0)	66.67 (-33.33)
CSR4	218.75	220.83 (+0.95)	216.00 (-1.26)	29.88	23.08 (-22.76)	10.09 (-66.23)	100.00	85.33 (-14.67)	60.00 (-40.00)	100.00	100.00 (0)	56.67 (-43.33)
Pure Mysore	215.25	215.25 (0.00)	195.00 (-9.41)	19.47	18.89 (-3.00)	16.50 (-15.25)	100.00	100.00 (-0.00)	100.00 (-0.00)	100.00	100.00 (0)	100.00 (0.00)
SEm±	0.87	2.41	0.94	0.57	0.53	0.29	0.00	2.00	4.44	0.00	0.00	3.94
CD at 5%	2.56	7.10	2.78	1.69	1.56	0.86	0.00	5.91	13.08	0.00	0.00	11.63
CV (%)	0.70	1.92	0.78	3.17	3.42	3.28	0	4.09	11.08	0	0	8.80
F-test	*	*	*	*	*	*	NA	*	*	-	-	*

Note :

- ✓ Positive and negative figures in the parenthesis indicate per cent increase (+) or decrease (-) over control, respectively
- ✓ * - Significant at 5 %; NA - Not analysed
- ✓ *B. bassiana* inoculation 6.86 X 10^4 spores per ml @ 0.5 ml per worm; High temperature treatment @ 36±1 °C for 6 hrs per day from 1st to 6th day of fifth instar

recorded in Pure Mysore (18.89 g), followed by B8 (22.82 g) and CSR4 (23.08 g). Highest reduction in larval weight was observed in CSR4 breed (22.76 %) and the least per cent reduction was observed in APS45 breed (0.66 %) over control (Table 1). Reduction in larval weight in high temperature treated silkworms might be attributed to low feeding activity of the silkworms (Pillai and Krishnaswamy, 1980). Our findings were also supported by Keerthana *et al.* (2020) where they recorded highest larval weight in B1 and B4 breeds (38.57 g / 10 silkworms each) after being exposed to high temperature of 36 ± 1 p C.

In *B. bassiana* inoculated batch, B2 breed recorded maximum larval weight of 18.59 g, followed by B1 and B4 breeds (18.07 g and 16.83 g, respectively) and minimum weight was found in CSR4 (10.09 g) and B8 (12.92 g). In the pathogen inoculated batch, highest reduction in larval weight was observed in CSR4 breed (66.23 %), followed by CSR2 breed (57.59 %) with the lowest reduction of 15.25 per cent in Pure Mysore breed over their respective control (Table 1). Decrease in body weight in *B. bassiana* infected silkworms is due to cessation of feeding, decrease in food consumption, digestion, relative consumption rate and efficiency of conversion of ingested food (Venkataramana Reddy, 1978 and Cai, 1989). In earlier studies B4, B2 and B1 exhibited highest larval weight (21.35 g, 20.78 g and 20.50 g, respectively) under *B. bassiana* inoculation (Keerthana *et al.,* 2020) which supports the present findings.

Effective Rate of Rearing (ERR) (%)

In this study ERR was affected significantly due to high temperature treatment and *B. bassiana* treatment.

In high temperature treated batch Pure Mysore showed cent per cent ERR followed by CSR2 (91.11 per cent), B4 (90.67 per cent) and B6 and APS12 breeds (90.00 per cent each). The least ERR was observed in B2 breed (48.00 per cent). Highest reduction of 52.00 per cent ERR was exhibited by B2 breed as against no change in Pure Mysore breed over control (Table 1). In earlier studies, the breeds NB_4D_2, NP2, KSO1, CSR_2 and CSR_4 resulted in cent per cent mortality after being exposed to a threshold temperature of 45 ºC (Vasudha *et al.*, 2006). Pillai and Krishnaswamy (1980) reported that, the low survival rate in the silkworms exposed to high temperature in fifth instar is attributed to low feeding activity of the silkworm resulting in the physiological imbalance and poor health of the larvae. The present findings were also in line with the results of Keerthana *et al.* (2020) where they recorded significantly highest ERR in B4 breed (84.67 %), followed by APS45, B8 and APS12 breeds (81.33, 76.67 and 74.00 per cent, respectively).

In *B. bassiana* inoculated batch, cent per cent ERR was recorded in Pure Mysore, followed by B2 (84 %), B1 (77.33 %) and B4 (74.00 %). Minimum ERR was recorded in APS12 (48.89 %) followed by APS45 (54.67 %), B6 (59.33 %) and CSR4 (60.00 %). APS12 breed showed highest (51.11 %) reduction in ERR, followed by APS45 breed (45.33 %), but no change was observed in Pure Mysore breed over control (Table 1). Previously, when eight races of silkworms *viz.,* Pure Mysore, Hosa Mysore II, C. Nichi, HS6, NN6D, NB_4D_2, KA, J122 were inoculated with nine conidial concentrations (10^1 - 10^9 spores / ml) of *B. bassiana*, variation in ERR over spore concentration and between the breeds was observed (Venkataramana Reddy, 1978). Infection of the thermotolerant silkworm breeds with *B. bassiana* resulted in highest ERR in B4 (54.67 %) than B8 (42.67 %) and B1 (40.00 %) breeds (Keerthana *et al.*, 2020). Similarly, the breed B4 performed better with respect to ERR under both high temperature treatment and *B. bassiana* inoculation in our study.

Per cent Pupation

Per cent pupation was not affected due to high temperature treatment, as cent per cent pupation was observed in all the breeds (Table 1). Whereas, in the *B. bassiana* inoculated batch significant differences were observed for the same. Under *B. bassiana* inoculation Pure Mysore and B1 breeds recorded cent per cent pupation followed by B8 (93.33 %) and B2 (86.67 %) breeds. But, the same was observed to be least in CSR4 and B6 breeds (56.67 % each), followed

by B4 and CSR2 (66.67 % each). Highest reduction in pupation percentage was observed in CSR4 and B6 breeds (43.33 % each), while no change in pupation percentage in Pure Mysore and B1 breeds over their respective control was observed (Table 1). These results corroborate with the findings of Suresh Kumar *et al*. (2002) who found that, CSR18 and CSR19 thermotolerant bivoltine silkworm breeds resulted in better pupation rate (92.30 & 92.00 %, respectively) than control breeds KA and NB4D2 (76.60 & 88.20 %, respectively). Presence of saturated fatty acids namely, capric acid and caprylic acid in the pupal cuticle were found to show antifungal activity against *B. bassiana* infection (Koidsumi, 1957; Chandrasekharan and Nataraju, 1998). This could be a possible reason to show increased per cent pupation in Pure Mysore, B1, B8 and B2.

Single Cocoon Weight (g)

Significant differences were observed among the silkworm breeds for single cocoon weight in both high temperature treated and *B. bassiana* inoculated batches. In high temperature treated batch, maximum cocoon weight of 1.79 g was recorded in CSR2 followed by B4 (1.76 g) and APS45 (1.73 g) breeds and it was minimum in Pure Mysore (1.21 g) followed by B8 (1.40 g) and CSR4 (1.52 g) breeds. An increase in cocoon weight over control was observed in Pure Mysore (6.04 %), APS45 (2.84 %) and CSR2 (2.78 %) and it decreased in other breeds. Highest reduction in the same was observed in CSR4 breed (9.46 %) followed by B6 breed (8.35 %) (Table 2). Previously, the thermotolerant silkworm breeds CSR46 and CSR47 yielded single cocoon weight in the same range (1.48 g and 1.34 g, respectively) when reared at 36 ± 1 p C (Suresh Kumar *et al.,* 2006). Also, when the thermotolerant silkworm breeds were treated with high temperature of 36 ± 1 p C, B8 breed (1.62 g) recorded the maximum cocoon weight, followed by B4 and APS45 (1.60 g each) (Keerthana *et al.,* 2020).

In *B. bassiana* inoculated batch, single cocoon weight was least affected in B4 (1.41 g), B1 (1.03 g) and B6 (1.00 g) breeds and it was most affected in CSR4 (0.71 g), B8 (0.83 g), APS12 and APS45 (0.85 g each) breeds. Highest per cent reduction in cocoon weight over control was observed in CSR4 breed (58.00 %) and it was lowest in Pure Mysore breed (18.00 %) (Table 2). The results of Raghavaiah (1986) in similar studies revealed that NB7 breed spun cocoons with maximum cocoon weight (1.027 g) compared to NB18 (0.940 g) when infected with muscardine fungus. Keerthana *et al.* (2020) have also recorded the maximum cocoon weight of 1.16 g, 1.06 g and 1.05 g in B4, B1 and B8 breeds, respectively under *B. bassiana* infection which supports the present finding with respect to the performance of B4 and B1 breeds.

Cocoon shell weight (g)

The breeds utilized for the study showed significantly different cocoon shell weights when they were subjected to thermal treatment and *B. bassiana* inoculation. In high temperature treated batch, highest cocoon shell weight of 0.39 g was recorded in APS45 breed, followed by CSR2 (0.38 g) and B1 (0.37 g). Whereas, Pure Mysore, B8 and B6 breeds exhibited lower cocoon shell weight of 0.14 g, 0.28 g and 0.29 g, respectively. Cocoon shell weight was increased by 14.82 per cent over control in APS45 breed and it was decreased by 18.10 per cent in CSR4 breed (Table 2). The results are consistent with earlier findings as in CSR18 and CSR19 thermotolerant bivoltine silkworm breeds which produced shell weight of 0.30 g and 0.23 g when reared at 36±1 p C and 85±5 per cent relative humidity (Suresh Kumar *et al.,* 2002) and APS12 which produced shell weight of 0.39 g at 32 ± 1 p C (Lakshmi and Chandrashekaraiah, 2006). Similarly, highest cocoon shell weight of 0.34 g was recorded in B4 breed, followed by B3, B6 and APS45 breeds (0.32 g each) (Keerthana *et al.,* 2020).

In *B. bassiana* inoculated batch, significantly highest cocoon shell weight was recorded in B4 (0.24 g), B1 (0.21 g), B6 and APS45 breeds (0.17 g each). Pure Mysore recorded the lowest cocoon shell weight of 0.11 g followed by B8 (0.13 g), B6 and APS12 (0.17 g each). Maximum reduction in cocoon shell weight over control was observed in CSR4 breed (72.23 %), followed by CSR2 breed (65.79 %) (Table 2). In earlier

TABLE 2

Effect of thermal treatment and B. bassiana infection on cocoon parameters of selected thermotolerant bivoltine silkworm breeds

BREEDS	Single cocoon weight (g)			Cocoon shell weight (g)			Pupal weight (g)			Cocoon shell ratio (%)		
	Control	Thermal treated	*B. bassiana* infected	Control	Thermal treated	*B. bassiana* infected	Control	Thermal treated	*B. bassiana* infected	Control	Thermal treated	*B. bassiana* infected
B1	1.69	1.59 (-6.07)	1.03 (-39.08)	0.37	0.37 (+0.45)	0.21 (-44.12)	1.30	1.22 (-6.39)	0.81 (-37.86)	21.92	23.40 (+6.75)	20.10 (-8.27)
B2	1.72	1.66 (-3.68)	0.88 (-48.86)	0.39	0.35 (-9.30)	0.16 (-57.58)	1.37	1.20 (-12.08)	0.74 (-45.77)	22.49	21.18 (-5.83)	18.66 (-17.04)
B4	1.84	1.76 (-4.70)	1.14 (-37.97)	0.39	0.35 (-9.15)	0.24 (-38.46)	1.42	1.33 (-6.35)	0.89 (-37.41)	21.18	20.18 (-4.72)	21.01 (-0.80)
B6	1.74	1.59 (-8.35)	1.00 (-42.54)	0.32	0.29 (-10.00)	0.17 (-46.88)	1.51	1.28 (-15.74)	0.88 (-41.61)	18.70	18.34 (-1.91)	17.29 (-7.54)
B8	1.42	1.40 (-1.06)	0.83 (-41.67)	0.26	0.28 (+5.42)	0.13 (-50.00)	1.11	1.13 (+1.63)	0.66 (-40.41)	18.66	19.88 (+6.52)	15.99 (-14.29)
APS12	1.66	1.54 (-7.23)	0.85 (-48.91)	0.35	0.30 (-15.25)	0.17 (-52.94)	1.26	1.22 (-2.83)	0.67 (-46.67)	21.28	19.49 (-8.41)	19.60 (-7.88)
APS45	1.68	1.73 (+2.84)	0.85 (-49.46)	0.34	0.39 (+14.82)	0.14 (-59.46)	1.24	1.36 (+9.41)	0.67 (-46.26)	20.13	22.49 (+11.71)	16.15 (-19.79)
CSR2	1.74	1.79 (+2.78)	0.86 (-50.79)	0.39	0.38 (-3.27)	0.13 (-65.79)	1.31	1.39 (+6.15)	0.69 (-47.71)	22.34	20.98 (-6.06)	15.53 (-30.49)
CSR4	1.68	1.52 (-9.46)	0.71 (-58.00)	0.35	0.29 (-18.10)	0.10 (-72.23)	1.44	1.20 (-16.35)	0.61 (-57.84)	20.93	18.94 (-9.53)	13.84 (-33.88)
Pure Mysore	1.14	1.21 (+6.04)	0.93 (-18.00)	0.13	0.14 (+0.74)	0.11 (-19.25)	0.97	1.04 (+7.23)	0.80 (-17.52)	11.85	11.29 (-4.73)	11.67 (-1.52)
SEm±	0.04	0.04	0.02	0.01	0.01	0.01	0.03	0.03	0.02	0.90	0.63	0.78
CD at 5 %	0.13	0.11	0.07	0.04	0.02	0.02	0.10	0.10	0.06	2.65	1.85	2.30
CV (%)	4.74	4.25	4.76	7.46	4.59	7.21	4.55	4.60	4.56	7.79	5.53	7.96
F-test	*	*	*	*	*	*	*	*	*	*	*	*

Note:

- ✓ Positive and negative figures in the parenthesis indicate per cent increase (+) or decrease (-) over control, respectively
- ✓ * - Significant at 5 %
- ✓ *B. bassiana* inoculation 6.86 X 10^4 spores per ml @ 0.5 ml per worm; High temperature treatment @ 36±1 °C for 6 hrs per day from 1st to 6th day of fifth instar

studies NB7 silkworm spun cocoons with maximum shell weight compared to NB4D2, KA and NB18 bivoltine silkworm breeds when they were subjected to *B. bassiana* infection (Venkataramana Reddy, 1978). Topical application of *B. bassiana* spores to ten thermotolerant silkworm breeds recorded the highest cocoon shell weight in B4 (0.24 g) and B1 (0.19 g) breeds (Keerthana *et al.,* 2020).

Pupal weight (g)

Pupal weight was significantly affected among the thermotolerant silkworm breeds due to high temperature treatment and *B. bassiana* inoculation. In high temperature treated batch, CSR2 breed exhibited significantly maximum pupal weight of 1.39 g, followed by APS45 (1.36 g), B4 (1.33 g) and B6 (1.28 g) breeds.

Pupal weight was minimum in Pure Mysore (1.04 g), followed by B8 (1.13 g) and CSR4 (1.20 g) breeds. Pupal weight was increased by 9.41 per cent over control in APS45 breed and it was decreased by 16.35 per cent in CSR4 breed (Table 2). Comparably, other thermotolerant silkworm breeds SR1 and SR4 recorded pupal weight of 1.17 g and 1.22 g, respectively (Sudhakara Rao *et al.,* 2006). In a similar high temperature treatment by experiment, Keerthana *et al.* (2020) recorded the highest pupal weight of 1.31 g in B8 breed, followed APS45, APS12 and B4 breeds (1.28 g, 1.27 g & 1.26 g, respectively).

In *B. bassiana* inoculated batch, significantly highest pupal weight was recorded in B4 (0.89 g) breed, followed by B6 (0.88 g) and B1 breeds (0.81 g) and it was significantly lowest in CSR4 (0.61 g), B8 (0.66 g) APS12 and APS45 breeds (0.67 g each). CSR4 breed recorded highest (57.84 %) reduction in pupal weight over control and it was lowest in Pure Mysore breed (17.52 %) (Table 2). Reduction in pupal weight in cross breed (PM x CSR_2) silkworm was observed when treated with sub-lethal concentration of *B. bassiana* conidial suspension (Rajitha and Savithri, 2015). The present findings were also supported by results of Keerthana *et al.* (2020), wherein B4 breed recorded maximum pupal weight of 0.92 g followed by B1, B6, B7 and B8 (0.87 g each).

CocoonShell Ratio (%)

Cocoon shell ratio was significantly affected due to high temperature treatment and *B. bassiana* inoculation among the thermotolerant silkworm breeds. In high temperature treated batch, B1 breed showed significantly highest cocoon shell ratio of 23.40 per cent, followed by APS45 (22.49 %), B2 (21.18 %) and CSR2 (20.98 %) breeds. APS45 breed showed increase in cocoon shell ratio by 11.71 per cent and it was decreased by 9.53 per cent in CSR4 breed (Table 2). Significantly lowest shell percentage was recorded in Pure Mysore (11.29 %), followed by B6 (18.34 %) and CSR4 (18.94 %). Thermotolerant breeds HTO5 and HTP5 exhibited shell percentage of 21.30 per cent and 22.3 per cent, respectively when exposed to 32 ± 1 p C (Lakshmi *et al.,* 2011). When, 20 silkworm breeds were reared at 36 ± 1 p C, CSR2 and CSR17 could produce shell percentage of 18.24 per cent and 18.25 per cent, respectively (Chandrakanth *et al.,* 2015). Likewise, among the ten thermotolerant bivoltine silkworm breeds, B3 breed recorded highest shell percentage of 21.83 per cent, followed by B4 (21.80 %) and B6 (20.75 %) breeds (Keerthana *et al.,* 2020).

In *B. bassiana* inoculated batch, B4 breed exhibited significantly highest cocoon shell percentage of 21.04 per cent, followed by B1, APS12 and B2 breeds (20.10, 19.60 and 18.66 %, respectively). Pure Mysore exhibited significantly lowest cocoon shell ratio of 11.67 per cent, followed by CSR4 (13.84 %) and CSR2 (15.53 %) breeds. Cocoon shell ratio was highly affected in CSR4 breed as it recorded 33.88 per cent reduction over control and it was least affected in Pure Mysore breed (1.52 %) (Table 2). In earlier studies, NB_4D_2 produced highest shell ratio compared to NB_7, KA and NB_{18} (Venkataramana Reddy, 1978) and crossbreed, PM x CSR_2 recorded reduced cocoon shell ratio of 12.80 per cent under *B. bassiana* infection compared to control (16.43 %) (Seema *et al.,* 2019).

Cumulative Survival Index (CSI) (%)

ERR and pupation rate being of paramount importance in deciding the survivability of silkworm breeds, the

TABLE 3

Ranking of selected thermotolerant bivoltine silkworm breeds subjected to high temperature treatment and *B. bassiana* inoculation based on CSI

High temperature treated	*B. bassiana* infected
Pure Mysore	Pure Mysore
CSR2	B1
B4	B2
B6	B8
APS12	B4
APS45	CSR2
CSR4	APS45
B1	APS12
B8	CSR4
B2	B6

cumulative survival indices were calculated utilizing those values for each breed under both high temperature treatment and *B. bassiana* inoculation. The breeds were ranked (Table 3) using the cumulative survival index and depicted in Fig. 1.

Pure Mysore ranked first (CSI, 100.00 %) in both high temperature treatment and *B. bassiana* inoculation, indicating its hardiness. CSR2 ranked second (CSI, 91.11 %), followed by B4 (CSI, 90.67 %), B6 and APS12 (CSI, 90.00 % each) breeds and B2 breed ranked last (CSI, 48 %) under high temperature treatment (Table 3; Fig. 1). The multivoltine strains, C. Nichi and Pure Mysore showed better survival

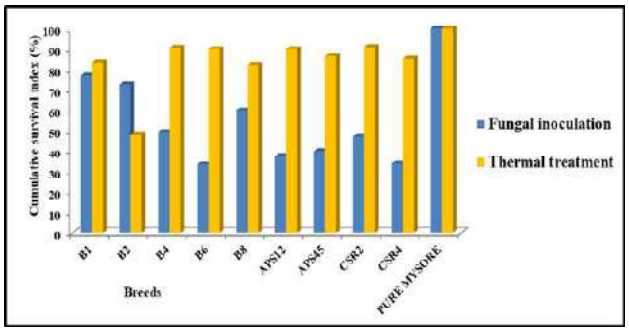

Fig. 1: Cumulative survival index of selected thermotolerant bivoltine silkworm breeds subjected to high temperature (36±1 p C) treatment and inoculated with *B. bassiana*

rates than the bivoltine strain NB_4D_2, when exposed to 41 ºC and above (Omana and Gopinathan, 1995). The multivoltine breeds *viz.,* Pure Mysore and APM1 were less susceptible to *B. bassiana* infection compared to bivoltine race APS8 (Lakshmi *et al*., 2005).

In *B. bassiana* inoculated batch, B1 breed ranked second (CSI, 77.33 %), followed by B2 (CSI, 72.80 %), B8 (CSI, 60.15 %) and B4 (49.33 %) breeds and the least rank was assigned to B6 and CSR4 breeds as they exhibited 33.62 per cent and 34.00 per cent of CSI, respectively (Table 3; Fig. 2). The thermotolerant bivoltine silkworm breeds which ranked above the mean CSI (84.73 % under high temperature treatment and 55.20 % under *B. bassiana* inoculation) were considered to perform better over other breeds. Therefore, the study results indicate that, among the thermotolerant bivoltine silkworm breeds selected for the study B4, B6, APS12, APS45 and CSR4 performed better under high temperature treatment. B1, B2 and B8 breeds were found to perform better under *B. bassiana* inoculation with respect to survivability.

The purpose of sericulture is to produce qualitatively and quantitatively superior cocoons which can be achieved through rearing of bivoltine silkworms. The present study results reveal that, the thermotolerant silkworm breeds B4, APS45 and B1 performed better under thermal treatment as they exhibited maximum ERR, single cocoon weight, cocoon shell weight, pupal weight and cocoon shell ratio. In *B. bassiana* inoculated breeds B1, B2 and B4 exhibited higher ERR, pupation percentage, single cocoon weight, cocoon shell weight, pupal weight and shell percentage. Results on quantitative and survival parameters obtained in the present study indicate that, B1 and B4 thermotolerant bivoltine silkworm breeds would be the potent sources with genetic plasticity to buffer against the dual stress conditions.

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Agronomic Investigations on Sida Hemp (*Sida alnifolia* L.) - A Medicinal Plant for Future

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Abstract

A field experiment was conducted to assess the effect of agronomic management on growth, yield and rhizosphere variations of Sida hemp (*Sida alnifolia* L.) during June 2018 to December 2018. Study comprised two growing conditions *viz*., open and 50 per cent shade, two levels of manuring *viz*., no manure and FYM@10 t ha^{-1} and four weed management practices *viz*., mulching with black polythene sheet, organic mulching with paddy straw @ 5 t ha^{-1}, hand weeding and no weeding. Taller plants were observed under 50 per cent shaded condition. Open condition showed superiority in case of biomass yield per plant and root shoot ratio at all growth stages of Sida hemp.The highest root yield per plant was recorded in treatment combination, black polythene mulching with FYM under open condition (11.81g). Total population of bacteria, actinomycetes and fungi and soil microbial biomass carbon were significantly higher under open condition.Among manuring, FYM @ 10 t ha^{-1} recorded higher biometric characters, total population of bacteria, actinomycetes and fungi and soil microbial biomass carbon. Mulching with black polythene recorded higher biometric characters and root yield where as soil microflora and soil microbial biomass carbon were enhanced by organic mulching.

Keywords : Sida hemp, Growing condition, Manuring, Weed management, Soil microflora, Soil microbial biomass carbon

Sida is a large genus with about 200 species distributed throughout the world. This genus has pronounced prominence in the Indian traditional system of medicine and is one among the most widely used raw drug in the production of different Ayurvedic formulations for over 2000 years. *Sida alnifolia* is a species belonging to family 'Malvaceae', found in tropical and subtropical regions of India. There are different common names *viz.,* Arrow leaf sida or Sida hemp (English), Bala (Sanskrit), and Kurumthotti (Malayalam). Roots are used in a variety of Ayurvedic medicines and oils to improve strength of bones, muscles and joints. The main Ayurvedic preparations containing *Sida* includes Bala Taila, Balarishta, Balahathadi Taila, Chandanbala lakshadi taila, Sudarshan churna and Balaguduchyadi Taila. According to National Medicinal Plant Board (NMPB), *Sida* is the 3rd most widely used drug in Ayurveda pharmaceutical industry and is mostly collected from the wild. Because of its high commercial value, the crop is included in the group of high volume traded medicinal plants sourced from waste lands. Cultivating plants under a micro climate similar to its niche original is found to be the viable solution for ensuring its therapeutic properties. An experiment therefore, designed to study the rhizosphere variations, growth and yield of Sida hemp as influenced by agronomic management.

Material and Methods

A field experiment was conducted in the Department of Agronomy, College of Horticulture, Vellanikkara during June - December 2018, using Randomized Block Design (factorial) with 16 treatment combinations and three replications. The plot size was 3 m x 2 m with a plant spacing of 50 cm x 25 cm. The treatments consisted of two growing conditions (open and 50 per cent shade), two manuring levels (no manure and FYM@10 t ha^{-1}), and four weed management practices (mulching with black polythene sheet of 25 micron thickness, mulching with paddy straw @ 5 t ha^{-1}, hand weeding at 1st, 3rd and 5th months and no

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weeding). Shade was introduced artificially by providing green colour shade net with 50 per cent permeability of sunlight. No fertilization was done except FYM (10 t ha^{-1}) which was applied as basal in half of the plots as per the treatments. One month old healthy, uniform sized seedlings (80,000 ha^{-1}) were transplanted in the main field as per treatments.

Randomly selected five plants per treatment and replication were tagged and observations *viz*., plant height, shoot biomass and root biomass were recorded at 1, 3, 5 months after planting and at harvest. For measuring shoot and root biomass, randomly selected plants in each treatment and replication were uprooted and average fresh weight per plant were calculated and expressed in grams. The fresh weight and dry weight of shoot and root was recorded separately. Total population of bacteria, actinomycetes and fungi were isolated from soil using serial dilution followed by pour plate method at initial, 4 MAP and at harvest. Soil microbial biomass carbon was analyzed by fumigation and extraction method at initial, 4 MAP and at harvest. The data collected were subjected to analysis of variance using the statistical package 'OPSTAT'.

Results and Discussion

Plant Height at 1, 3, 5 MAP and at Harvest

Taller plants were observed under 50 per cent shaded condition with black polythene mulch and FYM @ 10 t ha^{-1}throughout the growth stages (15.28cm, 123.33 cm, 135.07cm and 139.20 cm at 1, 3, 5 MAP and at harvest, respectively) (Table 1). As per Liu *et al*. (2016), plants that grow in shade tend to have elongated growth due to the activity of auxin, gibberillins and brassinosteroids. The significant increase in plant height with FYM application was due to the addition of secondary and micronutrients along with the major nutrients (Banik *et al*., 2006). Increase in soil temperature and soil moisture contents in the plots with black polythene mulching compared to bare soil might have contributed to better plant height in these plots (Ashrafuzzaman *et al.,* 2011).

Shoot Biomass

Significantly higher biomass yield per plant was recorded in crops grown under open condition (6.99g, 24.09g, 42.39g and 58.91g at 1, 3, 5 MAP and at

Table 1

Plant height of Sida hemp at different growth stages as influenced by manuring and weed management practices

Treatments	Plant height (cm)							
	1 MAP		3 MAP		5 MAP		Harvest	
	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade
No manuring x Black polythene	9.47	13.63	74.58	118.78	84.35	128.10	91.10	134.50
No manuring x Organic mulch	8.40	10.77	68.23	99.53	78.39	101.37	86.50	106.53
No manuring x Hand weeding	9.07	11.67	50.29	89.43	72.35	97.23	85.27	108.63
No manuring x No weeding	8.13	9.90	39.47	47.71	53.40	60.63	64.50	70.67
FYM @ 10t/ha x Black polythene	11.60	15.28	94.30	123.33	104.63	135.07	108.00	139.20
FYM @ 10t/ha xOrganic mulch	10.27	11.23	89.30	102.53	99.23	110.53	103.77	115.67
FYM @ 10t/ha xHand weeding	10.87	13.43	65.65	97.67	75.53	104.40	87.53	111.10
FYM @ 10t/ha xNo weeding	6.47	10.63	57.53	54.54	67.36	64.20	68.43	72.13
CD (0.05)	NS		3.34		3.95		5.16	
SE(m)	0.99		1.16		1.37		1.79	

TABLE 2

Effect of treatments on biomass yield per plant of Sida hemp at different growth stages

Treatments	Biomass yield per plant (g)			
	1 MAP	3 MAP	5 MAP	Harvest
Growing condition				
Open	6.99	24.09	42.39	58.91
50% Shade	6.09	16.45	29.15	42.20
CD (0.05)	0.80	1.16	1.16	1.37
SE(m)	0.092	0.03	0.21	2.08
Manuring				
No manure	6.20	18.17	31.09	44.89
FYM @ 10t/ha	6.88	22.36	40.45	56.22
CD (0.05)	NS	1.16	1.16	1.37
SE(m)	0.092	0.03	0.21	2.08
Weed management				
Black polythene	9.65	33.80	71.01	91.17
Organic mulch	6.38	18.60	30.63	47.69
Hand weeding	5.41	15.50	24.71	38.39
No weeding	4.72	13.17	16.74	24.97
CD (0.05)	1.14	1.64	1.64	1.93
SE (m)	0.13	0.04	0.30	4.16

harvest, respectively) (Table 2). Preference of open condition for better growth and performance of *Sida cordifolia* was reported by Latha and Radhakrishnan (2015). Significant variation was observed for biomass yield per plant with manuring. The highest biomass yield per plant was obtained in plots with FYM @ 10 t ha^{-1}at all growth stages (6.88g, 22.36g, 40.45g and 56.22g at 1, 3, 5 MAP and at harvest, respectively). Improved biomass yield and crop growth of different crops with addition of FYM was reported by Dejene and Lemlem (2012). Weed management significantly influenced the biomass yield per plant of *Sida alnifolia*. Black polythene mulching recorded the higher biomass yield per plant (9.65 g, 33.80g, 71.01g and 91.17 g at 1 MAP, 3 MAP, 5 MAP and at harvest, respectively). Significant increase in biomass yield of chilly with black polythene mulching was reported by Ashrafuzzaman *et al.* (2011). High soil moisture retention, optimum soil temperature and reduced weed density might have contributed to the increased biomass yield per plant under black polythene mulch.

Root Biomass

Growing condition, manuring and weed management significantly influenced the root:shoot ratio of *Sida alnifolia* (Table 3). Lower root:shoot ratio was observed under shaded condition throughout the growth period. This can be correlated with higher plant height and lower biomass yield per plant under shade (Table 1 and 2). In wheat, a negative correlation of root: shoot ratio with plant height was reported by Narayanan and Vara Prasad (2014). Higher root:shoot ratio was recorded in FYM applied plots (0.14, 0.26, 0.34 and 0.42 at 1, 3, 5 and harvest, respectively). According to Ibrahim *et al.* (2010), FYM provides a better environment for root development by improving the soil structure and this could be the reason for the increase in root volume and root yield with FYM

TABLE 3

Effect of treatments on root:shoot ratio of Sida hemp at different growth stages

Treatments	Root:shoot ratio			
	1 MAP	3 MAP	5 MAP	Harvest
Growing condition				
Open	0.15	0.26	0.35	0.42
50% Shade	0.13	0.23	0.29	0.38
CD (0.05)	0.01	0.02	0.01	0.01
SE(m)	0.008	0.024	0.002	0.009
Manuring				
No manure	0.13	0.23	0.31	0.38
FYM @ 10t/ha	0.14	0.26	0.34	0.42
CD (0.05)	NS	0.02	0.01	0.01
SE(m)	0.008	0.024	0.002	0.009
Weed management				
Black polythene	0.15	0.29	0.38	0.44
Organic mulch	0.14	0.26	0.34	0.41
Hand weeding	0.13	0.23	0.31	0.40
No weeding	0.12	0.20	0.36	0.33
CD (0.05)	0.02	0.03	0.02	0.02
SE (m)	0.008	0.034	0.002	0.012

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application. Among different weed management, black polythene mulching recorded higher root:shoot ratio. This might be due to better microclimate under black polythene mulch.

Interaction effect of growing condition, manuring and weed management was significant with respect to root biomass per plant (Table 4). The highest root biomass per plant was recorded in the treatment combination, black polythene mulching with FYM under open condition (11.81 g) followed by black polythene mulching without manure under open condition (8.57 g). Under all treatment combinations open condition recorded superiority in case of root yield per plant. This indicated the sun loving nature of *Sida alnifolia*. Ideal growing condition, nutrient availability, and reduced weed infestation in this combination might have contributed to higher root yield per plant.

TABLE 4

Interaction effect of growing condition, manuring and weed management on root biomass (g) of sida hemp

Treatments	Root biomass (g)	
	Harvest	
	Open	50% shade
No manuring x Black polythene	8.57	5.78
No manuring x Organic mulch	6.42	5.35
No manuring x Hand weeding	5.22	5.01
No manuring x No weeding	4.84	4.47
FYM @ 10t/ha x Black polythene	11.81	7.05
FYM @ 10t/ha x Organic mulch	7.82	5.92
FYM @ 10t/ha x Hand weeding	5.11	5.04
FYM @ 10t/ha x No weeding	4.94	4.57
CD (0.05)	2.44	
SE(m)	8.84	

Total Population of Bacteria, Actinomycetes and Fungi

At four MAP and at harvest, total population of bacteria (20.38 x 10^6 cfu g^{-1} and 16.92 x 10^6 cfu g^{-1}), actinomycetes (68.33 x 10^4 cfu g^{-1} and 72.75 x 10^4 cfu g^{-1}) and fungi (15.33 x 10^4 cfu g^{-1} and 18.17 x 10^4 cfu g^{-1}) were higher under open condition as compared to shaded condition (Table 5). Under 50 per cent shade, soil could receive reduced rhizodeposites by the host plant due to lower plant growth. Supply of rhizodeposites by the host plant greatly affected the size and functions of the soil microbial community (Siemannan and Roger, 2003). The higher microbial population in open condition is in accordance with higher soil microbial biomass carbon under full light intensity. Soil microbial biomass carbon had a close relationship with microbial biomass. Among manuring, FYM plots recorded higher population of bacteria (19.75 x 10^6 cfu $g^{-1}$and 16.46 x 10^6 cfu g^{-1}) actinomycetes (65.50 x 10^4 cfu g^{-1} and 68.75 x 10^4 cfu g^{-1}) and fungi.(13.54 x 10^4 cfu g^{-1} and 16.21 x 10^4 cfu g^{-1}) at 4 MAP and at harvest, respectively. According to Yassen *et al.* (2010), when farmyard manure is applied to soil, activity of soil microorganisms increases. Total population of bacteria (21.92 x 10^6 cfu g^{-1} and 19.29 x 10^6 cfu g^{-1}) and actinomycetes (66.92 x 10^4 cfu g^{-1} and 72.75 x 10^4 cfu g^{-1}) were higher under paddy straw mulch, where as fungal population (15.08 x 10^4 cfu g^{-1} and 17.25 x 10^4 cfu g^{-1}) were higher under plots without weeding. There are reports of the increased microbial population in soil under organic mulching (Kher *et al*., 2010). Organic mulching could increase the organic carbon content in the soil, which became food for the useful earthworms and microbes in the soil.

Soil Microbial Biomass Carbon

As compared to the pre experimental soil, higher soil microbial biomass carbon was observed at harvest stage (Table 5). Soil microbial biomass carbon was higher under open condition (265.25 µg g^{-1} and 287.97 µg g^{-1}) at 4 MAP and at harvest, respectively. Soil microbial biomass carbon is one of the indicators of soil microbial population. Lalfakzuala *et al*. (2006) reported a linear relationship between soil microbial population and microbial biomass carbon. Higher microbial biomass carbon was recorded in FYM applied plots as compared to no manure plots (245.29 µg g^{-1} and 274.94 µg g^{-1}) at 4 MAP and at harvest, respectively. Gogoi *et al.* (2010) observed increased microbial biomass carbon in plots applied with FYM and microbial biomass carbon increased with soil

TABLE 5

Effect of treatments on total population of bacteria, actinomycetes, fungi and soil microbial biomass carbon in the rhizosphere of Sida hemp at different growth stages

Treatments	Total population of bacteria (x106cfu g-1)		Total population of actinomycetes (x104cfu g-1)		Total population of fungi (x104cfu g-1)		Soil microbial biomass carbon (µg g-1) of soil	
	4 MAP	Harvest	4 MAP	Harvest	4 MAP	Harvest	4 MAP	Harvest
Growing condition								
Open	1.29 (20.38)	1.22 (16.92)	1.82 (68.33)	1.85 (72.75)	1.16 (15.33)	1.25 (18.17)	265.25	287.99
50% Shade	1.22 (16.83)	1.17 (14.88)	1.70 (51.00)	1.74 (55.46)	0.99 (10.96)	1.09 (12.83)	166.92	205.90
CD (0.05)	0.05	0.03	0.04	0.04	0.09	0.05	3.66	3.42
SE(m)	0.08	0.04	0.06	0.06	0.09	0.07	4.06	4.60
Manuring								
No manure	1.22 (16.46)	1.16 (14.89)	1.72 (53.83)	1.77 (59.46)	0.89 (12.75)	1.12 (14.79)	186.88	218.94
FYM @10 t/ha	1.28 (19.75)	1.21 (16.46)	1.80 (65.50)	1.83 (68.75)	1.09 (13.54)	1.19 (16.21)	245.29	274.94
CD (0.05)	0.05	0.03	0.04	0.04	0.09	0.05	3.66	3.42
SE(m)	0.08	0.04	0.06	0.06	0.09	0.07	4.06	4.60
Weed management								
Black polythene	1.22 (17.08)	1.17 (14.83)	1.76 (59.42)	1.79 (62.33)	0.87 (12.00)	1.14 (14.33)	181.50	207.93
Organic mulch	1.33 (21.92)	1.27 (19.29)	1.82 (66.92)	1.85 (72.75)	1.02 (13.08)	1.21 (16.92)	239.00	290.47
Hand weeding	1.20 (16.17)	1.17 (14.83)	1.68 (49.58)	1.73 (54.50)	0.83 (11.42)	1.10 (13.00)	134.75	161.19
No weeding	1.25 (19.25)	1.22 (16.78)	1.79 (62.75)	1.82 (66.83)	1.17 (15.08)	1.24 (17.75)	309.08	328.16
CD (0.05)	0.07	0.04	0.05	0.05	0.14	0.07	5.04	4.83
SE(m)	0.07	0.05	0.05	0.05	0.17	0.09	5.06	4.96
At sowing	14.00		63.33		17.00		95.33	

** Logarithmic transformed values, Original values are in parentheses

organic carbon. Among different weed management practices, no weeding plots (309.08 µg g^{-1} and 328.16 µg g^{-1} at 4 MAP and at harvest, respectively) recorded higher microbial biomass carbon followed by organic mulched plots. This is in line with the reports of Kher *et al.* (2010). According to them organic mulching could increase the organic carbon and microbial population under soil. This might be the reason for higher MBC under organic mulching plots.

Management methods exhibited great influence on growth and yield of Sida hemp by way of modifying rhizosphere properties. Open condition, application of FYM @ 10 t ha^{-1} and weed management by black polythene mulching can be recommended as optimum for better growth and yield for Sida hemp.

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Sulphur Status and Effect of Different Sources and Levels of Sulphur Application on Performance of Aerobic Rice (*Oryza sativa* L.)

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ABSTRACT

A survey was conducted to know the sulphur status in rice domains of Mandya district. Out of 119 soil samples collected from entire taluks of the district (4-5 samples for each hobli of all taluks), 92 samples (77.32 %) were sufficient and 27 samples (22.68 %) were deficient in sulphur content. Among the taluks, Mandya, Maddur, S.R. Patna and Pandavapura have a sufficient range of sulphur, whereas other taluks namely Malvalli, K.R. Pet and Nagamangala taluks have deficient sulphur status. Nagamangala taluk has the least sulphur status among taluks of Mandya district with all five hoblis showing deficiency range. To know the response of rice to different sources and levels of sulphur application, a field experiment was conducted during *kharif*, 2015 on sandy loam soil at the College of Agriculture, V.C. Farm, Mandya, University of Agriculture Sciences, Bangalore. The results revealed that application of RDF+FYM+26 kg sulphur ha^{-1} through ammonium sulphate recorded significantly higher grain and straw yield of 2716.45 kg ha^{-1} and 4240.49 kg ha^{-1}, respectively. Higher grain and straw yields were mainly attributed to growth parameters like higher plant height (85.87 cm), number of tillers (20.47) and number of leaves per hill (83.20) at harvest, and yield parameters *i.e.,* number of panicles per hill (15.93), length of panicle (20.03c m), number of grains per panicle (117.0), 1000 grain test weight (23.65g) and lower per cent chaffyness (6.33).

Keywords : Aerobic rice, Ammonium sulphate, Superphosphate, Elemental sulphur, Gypsum

RICE is a staple food for more than half of the world population and is generally grown by transplanting seedlings into a puddled soil in Asia. Transplanted puddled rice (TPR) is labor, water and energy intensive and is becoming less profitable as these resources are becoming increasingly scarce,especially water (Kumar and Ladha, 2011). Hence, shifting gradually from the traditional rice production system to growing rice aerobically especially in water scarce irrigated low lands can mitigate the occurrence of water-related problems. Aerobic rice system (ARS) is a new production system in which rice (*Oryza sativa* L.) is grown under unpuddled, unflooded, and unsaturated soil conditions as other upland crops (Prasad, 2011).

Paddy is one of the predominant crops in the southern dry zone (zone 6) of Karnataka and continuous paddy growing has shown evidence of soil nutrient depletion, imbalances and low nutrient use efficiency in the command area of the zone. This decline in soil fertility and productivity is attributed to the appearance of deficiencies of several plant nutrients including sulphur. Sulphur deficiency is wide spread now in India. Out of 142 million ha cultivated land in India, at least 57 m ha, that is about 40 per cent of the total, suffers from various degrees of S deficiency (Tripathi, 2003). Keeping this in view a survey was conducted to know the sulphur status in rice-growing regions of the Mandya district. Sulphur deficiency reduces crop yield and quality of the produce (Zuzhang *et al*., 2010).

In sulphur deficient soil, the application of high rates of other nutrients (N, P and K) may not result in increased yields, due to imbalances in the N/S and P/S ratios in the plants. In addition, an adequate and balanced supply of nutrients favors the proper development of crops, with a positive impact on the yield (Fageria *et al*., 2011). The application of sulphur increases growth and yields in rice (Singh *et al.,* 2012 and Jena and Kabi, 2012).Therefore, an attempt was made to study the response of aerobic rice to sources

and levels of sulphur application for achieving maximum production.

Material and Methods

Soil samples were collected from 0-15 cm depth in the paddy growing regions of Mandya district. The samples were collected randomly hobli wise (4-5 samples/hobli) and brought to the laboratory, shade dried and processed. These processed soil samples were analyzed for available sulphur content by using 0.15 per cent $CaCl_2$ extraction by turbidimetry method.

A field experiment was carried out at the College of Agriculture, V.C. Farm, Mandya during *kharif* 2015. The soil was sandy loam in texture with neutral reaction (pH 7.4), electrical conductivity was 0.14 dSm^{-1} and organic carbon content was medium (7.5 g kg^{-1}). The soil was medium in available nitrogen (439 kg ha^{-1}), phosphorus (53.86 kg ha^{-1}) and exchangeable potassium (176.4 kg ha^{-1}), with low available sulphur (5.21 mg kg^{-1}).

The experiment was laid out in Randomized Complete Block Design (RCBD) with twelve treatments and three replications. The treatment combinations consisting of five sources of sulphur fertilizers (*viz.,* Gypsum, Ammonium Sulphate, Elemental Sulphur, 20:20:0:13 and SSP) and two levels of sulphur (13 and 26 kg Sulphur) ha^{-1} from each source along with one absolute control and recommended dose of fertilizers. Here 13 and 26 kg S ha^{-1} was fixed mainly because the complex used in the experiment was 20:20:0:13 and based on 5 kg S $acre^{-1}$ as standard was fixed. The recommended quantity of FYM at the rate of 10 t ha^{-1} was applied and mixed into the soil two weeks before sowing. As per the treatments, fifty per cent of nitrogen and the entire quantity of phosphorus, potassium and sulphur were supplied at the time of sowing as a basal dose to each plot and the remaining fifty per cent of nitrogen was applied as top-dressing at 30 days after sowing. The contribution of N and P from applied S sources *viz.,* Ammonium sulphate and SSP was made good by reducing the quantity of fertilizer nutrient in respective treatment. Good quality seeds of the cultivar (Rashi) were sown manually at the rate of one seed per hill with a spacing of 25 cm × 25 cm as inter and intra row spacing. Irrigation was given as per requirement. Usually, every four to five days once irrigation was given based on the moisture prevailing in the field as per the recommendation for aerobic rice to keep optimum moisture. Three hand weedings were done to keep the plots free from weeds at 30, 45 and 60 DAS.

Results and Discussion

The mean available sulphur status of rice grown regions of the Mandya district is given in Tables 1 and 2. As per the sulphur content, the data was categorized into two groups: one is taluk with high sulphur status and the other one taluk with low sulphur status according to hobli wise.

As per the statistical analysis, in Mandya taluk sulphur concentration was significantly highest in Mandya hobli with an average mean concentration of 18.87 ppm followed by Duddha (17.16 ppm). The lowest (13.74 ppm) sulphur status was observed in Kothattihobli. In Maddur taluk, a high sulphur concentration of 15.89 ppm was in Chikkarasikere hobli followed by Koppa (15.48 ppm). The lowest (13.43 ppm) sulphur status was observed in Athagurhobli. In Malvalli taluk sulphur concentration was significantly highest in B.G. Pura hobli with an average mean concentration of 15.76 ppm followed by Halagur (15.27 ppm). The lowest of 11.72 ppm of sulphur status was observed in Kirugavaluhobli. In S.R. Patna taluk sulphur concentration of 20.22 ppm was in Arkerehobli followed by S.R. Patna (19.22 ppm). The lowest (13.63 ppm) sulphur status was observed in Belgolahobli. In Pandavapura taluk sulphur status was significantly highest in Melkote hobli with a concentration of 15.97 ppm followed by Chinnakurli (15.02 ppm). The lowest of 13.76 ppm of sulphur status was observed in Pandavapura hobli. In K.R.Pet taluk sulphur status was highest in Akki Hebbal hobli with a concentration of 22.41 ppm followed by the K.R. Pet (14.51 ppm). The lowest of 12.15 ppm of sulphur status was observed in Bukinakere hobli. In Nagamangala taluk sulphur status was significantly highest in Bellur hobli with a concentration of 14.48 ppm followed by

TABLE 1
Paddy growing areas in Mandya with high-S status

Taluks	Hoblis	Mean sulphur (ppm)	± Sd
Mandya	Mandya	18.87	5.484
	Duddha	17.16	5.627
	Basaralu	14.54	4.555
	Keregodu	14.44	2.573
	Kothatti	13.74	1.093
		15.75	**4.272**
Maddur	Maddur	13.57	1.338
	Koppa	15.48	1.442
	Athagur	13.43	1.908
	Chikkarasikere	15.89	4.800
		14.60	**2.722**
Malvalli	Malvalli	12.41	1.434
	Halagur	15.27	1.245
	Kirugavalu	11.72	0.615
	B.G.Pura	15.76	6.489
		13.71	**3.529**
S.R.Patna	S.R.Patna	19.22	3.852
	K.Shettihalli	15.23	0.416
	Arkere	20.22	6.256
	Belgola	13.63	1.947
		17.07	**4.420**
Pandavapura	Pandavapura	13.76	1.489
	Chinnakurali	15.02	4.164
	Melkotae	15.97	0.794
		14.73	**2.554**
K.R.Pet	Bukinakere	12.15	-
	Akkihebbal	22.41	3.594
	K.R.Pet	14.51	2.917
	Seelanare	14.22	0.634
		15.82	**4.888**
Nagamangala	Nagamangala	11.53	1.082
	Bindiganavile	12.29	0.000
	Bellur	14.48	0.622
	Devalapura	12.15	-
		12.74	**1.491**

TABLE 2
Paddy growing areas in Mandya with low-S status

Taluks	Hoblis	Mean sulphur (ppm)	± Sd
Malvalli	Halgur	9.11	0.863
	Kirugavalu	7.03	0.368
	B.G.Pura	7.63	0.000
		7.92	**1.158**
K.R.Pet	Bukinakere	8.85	0.240
	K.R.Pet	8.33	0.000
	Kikkeri	6.72	1.655
		7.97	**1.190**
Nagamangala	Nagamangala	8.24	0.368
	Bindiganavile	6.94	0.240
	Bellur	9.03	0.983
	Deevalapura	8.76	0.368
	Honakere	8.85	0.240
		8.36	**0.965**

Bindiganavile (12.29 ppm). The lowest (11.53 ppm) sulphur status was observed in Nagamangala hobli.

Taluk-wise hoblis deficient in available sulphur concentration are presented in Table 2. As per the statistical analysis, in Malvalli taluk the sulphur concentration was significantly more deficit in Halgur hobli with a concentration of 9.11 ppm was, followed by B.G. Pura (7.63 ppm). The lowest of 7.03 ppm of deficit sulphur concentration was observed in Kirugavalu hobli. In K.R. Pet taluk the sulphur concentration significantly more deficit in Bukanakere hobli with a concentration of 8.85 ppm, followed by K.R. Pet (8.33 ppm). The lowest of 6.72 ppm of deficit sulphur status was observed in Kikkeri hobli. In Nagamangala taluk sulphur concentration significantly more deficit in Bellur hobli with a concentration of 9.03 ppm followed by Honakere (8.85 ppm). The lowest of 6.94 ppm of deficit sulphur concentration was observed in Bindiganavile hobli.

Taluk wise sufficient in available sulphur concentration are presented in Table 1. As per the statistical analysis in the Mandya district sulphur concentration was significantly highest in S.R. Patna taluka with an

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average mean concentration of 17.07 ppm followed by K.R. Pet (15.82 ppm). The lowest of 12.74 ppm of sulphur status was observed in Nagamangala taluk. As per the statistical analysis, the overall per cent of the highest sulphur concentration was observed in S.R. Patna taluk.

Taluks, deficient in available sulphur concentration are presented in Table 2. As per statistical analysis in Mandya district, the sulphur concentration was significantly more deficit in Malvalli taluk with a concentration of 7.92 ppm followed by K.R. Pet (7.97 ppm). 8.36 ppm of sulphur status was observed in Nagamangala taluk. As per the statistical analysis, the overall per cent of lowest sulphur status was observed in Malvalli taluk.

In the field experiment sulphur application at different levels through different sources significantly influenced the growth and yield parameters of aerobic rice. The growth parameters of aerobic rice *viz.,* plant height (cm), number of tillers per hill, number of leaves per hill, as influenced by different sources and levels of sulphur at different growth stages are presented in Table 3.

Plant Height

The plant height (cm) of aerobic rice was significantly influenced by various levels and sources of sulphur application at all the growth stages and the same is presented in Table 3. At 30, 60, 90 DAS and harvest, significantly higher plant height (27.13 cm, 59.73 cm, 77.93 and 85.87 cm, respectively) was observed with RDF + 26 kg sulphur per hectare through ammonium sulphate (T_6 treatment). Significantly lowest plant height was observed in absolute control (21.33 cm, 46.40 cm,67.07 and 74.13 cm, respectively).

Number of Tillers per Hill

The results on the number of tillers per hill of aerobic rice, as influenced by different sources and levels of sulphur at different growth stages are presented in Table 3. The number of tillers per hill varied significantly by different sources and levels of sulphur at all growth stages. At 30, 60, 90 DAS and at harvest, a significantly higher number of tillers (12, 15.8, 19.07 and 20.46 hill^{-1}, respectively) were observed with RDF + 26 kg sulphur per hectare through ammonium sulphate (T_6 treatment). Significantly lower numbers of tillers (7.13, 11.33, 14.73 and 17 tillers hill^{-1}) were observed under absolute control.

Number of Leaves per Hill

The data on a number of leaves hill^{-1} recorded at 30, 60, 90 DAS and at harvest as influenced by the application of different levels and sources of sulphur are presented in Table 3. The effect of different levels and sources of sulphur on the number of leaves per hill in aerobic rice crops was significant. At 30 and 60 DAS significantly the lower number of leaves hill^{-1} (27.27 and 40.37, respectively) was recorded in T_1 treatment (absolute control) and a significantly higher number of leaves hill^{-1} (49 and 65.07, respectively) was recorded in T_6 treatment.

Similarly, at 90 DAS and harvest, T_6 treatment (RDF + 26 kg sulphur per hectare through ammonium sulphate) registered a significantly higher number of leaves hill^{-1} (79.47 and 83.20, respectively) and it is at par with T_5 treatment (77.33 and 81.27, respectively) as compared to absolute control (59.67 and 66.93, respectively).

The plant height, the number of leaves per plant and the number of tillers per plant increased due to the application of S through different sources and levels of sulphur. In the effect among sources of sulphur, ammonium sulphate followed by elemental sulphur had a significant influence and was relatively better than other sources. With regard to levels, the highest growth parameters were recorded with the highest level of sulphur application @ 26 kg ha^{-1}. The two levels of S application varied significantly in their effect on growth components of aerobic rice.

The highest plant height, number of tillers per plant and number of leaves per plant was observed in T_6 treatment (RDF + FYM + 26 kg S per hectare through ammonium sulphate) at all the growth stages of plant 30, 60, 90 DAS and at harvest (Table 3). This could be attributed to the availability of nutrients in the root

TABLE 3

Effect of different sources and levels of sulphur on plant height, number of tillers and number of leaves per hill of aerobic rice

Treatments	Plant height (Cm)				No of tillers per hill				Number of leaves per hill			
	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest
T_1 - Absolute control	21.33	46.40	67.07	74.13	7.13	11.33	14.73	17.00	27.27	40.37	59.67	66.93
T_2 - RDF+FYM	21.87	46.40	67.47	75.07	9.87	11.93	15.00	17.13	28.87	41.87	64.00	70.27
T_3 - T_2+13 kg S ha^{-1} (Gypsum)	22.07	48.27	68.93	76.20	8.47	12.53	16.00	17.20	33.40	43.40	61.53	70.47
T_4 - T_2+26 kg S ha^{-1} (Gypsum)	23.47	51.13	69.67	81.67	7.67	13.67	17.30	17.67	35.67	55.67	64.47	72.53
T_5 - T_2+13 kg S ha^{-1} (Ammonium sulphate)	25.87	57.60	75.13	82.93	12.00	13.63	17.40	17.67	45.07	62.07	77.33	81.27
T_6 - T_2+26 kg S ha^{-1} (Ammonium sulphate)	27.13	59.73	77.93	85.87	10.07	15.80	19.07	20.47	49.00	65.07	79.47	83.20
T_7 - T_2+13 kg S ha^{-1} (Elemental sulphur)	21.80	49.07	68.20	77.93	8.40	12.20	16.20	17.53	30.30	43.67	64.33	71.47
T_8 - T_2+26 kg S ha^{-1} (Elementalsulphur)	23.00	50.87	74.07	78.87	8.00	12.67	16.43	17.60	31.00	49.60	67.47	73.33
T_9 - T_2+13 kg S ha^{-1} (20:20:0:13)	21.93	47.33	67.67	75.67	7.87	12.27	15.93	16.87	31.60	50.00	70.27	77.87
T_{10} - T_2+26 kg S ha^{-1} (20:20:0:13)	22.60	47.80	70.20	80.13	7.67	12.87	16.93	17.33	33.20	55.00	71.73	77.00
T_{11} - T_2+13 kg S (SSP)	22.27	49.00	68.27	77.47	10.40	12.40	16.13	17.20	32.93	59.33	70.27	74.89
T_{12} - T_2+26 kg S (SSP)	23.93	51.13	70.87	80.93	8.93	13.87	17.40	17.73	41.80	60.20	72.67	79.47
SEm±	0.89	2.30	2.17	2.34	0.49	0.41	0.52	0.54	1.07	2.18	2.17	2.31
CD (p=0.05)	2.64	6.82	6.43	6.94	1.45	1.21	1.55	1.61	3.16	6.49	6.45	6.85

zone of plants, where plants were able to utilize maximum nutrients. The superiority of ammonium sulphate over other sources of sulphur is mainly due to the agronomic efficiency of the fertilizer. The research findings also proved that combined application of nitrogen with sulphur source in chemically bound form proved better compared to the individual application of nitrogen and sulphur to the soil. Results of Fageria *et al.* (2011) also reported that ammonium sulphate is the most efficient source of fertilizer for paddy, which outperformed in all growth attributing characters of paddy by producing about two per cent higher plant height, four per cent higher shoot dry weight compared to urea as a source of N. Further they reported that in upland rice maximum plant height was achieved at 260 mg N kg^{-1} ammonium sulphate. Ahmed *et al.* (1989) also reported similar findings that sulphur fertilization to rice on clay loam soils produced a significantly higher number of tillers per plot.

Yield and Yield Components of Aerobic Rice

The data on yield components *viz.*, a number of panicles per hill, length of the panicle, the total number of grains per panicle, thousand-grain weight, per cent chaffyness, straw yield and grain yield of aerobic rice as influenced by different levels and sources of sulphur application are presented in Table 4.

Significantly greater number of panicles (15.93 $hill^{-1}$) was recorded in T_6 treatment (RDF + 26 kg sulphur per hectare through ammonium sulphate), followed by T_5 and T_{12} treatments (15.47 and 15.20 $hill^{-1}$, respectively). However, a lower number of panicles per hill was recorded in T_1 treatment, absolute

TABLE 4

Effect of different sources and levels of sulphur on yield parameters and yield of aerobic rice

Treatments	No of panicles /hill	Length of the panicle (cm)	No of grains / Panicle	Test Weight (g)	% Chaffyness	Straw Yield (kg ha^{-1})	Grain Yield (kg ha^{-1})
T_1 - Absolute control	12.33	17.23	76.53	20.05	11.67	3037	1999
T_2 - RDF+FYM	13.07	17.41	83.00	20.66	10	3116	2087
T_3 - T_2+13 kg S ha^{-1} (Gypsum)	13.93	18.02	83.53	20.84	7.67	3182	2116
T_4 - T_2+26 kg S ha^{-1} (Gypsum)	15.00	19.37	86.40	21.46	6.67	3294	2214
T_5 - T_2+13 kg S ha^{-1} (Ammonium sulphate)	15.47	18.48	107.80	22.80	7.00	3826	2564
T_6 - T_2+26 kg S ha^{-1} (Ammonium sulphate)	15.93	20.03	117.00	23.65	6.33	4240	2717
T_7 - T_2+13 kg S ha^{-1} (Elemental sulphur)	14.60	17.63	89.07	20.71	7.33	3721	2209
T_8 - T_2+26 kg S ha^{-1} (Elementalsulphur)	15.07	17.79	98.33	21.54	6.67	3774	2302
T_9 - T_2+13 kg S ha^{-1} (20:20:0:13)	13.53	18.02	83.73	21.01	8.33	3121	2286
T_{10} - T_2+26 kg S ha^{-1} (20:20:0:13)	14.53	18.16	92.33	21.25	8.0	3639	2428
T_{11} - T_2+13 kg S (SSP)	14.27	18.47	91.20	21.77	7.0	3734	2337
T_{12} - T_2+26 kg S (SSP)	15.20	19.50	100.60	22.31	8.33	3899	2440
SEm±	0.61	0.57	2.71	0.64	_	243.14	123.40
CD (p=0.05)	1.82	1.71	8.05	1.91	_	722.07	366.49

control (12.33 hill^{-1}). Application of RDF + 26 kg sulphur per hectare (T_6 treatment) registered significantly higher panicle length (20.03 cm), followed by T_{12} and T_4 treatments (19.50 and 19.37 cm, respectively). Treatment T_1 (absolute control) recorded the lowest panicle length of 17.23 cm. Different levels and sources of sulphur had a significant effect on the number of grains per panicle of aerobic rice. The significantly higher number of grains per panicle (117) was recorded in T_6 treatment followed by T_5 and T_{12} treatments which were on par with each other. However, the lowest number of grains per panicle was observed in absolute control T_1 (76.53).

Different levels and sources of sulphur exerted a significant influence on thousand-grain weight (g) in aerobic rice. The highest thousand-grain weight (23.65 g) was recorded in T_6 treatment and was at par with T_5 and T_{12} treatments (22.80 and 22.31 g respectively). However, the lowest thousand-grain weight (20.05 g) was noticed in absolute control. Numerically lowest chaffy grain percentage (6.33) was recorded in T_6 treatment (RDF + 26 kg sulphur per hectare through ammonium sulphate) and the highest chaffy grain per cent was noticed under absolute control (11.67).

Grain and Straw Yield

The grain and straw yield of aerobic rice as influenced by different levels and sources of sulphur is presented in Table 4. A significantly higher straw yield (4240 kg ha^{-1}) was recorded with T_6 treatment followed by T_{12} and T_5 treatments (3899 and 3826 kg ha^{-1}, respectively). The absolute control recorded the lowest straw yield of 3037 kg ha^{-1}. Grain yield of aerobic rice varied significantly with different levels and sources of sulphur treatments. RDF + 26 kg sulphur per hectare through ammonium sulphate recorded significantly higher grain yield (2717.85 kg ha^{-1}) and was on par with T_5, T_{10} and T_{12} treatments. However, the lowest grain yield was recorded under absolute control (1999 kg ha^{-1}).

The growth and yield of aerobic rice differed significantly by the application of suplur and further increased with increased doses. In the effect among sources of sulphur, Ammonium Sulphate followed by elemental Sulphur had a significant influence and relatively better than other sources, which indicated the better utilization of all nutrients due to ammonium sulphate application and hence moregrains. Further, the lowest percent chaffyness was also observed under ammonium sulphate treatment and these are confirmed with the results of Fageria *et al.* (2011), which reported that ammonium sulphate accounted for 70 per cent variability in panicle number, produced 12 per cent lower spikelet sterility and highest 1000 grain test weight of 22.7 g over other treatments and also concluded that ammonium sulphate was superior fertilizer for panicle production. The increased number of panicles per hill, panicle length, and higher test weight in treatment T_6 have contributed to significantly higher yield, which in turn increased growth parameters in this treatment.

As per the statistical analysis, among the 119 soil samples analysed for available sulphur content of paddy growing areas of Mandya district ninetytwo (77.32 %) samples were found sufficient and twenty seven (22.68 %) samples were deficit. In different taluks of Mandya district, four taluks *i.e.,* Mandya, Maddur, S.R. Patna and Pandavapura have recorded a sufficient range of sulphur status, whereas in other taluks namely Malvalli, K.R. Pet and Nagamangala taluks with deficient sulphur status were observed. Nagamangala taluk has the least sulphur status among all the taluks of Mandya district with all the five hoblis showing deficiency range of sulphur status. Overall the Mandya district has a good amount of sulphur content in paddy growning soil sand the high status of sulphur in these soils may be due to the application of sulfur-containing fertilizers and because of application of $ZnSO_4$ to soil and low sulphur use efficiency because of continuous paddy cultivation in most of the taluks of Mandya district. This has resulted in a buildup of sulphur in these soils.

Based on the present findings, it is concluded that irrespective of the sources, the increase in S levels (13 to 26 kg/ha) resulted in significant improvement in growth and yield attributes. The sulphur application

@ 26 kg/ha applied through ammonium sulphate improved growth and yield attributes and hence grain yield of aerobic rice. Among different sources of sulphur ammonium sulphate performed better.

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Microbial Fermentation of Blended Jackfruit Juice for Quality Improvement of Jackfruit Wine

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Abstract

Jackfruit (*Artocarpus heterophyllus* Lam) is one of the important underutilized fruit which is known for its therapeutic and nutritive values and available plenty during season. The experiment on microbial fermentation jackfruit juice blending with different juices *viz.,* pineapple (20 and 25 %), amla (10 and 15 %) and aloevera (5 and 10 %) by yeast strain *Saccharomyces cereviceae* MTCC 170 was carried out for quality improvement of jack fruit wine. The results revealed that the jackfruit juice blending with amla juice (10 and 15 %) significantly influenced reduction of pH (3.16) and TSS (6.25), highest titrable acidity (0.52), vitamin C (193.3 mg), alcohol (12 %) and overall acceptability (16.33/ 20.0) compared to pine apple and aloevera blending. Jackfruit juice blending with 15 per cent amla juice improved the nutritional and sensory quality of jackfruit wine.

Keywords : Jackfruit juice, Blending, Yeast, Fermentation, Wine

Jackfruit (*Artocarpus heterophyllus* Lam) is one of the important underutilized fruit which is known for its therapeutic and nutritive values with an excellent flavor and attractive colour. It is widely cultivated in Malaysia, Myanmar, Bangladesh, Sri Lanka, Brazil, Phillipines, West Indies, Pakistan and other tropical countries. Jackfruit is grown throughout Karnataka especially in coffee and tea estates of Western Ghats, southern plains and Malnad region in an area of about 11,333 ha producing about 2.60 lakh tonnes of fruits per annum (Anonymous, 2000). There are several research reports on wine making process from different major and minor fruits by different research workers. In order to meet the diversity of consumer needs, extensive researches have been carried out to find other possible sources of wine making process from different fruits like banana, pineapple (Isitua and Ibeh, 2010), kiwi (Duarte *et al*., 2010), apple (Polychroniadou *et al*., 2013), orange (Selli *et al*., 2008), cashew apple (Attrii, 2009), pomegranate (Sevda and Rodrigues, 2011), jackfruit (Kumoro *et al*., 2012 and Dushyanth *et al*., 2006) and other fruit juices. The wine quality depends on variety, composition of fruits and efficiency of yeast strain used (Ethiraj and Suresh.,1993). However, there is paucity of information on processing of underutilized jackfruit for wine production. Good quality of wines can be prepared by blending with musts of different fruits or fruits of different cultivars of the same fruit (Timofeev and Krechetov, 1998). There are number of grape wine varieties with unique and distinct flavours. Ethiraj and Suresh (1993) prepared good quality of sweet wines by mixing mango pulp with seedless grape must in the ratio of 1:1 with pronounced mango flavour. Similarly, Suresh *et al*. (1983) reported that quality of blended wines from mixing of gulabi variety of grape with musts of rubi red, thompson seedless and anab-E-shahi in different ratios. Keeping in view of the above facts, the study was under taken to improve the quality of jackfruit wine by blending with other fruit juices.

Material and Methods

Preparation of Jackfruit Juice and Blended Juice

Well matured, ripe and healthy jack fruits of hard flesh jackfruits were procured from Doddaballapura, Bengaluru North. The selected fruits were cut along their equatorial axis with the help of a sharp knife smeared with edible oil. The bulbs were carefully separated from the rind and placenta. Care was taken to handle the bulbs with minimum damage. The bulbs were cut into small pieces and using a mixer grinder

made into fine slurry in the form of pulp. The pulp was blended by addition of water (1:3.5 ratio), sugar (TSS was adjusted to 20^0 Brix), potassium metabisulphite @ 200 ppm was added to suppress wild yeast present in the juice and homogenized juice was heated to 60 – 70 ^{0}C for five minutes and the same was used for further experiment.

Blending with other Fruits: Per cent pulp percentage was calculated for the preparation of blended jackfruit juice.

Amla Fruits: Fresh amla fruits measuring about 2.5 cm in diameter were collected from the local market and were washed in clean water and were processed into pulp.

*Aloevera***:** Aloevera leaves were collected from Regional Research Station, GKVK, Medicinal and Aromatic Garden and colourless gel was extracted from the leaves and the same was used for blending with jackfruit pulp.

Pineapple: Well ripe healthy pine apple fruit was procured from the local market and processed into pulp and same was used for the study.

Preparation of Blended Juices: Grinded and filtered juice from well ripen pineapple and amla were used for the study. Direct jelly extract of aloevera is used for blending.

Preparation of Starter Cultures of Yeast: A loop full of purified inoculum yeast culture was transferred to YEPDA broth containing in 250 ml conical flasks and were incubated overnight at 28 ^{0}C for growth. This yeast culture was containing 10^7 cfu/ml and same was used for inoculation.

Treatment details

Treatments	
T1	Jack fruit juice only (100 %) + yeast
T2	Jackfruit juice (80 %) + Pine apple juice (20 %) + yeast
T3	Jackfruit juice (75 %) + Pine apple juice (25 %) + yeast
T4	Jackfruit juice (90 %) + Amla juice (10 %) + yeast
T5	Jackfruit juice (85 %) + Amla juice (15 %) + yeast
T6	Jackfruit juice (95 %) + Aloevera juice (05 %) + yeast
T7	Jackfruit juice (90 %) + Aloevera juice (10 %) + yeast

Replications: 3

Fermentation

The starter culture of yeast strain containing 10^7 cfu/ml was inoculated at three per cent (v/v) for fermentation of different blended jackfruit juice of 300 ml contained in a 500 ml conical flasks. The inoculated flasks and control flasks were plugged with rubber cork with bent tube and kept for fermentation for six days under room temperature (27-30 ^{0}C).

Filtration

After six days of fermentation, the fermented juice was filtered through muslin cloth and the filtrate was kept in sterilized glass bottles. The filtrate fermented juice was subjected for biochemical and sensory analysis by following standard procedures

Biochemical Analysis

pH: The pH of the fermented jackfruit samples was determined using a digital pH meter (YORCO pH meter, model: YSI - 601). The pH meter was standardised with buffer solutions of different pH (4.0, 7.0, and 10.0) were used to calibrate the instrument. Each sample was replicated three times and its mean value was taken as pH of the sample (Sadasivam and Manickam, 1996).

Titrable acidity: Fresh filtered homogenised pulp10g was made up to 100 ml with distilled water. From this 10 ml of the prepared solution was titrated against 0.1N NaOH solution using phenolphthalein as indicator. The appearance of a light pink colour was the end-point that quantifies the NaOH required to neutralise the juice. The titrable acidity was calculated and expressed as per cent citric acid (Srivastava and

Kumar, 1993). Amount of titrable acidity present in 100 g of sample was calculated.

Total soluble solids: Total soluble solid (TSS) was measured using a hand refractometer. One or two drops of juice were placed on the hand refractometer for TSS measurement. It was expressed in degree Brix (Ranganna, 1995).

Ascorbic acid: Ascorbic acid was determined by dye method (Sadasivam and Manickam, 1992).

Estimation of reducing sugars: The reducing sugars was estimated by following the method as given by Shaffer-Somagyi micro method (A.O.A.C.,1980).

Estimation of total sugars: Twenty-five ml of filtrate was taken in a 50 ml volumetric flask. 5 ml of HCL and water in the ratio of 1:1 was added. The content were allowed to stand for 24 hr at room temperature. After 24 hr, the content were neutralized exactly with NaOH using Phenolphthalein as an indicator and the volume was made up with water. An aliquot was taken and the invert sugars as in case of reducing sugars were determined as per the method followed by (Sadasivam and Manickam, 1996).

Estimation of alcohol: Alcohol was estimated calorimetrically as described by Caputi *et al*. (1968).

Colour: Hunter Lab colourimeter (Mini Scan XE Plus) was used for the colour measurement in the study. It works on the principle of collecting the light and measures energy from the sample reflected across the entire visible spectrum. The sample colour was measured by filling the cut samples of fermented jackfruit juice in the transparent cup without any void space. The deviation of colour of samples from the standard were observed and recorded in the computer interface. Each sample was replicated three times and the average value of 'L', 'a' and 'b' were determined. (Clydesdale, F. M., 1978).

Organoleptic evaluation: The developed fermented beverage from blended jackfruit juices were evaluated by selected five panel members with 20 point hedonic scales (Amerine *et al.,* 1972) was taken into consideration, which was based mainly on the appearance, color, aroma, taste and acceptability.

Statistical analysis: The data obtained from the investigation was subjected to analysis of variance by completely randomized design, the treatment difference were separated at one per cent significance level using factorial Complete Block Design.

Results and Discussion

The results of the fermentation of jackfruit blended juices on quality with respect to pH, TSS, acidity, pattern of total sugars utilization and alcohol production, colour and sensory attributes is discussed here under.

pH: Changes in pH and TSS of the fermented blended jackfruit juice as influenced by with and without blending are presented in Table 1. The results revealed that the initial pH of the jackfruit juice was 5.18, when it was blended with different proportions of other fruit juices it varied from 4.96 to 5.18. Jackfruit juice blending with 15 per cent amla juice recorded lowest pH (4.96) compared to other treatments. After six days of fermentation, the change in pH varies from 3.16 to 4.1. The results indicating that jackfruit juice blending with amla juice significantly influences on pH in the fermented jackfruit juice. pH of wines depends upon the acids and sugar contents in the fruits which influences on fermentation. Jackfruit wine blended Amla showed a pH 3.16 indicating that organic acids present in the fruits and increase in the acidity. Fermentative activity of yeast only reduced the pH level compared to uninoculation, mainly due to the utilization of sugar to alcohol and acids in Amla wine and these results supports the work of Soni *et al.* (2009) reduction of pH by fermentation in amla wine.

TSS (°Brix): The initial TSS of the jackfruit juice with blending varies from 19.90 - 20.63. After six days of fermentation the change in TSS (brix) of the fermented jackfruit juice varies significantly from 6.25 - 7.70 between the treatments. Upon the fermentation the TSS of blended jackfruit juice decreases as shown in Table 1. The TSS of the fermented product with Amla 15 per cent blending (6.25 brix). Utilization of sugars

TABLE 1

Changes in pH and TSS of the fermented jackfruit juice as influenced by blending of other fruit juices

Treatments	pH		TSS (brix)	
	Initial	After fermentation	Initial	After fermentation
T1 - Jack fruit juice only + yeast	5.18	4.11	19.90	7.70
T2 - Jackfruit juice + pine apple juice (20%) + yeast	5.04	3.98	20.63	7.07
T3 - Jackfruit juice + pine apple juice (25%) + yeast	5.06	3.97	19.90	7.00
T4 - Jackfruit juice + amla juice (10%) + yeast	4.96	3.24	20.03	6.47
T5 - Jackfruit juice + amla juice (15%) + yeast	4.98	3.16	19.90	6.25
T6 - Jackfruit juice + aloevera juice (5%) + yeast	5.02	3.97	20.05	7.35
T7 - Jackfruit juice + aloevera juice (10%) + yeast	5.04	3.96	20.05	7.40
M	5.04	3.77	20.07	7.03
SEm±	0.019	0.044	0.148	0.193
CD (p=0.05)	0.058	0.134	0.450	0.585
CV%	0.661	2.038	1.280	4.751

by the yeasts in juice results in production of alcohol (8.5 %) and lowering of TSS (6.25 %) of the wine. This could be due to fermentation efficiency and sugar conversion capacity by the yeast (Vyas and Kochhar (1993) as observed in apricot wine.

Titrable acidity

The changes in titrable acidity (%) and vitamin C of the fermented jackfruit juice as influenced by blending of other juices are indicated in Table 2 . The initial titrable acidity of the jackfruit juice significantly blended with other juices varies between 0.14 to 0.38. After six days of yeast fermentation, acidity varies from 0.21

TABLE 2

Changes in titrable acidity and vitamin C of the fermented jackfruit juice as influenced by blending of other fruit juices.

Treatments	pH		TSS (brix)	
	Initial	After fermentation	Initial	After fermentation
T1 - Jack fruit juice only + yeast	0.18	0.29	1.10	0.95
T2 - Jackfruit juice + pine apple juice (20%) + yeast	0.24	0.38	1.95	1.79
T3 - Jackfruit juice + pine apple juice (25%) + yeast	0.30	0.41	1.60	1.17
T4 - Jackfruit juice + amla juice (10%) + yeast	0.38	0.52	22.33	19.33
T5 - Jackfruit juice + amla juice (15%) + yeast	0.37	0.52	20.67	17.53
T6 - Jackfruit juice + aloevera juice (5%) + yeast	0.18	0.24	1.60	1.37
T7 - Jackfruit juice + aloevera juice (10%) + yeast	0.14	0.21	1.50	1.13
M	0.25	0.37	7.25	6.18
SEm±	0.011	0.005	0.180	0.152
CD (p=0.05)	0.034	0.015	0.545	0.461
CV%	7.612	2.363	4.296	4.262

- 0.52 between the treatments. Upon completion of yeast fermentation of blended jackfruit juice, the enhancement of titrable acidity is more important in the fermented products, the highest titrable acidity (0.52 %) was recorded in the jackfruit blended with Amla juice treatments, whereas least acidity enhanced in the treatments blended with Aloevera. This indicated the availability of fermentable sugar favouring yeast in Amla compared to other blended juices in which there was no significant variation in biochemical constituents. These results are in line with the observation made by Nandagopal and Nair (2013) in wine from ginger and Indian gooseberry.

Vitamin C

The initial vitamin C content of the jackfruit juice blending with other fruit juices varied from 5.10 to

223.3 mg/100g between the treatments, after six days of yeast fermentation. The reduction of vitamin C varied from 0.95 - 193.3 mg / 100 mg between the treatments which differed significantly. Upon completion of yeast fermentation of blended jackfruit juice, the vitamin C content varied from 11.13 to 193.3 mg/100g between the treatments (Table 2). The highest vitamin C (193.3 mg) was recorded in the jackfruit juice blended with 10 per cent Amla juice followed by treatment (175.3 mg). The least vitamin C content was observed in the jackfruit juice without blending and blend with aloevera juice. The reduction in vitamin C content indicates that yeast utilized vitamin C required for the metabolism and growth during fermentation which is observed by Nandagopal and Nair (2013) in the study of ginger and Indian gooseberry.

Total Sugar per cent and Alcohol per cent

The initial mean value of total sugar level was 19.37 per cent between the treatments. After six days of fermentation, total sugar content varied between the treatments in the range of 6.18 to 7.47 per cent which were found to be significant each other. Utilization of sugar is indicative of growth and fermentative efficiency of the yeast. Low total sugar per cent (6.18 %) in the treatment T5 *i.e.,* blended with 15 per cent Amla is due to high fermentative character of the yeast. however some amount of sugar was left in the fermentation juice after fermentation process where in the highest total sugar (7.47 %) was observed in the treatment without blending indicating the low sugar utilization efficiency when compared to blended juice fermentation.

The alcohol production in the blended jackfruit wine samples is presented in Fig. 1. The highest alcohol per cent (12 %) was obtained with jackfruit juice blended with 15 per cent amla juice followed by treatment (10 %). Alcohol content in the final product is an important factor in determining the quality of wine. The highest alcohol (12 %) was obtained with jackfruit juice blended with 15 per cent Amla juice followed by the treatment (10 per cent Amla) which is proportionate to decline in TSS brix (6.25) which showed a

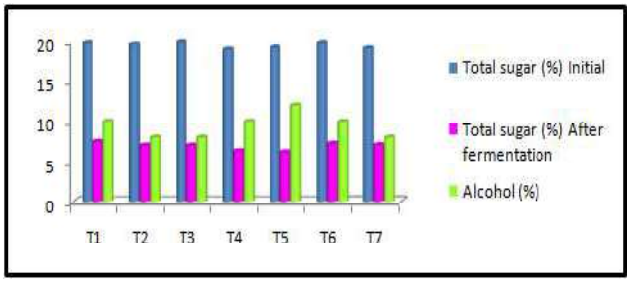

Fig. 1 : Total sugar utilization and alcohol production of the fermented jackfruit juice as influenced by with without blending of other fruit juices

favourable for fermentative yeasts in the mix. This observation is in agreement with reports of Borate *et al*. (2008), Ethiraj and Suresh (1987) in fermented blended grape juice and with data reported by Soni *et al.* (2009) in *Amla* wine.

The pattern of total sugar utilization and alcohol production in the fermented jackfruit juice with and without blending is presented in Fig.1.

Fig. 1 represents alcohol content has increased more in the JF blending with amla juice which is proportionate to decline in TSS brix in the final product is an indication of effective activity of yeasts during the fermentation process. The probable reason could be the fruit juices having relatively lower levels reducing sugars

Colour

The results for visual perception of colour is represented by three axes value (L), hue (a) and chroma (b) of hunter calorimeter, the L and b values decide the quality of the fermented products. The highest L and b values were recorded for the amla blended wine (88.28 and 8.69), followed by treatment only jackfruit wine (89.36 and 5.50) which indicate good quality of the product. Blending has increased the colour of wine that might be due to the combined effect of components of both the wines.This is supported by the work of Patil and Shibamoto (2003) in blended wines from pomegranate.

Organoleptic Evaluation

Fermented beverage used for human consumption should be evaluated by organoleptic procedure as they have pleasant aesthetic refreshing qualities due to their

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TABLE 3

Colour variation of the fermented jackfruit juice as influenced by with and without blending of other fruit juices

Treatments	colour		
	L*	a*	b*
Jack fruit juice only + yeast	89.36	-0.20	5.51
Jackfruit juice + pine apple juice (20%) + yeast	82.36	0.63	14.3
Jackfruit juice + pine apple juice (25%) + yeast	86.73	-0.18	9.73
Jackfruit juice + amla juice (10%) + yeast	88.28	-0.41	8.69
Jackfruit juice + amla juice (15%) + yeast	88.28	-0.08	8.50
Jackfruit juice + aloevera juice (5%) + yeast	85.35	-0.54	5.00
Jackfruit juice + aloevera juice (10%) + yeast	87.32	-0.52	4.03

color and tactile sensation. Therefore it is essential to go for organoleptic evaluation. Taste varies from person to person some people may like fermented beverage with more alcohol content, some may like fermented beverage having more sweet taste. Based on that, the taste of fermented beverage prepared from with and without blended jackfruit juice was analysed for organoleptic evaluation on different parameters.

Organoleptic evaluation of fermented jackfruit product indicated that in general, the products acceptance is good with blending of Amla at 15 and 10 per cent. Jackfruit juice blending with Amla with 15 per cent had highest score (16.33 out of 20.0) followed by jackfruit juice blending with 10 per cent Amla with 15.34 out of 20. The least score was recorded in the juice without blending and with aloevera blending. Amla may be helping in modulating acidity as well as alcohol production and creating sweetness for better acceptability. Jackfruit juice blending with Amla fermented by yeast was found to be very superior in characteristics like appearance, aroma, colour, flavour and general quality.

TABLE 4

Organoleptic evaluation of fermented jackfruit juice as influenced by blending of other fruit juices (mean average of 10 judges)

Treatment	Appearance (2)	Colour (2)	Aroma (2)	Bouquet (1)	Vinegar (2)	Total acidity (2)	Sweetness (2)	Body (1)	Alcohol (2)	Astringenc (2)	General quality (2)	Overall acceptability (20)
T1	1.50	1.50	1.95	0.9	1.0	1.75	1.2	0.75	1.25	1.25	1.25	14.55
T2	1.85	1.95	1.75	1.0	1.0	1.45	1.0	0.70	1.00	1.5	1.0	13.72
T3	1.80	1.75	1.75	1.0	1.0	1.45	1.0	0.70	1.00	1.5	1.0	13.45
T4	2.0	2.0	2.0	1.0	0.5	2.0	1.2	0.90	1.50	1.0	1.5	16.33
T5	1.62	2.0	1.62	1.0	0.5	2.0	1.2	0.90	1.50	1.0	1.5	15.34
T6	1.50	1.7	1.47	1.0	0.75	1.5	0.9	0.85	1.00	1.5	0.75	12.92
T7	1.60	1.5	1.65	0.9	0.75	1.25	0.95	0.85	1.00	1.5	0.75	12.71

T1 - Jack fruit juice only + yeast : T2 - Jackfruit juice +pine apple juice (20%) + yeast : T3 - Jackfruit juice +pine apple juice (25%) + yeast
T4 - Jackfruit juice +amla juice (10%) + yeast : T5 - Jackfruit juice +amla juice (15%) + yeast : T6 - Jackfruit juice + aloevera juice (5%) + yeast
T7 - Jackfruit juice + aloevera juice (10%) + yeast

The results clearly indicated that the jackfruit juice blending with Amla has improved all sensory attributes of colour, appearance, taste, aroma, body, alcohol, general quality and overall acceptability of wine, this might be due to the combined effect of chemical components of jackfruit and Amla fruits. Similar results were reported by Patil and Shibamoto (2003) in blended wines from pomegranate. Blended wine of mango pulp (Suresh and Ethiraj ,1983) and Thompson seedless grapes, (Chowdhury and Ray, 2007) in jamun wine.

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Effect of Irradiation and Packaging on the Shelf Life of Foxtail Millet Flour

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Abstract

The use of irradiation alone as a preservation technique will not solve the problems of post-harvest food losses but it can play an important role in cutting losses in many cases when used judiciously along with good packaging. Hence, the study was planned to irradiate the foxtail millet flour at 1.5 kGy (IR) and stored in different packaging materials (LDPE, PP, PET and MPP) for a period of three months by taking flour stored without irradiation in steel box as control. Set of flour packed in different packaging materials (LDPE, PP, PET and MPP) without irradiation served as non-irradiated sample (NIR). Every fortnight the samples in three different treatments were drawn for biochemical changes (moisture, peroxide value and FFA), insect infestation and microbial growth. Significantly higher increase of moisture, peroxide value and FFA content was noticed in control sample followed by non irradiated PP and LDPE packed flour. Insect infestation started after 30 and 45 days of storage in steel boxes and non irradiated PP, LDPE covers, respectively, while no infestation of insects in case of MPP and PET packed flour. Further, significantly less biochemical changes (moisture, peroxide value and FFA) without fungal growth was noticed in irradiated MPP and PET packed samples. Thus, the foxtail millet flour stored in MPP and PET pouches with irradiation dose of 1.5 kGy was found suitable for safe storage up to three months under room temperature.

Keywords: Peroxide value, Insect infestation, Free fatty acids, Irradiation, Foxtail millet

India is the world's largest producer of millets. Millets are important crops of Asia and Africa (especially in India, Nigeria and Niger) with 97 per cent of millet production occurring in developing countries (McDonough *et al*., 2000). Millets have been considered as important food staples in human history. They have been in cultivation in East Asia for the last 10,000 years. National Nutrition Monitoring Bureau has reported that the consumption of millets was higher in the states of Gujarat (pearl millet, maize), Karnataka (finger millet), Maharashtra (sorghum) but negligible in the states of Kerala, Orissa, West Bengal and Tamil Nadu where rice is the most consumed cereal (NNMB, 2006). Millets contain 60-70 per cent carbohydrates, 7-11 per cent proteins, 1.5-5 per cent fat and 2-7 per cent crude fibre and are also rich in vitamins and minerals. They are excellent source of vitamin B, magnesium and antioxidants. Milles are also a good source of other dietary minerals like manganese, phosphorus and iron. Millet proteins are good source of essential amino acids except lysine and threonine but are relatively high in sulpture containing amino acids methionine and cysteine and are gluten free (Singh *et al.,* 2012). Foxtail millet is grown in china, Bangladesh and India. It requires warm weather and matures quickly in the hot summer months. They are nutritionally comparable or even superior to staple cereals such as rice and wheat in protein, fat and fiber contents (Gopalan *et al*., 2004).

Due to increasing awareness of consumers regarding advantages of consumption of millet based staple foods, the production, availability and access plays a key role towards increasing consumption. The major drawback of millet consumption is its smaller grain size, accidental addition of pebbles or stones, lack of availability of processing machinery at local places and non-awareness of women folk regarding methods of cooking that has made it difficult for production of recipes. In addition to this, increased availability of preferred cereals such as rice and wheat at subsidized prices also contributes for lesser usage. However, with

the support of governments, the area under millets is increasing now-a-days so millet consumption has also increased among urban consumers due to awareness with respect to health benefits of millet consumption in urban dwellers. Today's woman finds it difficult to cook many of our traditional recipes due to non availability of millet flour in ready–to-useable form like wheat flour or rice flour. As such whole foxtail millet will not deteriorate readily, once the outer coat is removed or milled into flour, it readily deteriorates due to rancidity and attack of insects and micro organisms. The deterioration in storage due to the infestation by red flour beetle (*T. castaneum)* and other microorganisms leads to losses which in turn has adverse effects on the economy of the nation and health of the people. Grains milled into flours could intensify the activity of secondary pests in storage (Haines 1991). The rust-red flour beetle *T. castaneum* (Herbst) is a serious secondary storage pest of flours of all the important cereals namely maize (*Zea mays* L.), sorghum (*Sorghum bicolor* L.), wheat (*Triticum aestivam* L.), rice (*Oryza sativa* L.) and Bajra (*Pennisetum glaucum* L.). The infestation by *T. castaneum* could directly result in weight loss and the beetle indirectly imparts a brownish tinge and pungent smell to infested flour by secretion of benzequinones (Appert, 1987 and Hodges *et al.,* 1996).

It is therefore necessary that such losses can be reduced through the use of technology so as to provide adequate information that will guarantee food security and food safety to the population.

Food irradiation is already recognized as a technically feasible method for reducing post harvest food losses, ensuring the hygienic quality of food and facilitating wider food trade (Jyoti *et al.*, 2009). Food is irradiated to utilize the destructive power of ionization radiation on the microorganisms with minimum changes in food constituents (Zenthen and Sorensen, 2003). The use of irradiation alone as a preservation technique will not solve the problems of post-harvest food losses which are severe but it can play an important role in cutting losses in many cases. Extensive research work done at the Bhabha Atomic Research Center (BARC) Mumbai have shown that low dose gamma irradiation (0.2-0.3 kGy) is effective in controlling insect infestation in rawa (Rao *et al*., 1994) and many other food products.

As per the literature cited, wheat and soya flours are normally irradiated at the rate of 1.0 kGy and health mix containing ragi is irradiated at the rate of 0.5 kGy. However, FSSAI proposed standards for irradiation of foods under class 3 (cereals, pulses and their milled products) provided the range of 0.25-1.0 kGy for insect disinfestations and 1.5 to 5.0 kGy for reduction of microbial load. Results of innumerous studies assured that the intake of irradiated food is absolutely safe for the consumers (Farkas, 2006). Cleaned and dehusked millet grains are already available in the market in good number of packages; however millet flours stored in suitable packing material with good shelf life is very essential as a staple food for daily consumption. Flour packed and stored in right conditions can prevent the loss or gain of moisture, entry of microorganisms, changes in fatty acid profile. Good packaging serves two purposes which are essentially technical and presentational. Technical aspects in packaging aim to extend the shelf life by providing better protection from all the hazards during storage. The temperature variation in flour products could result in either hydrolytic or oxidative rancidity, triggering destabilization of flour quality. Hence, good and shelf stable package under sealed condition could prevent moisture absorption, free radical build up, prolong keeping quality and prevent microbial proliferations**.** Hence, Shelf life of any flour is very important from the point of producer as well as the consumer. Studies on storage of millets in different conditions and different packaging materials are available in plenty (Thilagavathi *et al*., 2015 and Chaturvedi *et al*., 2013). However, systematic studies on storage of millet flour which is the basic raw material for the preparation of conventional (Ranganna *et al*., 2012 and Kalpana *et al*., 2013) as well as fancy products (Nargis *et al*., 2021) is available in very less numbers except for pearl millet flour (Bunkar *et al.,* 2014, Sindhu *et al*., 2016 and Bhatt *et al*., 2017)**.** However, studies on combined effect of radiation as well as packaging on quality of foxtail millet flour are not available. Hence, the study entitled 'Effect of Irradiation and Packaging on the

Shelf Life of Foxtail Millet Flour' was taken up to assess the effect of different packaging and radiation treatment on the shelf life of foxtail millet flour under room temperature.

Material and Methods

The foxtail millet (SIA-3088), was procured from AICRP (Small millets), ZARS, V.C. Farm, Mandya and was cleaned and dehusked at 'Centre of Excellence for Small Millet Processing', GKVK, Bengaluru. The dehusked grains were milled into flour using domestic flour mill and packed in different packaging material [250 gauge Low density polyethylene (LDPE), 250 gauge Polypropylene (PP), 400 gauge Metalized Polyester Polyethylene (MPP) and 420 gauge Polyethylene Teraphthalate (PET)] as per the experimental design. One set of flour samples immediately after milling packed into above packaging material were sent to BARC (Bhabha Atomic Research Centre) Mumbai for irradiation. The irradiation process was carried out by exposing the packed milled flour samples to gamma irradiation at the rate of 1.5 kGy (IR). Another set of flour samples without irradiation treatment packaged in different packaging material (LDPE, PP, PET and MPP) were kept under refrigeration until the arrival of irradiated samples (NIR). The millet flour samples stored in stainless steel boxes (normal house hold practice) served as Control.

Storeage study: Control, irradiated (IR) and non radiation (NIR) samples packed in different packaging material were stored under normal room temperature ($30 \pm 2\ ^0C$) with a relative humidity of 75 ± 5 per cent for a period of three months. The stored millet flour samples were analyzed every fortnight for various flour quality parameters.

Nutritional composition: Nutritional composition of the foxtail millet flour (moisture, protein, fat, ash, crude fiber, calcium, iron, magnesium, phosphorus and potassium) immediately after milling were analyzed according to standard AOAC (2005) procedure.

Functional parameters: Water Absorption Index (WAI), Water Solubility Index (WSI), Water Absorption Capacity (WAC) and Oil Absorption Capacity (OAC) of foxtail millet flour were analyzed immediately after milling as per Thilagavathi *et al.* (2015).

Bio-chemical changes: Bio-chemical changes of stored millet flours such as moisture, flour acidity, free fatty acids and peroxide values were analyzed every fortnight as per standard AOAC (2005) protocol.

Insect infestation: Visual observation for dead or live insects (including larvae and adults) was done using the sieve method. Data on insect infestation was recorded on the total number of larvae and adults as insect population from each replication by taking 20 grams of flour into 90 cm diameter petri dish and counting the same using magnifying glass and converting into percentage (Mali and Satyavir, 2005).

Microbial analysis: Microbial load of the stored flour including total bacterial count (TBC), fungal count (FC) and Escherichia coli (*E. oli*) were assessed every fortnight as per Chaturvedi *et al.* (2013). For microbial analysis, Nutrient Agar (Bacteria), Potato Dextrose Agar (Fungi) and MacConkey-Sorbitol Agar (*E. coli*) were procured from Himedia and enumeration was done using serial dilution technique.

Statistical analysis : Data obtained in triplicates was statistically analyzed using three factor ANOVA to assess the significant difference (0.05 %) among the treatments, the time intervals and the packaging material on the shelf life of foxtail millet flour.

Results and Discussion

Nutritional and Functional Quality of Milled Foxtail Millet Flour

The nutritional and functional properties of foxtail millet flour immediately after milling is depicted in Table 1. The foxtail variety, SIA-3088 contained protein (8.50 %), crude fiber (7.40 %), calcium (32.13 mg %) and iron (2.60 mg %). The values reported in this work are in line with Gopalan *et al.* (2014) for most of the nutrients. The functional properties such as bulk density (1.53 g / ml), water and oil absorption capacity (72.43, 71.30 ml / 100 g) reported for foxtail millet flour in this work are in line with the values reported for selected

TABLE 1
Initial nutritional and functional properties of foxtail millet flour

Nutrients (per 100 g)	Foxtail millet flour (SIA -3088)
Moisture (%)	10.27 ± 0.04
Ash (%)	3.4 ± 0.06
Fat (%)	4.5 ± 0.10
Protein (%)	8.50 ± 0.10
Crude fiber (%)	7.40 ± 0.10
Carbohydrate (%)	66.63 ± 0.15
Energy (K. Cal)	341 ± 11.10
Calcium (mg)	32.13 ± 0.15
Phosphorus (mg)	289.86 ± 0.80
Iron (mg)	2.60 ± 0.09
Functional properties of foxtail millet flour sample	
Bulk density (g/ ml)	1.53 ± 0.01
Water absorption capacity (ml / 100 g)	72.43 ± 0.04
Oil absorption capacity (ml / 100 g)	71.30 ± 0.80
Water absorption Index (%)	8.96 ± 0.27
Water solubility Index (%)	8.72 ± 0.24

Values are mean of three replications ± SD

millet and pulse flour by Thilagavathi *et al.* (2015) and Shobha *et al.* (2012) for maize flour.

Effect of Storage on the Biochemical Parameters

a) Peroxide Value

Peroxide values are usually used as an indicator of deterioration of fats, as oxidation takes place. The double bond in the unsaturated fatty acids is broken down to produce secondary oxidation products which in turn causes rancidity. Initial peroxide value of foxtail millet flour (Table 2) was 4.40 m.eq / kg fat which increased steadily as the storage period progressed. However, by the end of storage period the increase was more significant in control (15.26 m.eq / kg fat) followed by non-irradiated LDPE and PP packed flour (14.40 and 14.30 m.eq / kg fat), respectively. However, by the end of storage period, the changes in peroxide value of stored flour was significantly less in case of irradiated MPP (9.26 m.eq / kg fat) and irradiated PET (10.10 m.eq / kg fat) pouches. Similar kind of peroxide value changes was also reported by Gahalwat and Sehgal (1992) and Kwaku *et al.* (2004). As per report of Eagan *et al.* (1981) the peroxide value of fresh oil and fats is usually below10 meq /kg and for rancid oils

TABLE 2
Effect of storage on Peroxide value of foxtail millet flour

Storage days	Irradiation (IR)					Non irradiation (NIR)				
	B_1	B_2	B_3	B_4	B_5	B_1	B_2	B_3	B_4	B_5
0	4.40	4.40	4.40	4.40	4.40	4.40	4.40	4.40	4.40	4.40
15	8.40	5.20	6.20	7.20	8.20	9.80	8.40	8.20	9.20	9.20
30	9.13	6.20	7.16	8.26	9.20	11.30	9.13	9.26	10.20	10.20
45	10.20	6.73	8.26	10.16	10.60	12.26	10.20	10.30	11.20	11.26
60	11.20	7.20	9.40	11.26	11.40	13.33	11.20	11.30	12.33	12.36
75	12.33	8.20	9.70	12.40	12.40	14.23	12.33	12.30	13.30	13.26
90	15.26	9.26	10.10	13.40	13.30	15.26	13.26	13.23	14.30	14.30

Parameter		F-Value	SEm ±	CD@5%
Peroxide value (m eq/kg fat)	Between treatment	3285.9	0.023	0.063
	Between packaging	665.3	0.036	0.100
	Between days	4337.08	0.042	0.118
	Treatment x packaging x days	11.07	0.134	0.373

Note: B_1- Control, B_2-MPP, B_3- PET, B_4- LDPE, B_5-PP. Significant @ 5 %

and fats is above 20 meq/ kg. Peroxide values in this study are within the BIS limits (<10 meq/kg of fat) for irradiated MPP followed by irradiated PET packed flour.

b) **Free Fatty Acids (FFA)**

Free fatty acids are indicators of deterioration of fat. Free fatty acids (FFA) are produced by the hydrolysis of oils and fats, since FFA's are less stable than neutral oil, they are more prone to oxidation thus turning to rancid. Thus, FFA is a key feature linked with the quality and commercial value of oils and fat. The FFA in this study increased significantly from 0 to 90 days and the increase was more pronounced in control (steel box) as it was neither irradiated nor packed in specific packaging, followed by non irradiated LDPE (1.62 %) and PP (1.72 %). However, the changes in FFA content were significantly less in irradiated MPP (1.10) and PET (1.20) covers as compared to non-irradiated samples in different packaging types. The changes between the treatments, between the packaging as well as between the storage duration were found to be significant (Table 3). Significantly higher FFA content of foxtail millet flour stored in steel boxes followed by non irradiated PP and LDPE covers was probably because of higher moisture content of these samples which lead to more rapid hydrolytic action of lipases at higher moisture levels (Table 3) rendering to development of more FFAs. Research work carried out by Panjin *et al.* (2006) and Monika and Mridula (2015) on the effect of storage period on the *dragge* (Chikki like product obtained by coating a confectionary sunflower kernel with sugar syrup) sunflower kernel based nutritious bar and maize based fortified nutritious bar respectively indicated a significant increase in free fatty acid content and which was within the acceptable limit for three months of storage. Free fatty acid is an important parameter for storage of bajra flour and FFA was found significant after 16 days of storage in the cotton bag as compared to other packaging material such as Tin and HDPE container (Bhatt *et al.,* 2017). The FFA level should not exceed 1.5 per cent and peroxide value 20-40 meq /kg fat for noticeable rancidity (Shobha *et al.,* 2012).

TABLE 3

Effect of storage on Free fatty acid (FFA) content of foxtail millet flour

Storage days	Irradiation (IR)					Non irradiation (NIR)				
	B_1	B_2	B_3	B_4	B_5	B_1	B_2	B_3	B_4	B_5
0	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21
15	0.57	0.26	0.35	0.34	0.43	0.57	0.34	0.42	0.52	0.73
30	0.94	0.36	0.53	0.45	0.62	0.94	0.46	0.66	1.05	1.13
45	1.13	0.46	0.87	0.56	1.06	1.13	0.58	0.71	1.20	1.23
60	1.21	0.63	1.05	0.74	1.21	1.21	0.72	0.89	1.21	1.33
75	1.35	0.83	1.13	0.93	1.23	1.35	0.94	1.03	1.42	1.51
90	1.76	1.10	1.20	1.23	1.32	1.76	1.25	1.30	1.48	1.59

Parameter		F-Value	SEm ±	CD@5%
Free fatty acid	Between treatment	333.15	0.006	0.017
(% oleic acid)	Between packaging	355.67	0.009	0.026
	Between days	1261.5	0.011	0.031
	Treatment x packaging x days	2.839	0.035	0.099

Note : B_1- Control, B_2-MPP, B_3- PET , B_4- LDPE, B_5-PP . Significant @ 5 per cent

c) **Moisture Content**

The moisture of any food product plays an important role in determining the shelf life of particular product. Generally, moisture content decreases or increases during storage depending upon the storage conditions and packaging material. The effect of storage on the moisture content of foxtail millet flour is depicted in Table 4. The flour stored in steel box (control) absorbed the highest moisture from the atmosphere, as it was obvious that during sampling, the lid of the box was widely exposed to the atmosphere leading to higher absorption of atmospheric moisture content. The non irradiated samples stored in LDPE and PP covers exhibited significantly higher moisture absorption of 16.36 and 17.43 per cent, respectively indicating that the permeability for moisture transmission was quite high in these packages irrespective of irradiation treatment. It even crossed the Codex Alimentarius upper acceptable limit of 15.5 per cent for safe storage (Saad *et al.,* 2014). However, the flour stored in MPP and PET (Table 4) showed significantly less changes in moisture content (below 10 %) and is considered to be safe for storage. As per Bhatt *et al.* (2017), the moisture content of bajra flour was found significant after 16 days of storage and the increasing trend was found in treatment of all the varieties of bajra flour kept in cotton bag at room temperature. Even the study of Veena *et al.* (2012) also reports higher moisture gain in papad samples during storage period of 90 days. The increase of moisture content in pearl millet grain over 12 months' storage was reported by Mali and Satyavir (2005) where in initial moisture content (5.15 %) of the grain increased to13.7 per cent after 12 months of storage at 25 °C.

Effect of Storage on Insect Infestation

The effect of storage on the insect infestation of foxtail millet flour is depicted in Fig. 1. Significantly higher numbers of insects (larvae and adults) were noticed in control sample. Insects appeared after 30 days of storage in non-irradiated PP (20/100 g flour) and LDPE (15 / 100 g of flour) packed samples. Number of insects (larvae and adults) increased significantly in steel boxes from 30 days of storage followed by non-irradiated

TABLE 4

Effect of storage on Moisture content of foxtail millet flour

Storage days	Irradiation (IR)					Non irradiation (NIR)				
	B_1	B_2	B_3	B_4	B_5	B_1	B_2	B_3	B_4	B_5
0	7.40	7.40	7.40	7.40	7.40	9.26	9.26	9.26	9.26	7.40
15	11.33	8.20	8.00	10.70	11.10	12.16	9.83	10.36	11.03	11.33
30	12.40	8.70	8.30	11.00	11.50	13.23	10.23	11.40	12.30	12.40
45	14.26	9.10	8.90	11.30	12.00	14.46	11.26	12.40	13.46	14.26
60	15.33	9.35	9.40	11.90	12.50	15.40	12.36	13.40	14.33	15.33
75	16.36	9.51	9.62	12.70	12.70	16.56	13.46	14.46	15.53	16.36
90	17.43	9.60	9.79	13.90	13.90	17.33	14.33	14.88	16.36	17.43

Parameter		F-Value	SEm±	CD@5%
Moisture (%)	Between treatment	2105.3	0.029	0.080
	Between packaging	763.69	0.045	0.127
	Between days	1738.9	0.054	0.150
	Treatment x packaging x days	4.224	0.170	0.475

Note : B1- Control, B2-MPP, B3- PET, B4- LDPE, B5-PP . Significant @ 5 %

PP and LDPE covers (Fig. 1). There was no insect infestation in MPP and PET covers irrespective of irradiation treatment (Fig. 1). The increase in insect infestation in steel boxes as compared to other materials was due to retention of higher moisture inside steel boxes that resulted in faster multiplication of the insect. The present study revealed that the increase of insect population in LDPE and PP packaged flour implies that it is not only the moisture content of the outer environment but also the insect population that created more humidity in the air by their metabolic activity which further increased grain moisture and insect population, as reported by Mali and Satyavir (2000).

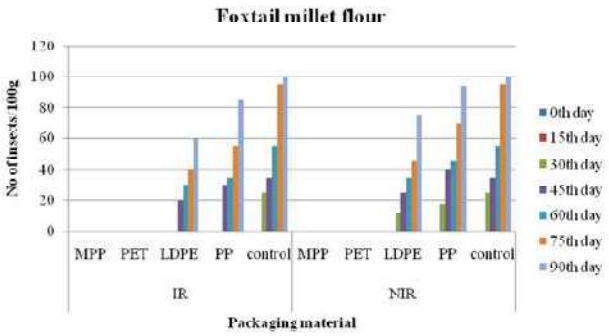

Fig. 1: Effect of storage on insect infestation in foxtail millet flour

The type of insects noticed in this study were majorly red coloured Red flour beetle (*Triboliumca staneum*) followed by black coloured Rice weevil (*Sitophilus oryzae*) and few cream colored larvae of Rice moth (*Corcyra cephalonica*). Since, the unpolished flour was used, the growth of insects is quite high, as polishing reduces the available essential nutrients required for successful growth and development of pest species. Bran of millet contains some essential nutrients and has been implicated in supporting higher population of *T. castaneum* in whole flour than polished flour. Similarly, study conducted by Mali and Satyavir (2005) on the storage of pearl millet found that grains were majorly infested with the larvae and adults of lesser grain borer (*Rhizopertha dominica*) and red flour beetle(*Triboliumca staneum*). Further, insect population (larvae and adults) were significantly higher in tin containers and jute bags at room temperature and 25 °C.

Effect of Storage on Microbial Quality

The perusal of Fig. 2 depicts the microbial load of foxtail millet flour stored in different packaging material, where in there was no *E. coli* infestation in any of the samples, indicating that the methods followed during flour making and storage were hygienically safe. Significantly higher bacteria (18.5 cfu/g) and fungi (5.0 cfu/g) were noticed in control samples by the end of storage period. Number of bacteria and fungi were significantly more in steel boxes followed by non irradiated PP covers (17.8 cfu/g and 7.0 cfu/g), while less than five number of bacteria (1.0 and 1.5 log cfu/ g) were noticed in case of irradiated MPP and PET packed flours which it did not increase throughout the storage period (Fig. 2). No fungal colonies were noticed in irradiated MPP and PET packed flour. The highest bacterial and fungal counts in PP package irrespective of irradiation treatment (Fig.2) might be due to damage caused to PP covers while handling, transportation and storage. Similar results were reported in irradiated processed ragi and barly by Chaturvedi *et al.* (2013). Even the results of Ramasri

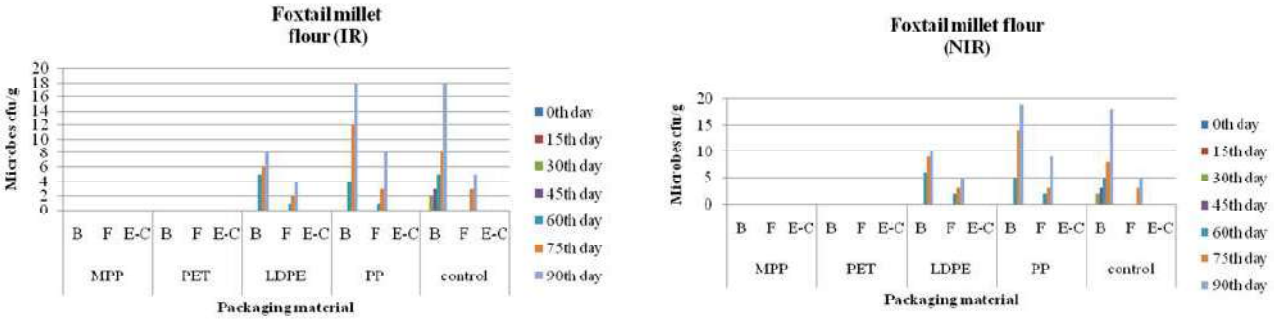

Fig. 2 : Effect of storage on microbial quality of foxtail millet flour

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et al. (2014) concluded that irradiation treatment (0.5 kGy upto 3 kGy) of health mix reduced the bacterial count and increased the shelf life. The results are in line with the findings of Singh *et al*. (2006), Mallesi *et al*. (1996) where in they found that there was no mould growth in irradiated formulation at the dosage of 0.5 kGy.

In the present study, the MPP and PET packages served as better packaging material for safe storage of foxtail millet flour. Further, irradiation along with good packaging led to control of insect and bacterial population. Similar kind of study conducted by Panjin *et al*. (2006) reported that metalized polyester polyethylene; labeled metalized PET / PE containers were most suitable for storage of *dragee* product. The packaging materials such as metalized polyester/ polyethylene; labeled metalized PET/ PE containers had lowest oxygen permeability (8.0 mLm-2 / dan "p1bar) which had strong influence in the prevention of hydrolytic and oxidative changes in the final product. Even the results of Bhatt *et al.* (2017) demonstrated that Tin and HDPE container are suitable for storage of bajra flour under room temperature for a short period of 16 days, but with irradiation the storage period can be extended significantly. Thus, the study demonstrates that the irradiation alone will not provide lasting disinfestations effect, therefore, it is also important to select the suitable packaging materials that cannot be penetrated by insects or beetles should be used to avoid post irradiation infestation. The use of irradiation alone as a preservation technique will not solve the problem of post-harvest food losses but it can play an important role in cutting losses in many cases when used judiciously along with good packaging. Hence, the present study revealed that the foxtail millet flour stored in MPP and PET pouches with irradiation dose of 1.5 kGy found suitable for safe storage up to three months under room temperature.

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Economic Impact of UAS-B Released Sugarcane Variety (VCF 0517) in Southern Dry Zone of Karnataka

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ABSTRACT

Sugarcane is the main source of sugar which accounts for 80 per cent of global sugar requirement and holds a prominent position as a cash crop. It is one of the main commercial crops of earning foreign exchange and plays a pivotal role in the agro-industrial economy of India. Because of its commercial importance, there has been lot of focus and support for its research and extension activities in order to improve its production and productivity. Research institutes are coming out with more technological innovations in sugarcane in order to improve its productivity. Assessing the economic impact of these technologies is an important task for economists. With this background, the present study focuses on finding out the economic impact of technological innovation in sugarcane (VCF 0517) on the income of sugarcane growing farmers vis-à-vis efficiency of resources used in sugarcane production by collecting primary data from 100 respondents growing VCF 0517 released by UAS-B and Co 86032 as a control variety from Mandya and Mysuru districts of Karnataka. The results indicated that the VCF 0517 growing farmers obtained higher cane yield (189 t/ha) than Co- 86032 farms (153 t/ha). The net returns from sugarcane cultivation was also higher for VCF 0517 farms (Rs.1,99,580) compared to Co- 86032 farms (Rs.1,35,540). The results of partial budgeting reconfirmed the superiority of VCF 0517 over Co- 86032 by fetching additional net gain of Rs.67378 per hectare. The returns per rupee of expenditure was higher in case of VCF 0517 farms (1.74) than that of Co 86032 farms (1.53). The study thus concluded that adoption of new technology (variety) has substantially increased the income and inturn standard of living of farmers. Hence, adoption of these UAS-B released high yielding variety along with associated better management practices for sustainable use of resources.

Keywords : Sugarcane, Cost and returns, VCF 0517, Resource use efficiency, Partial budgeting

SUGARCANE (*Saccharum officinarum* L.) is indigenous to tropical South and Southeast Asia and is one of the most important commercial crops of the tropics. The top ten producing countries (India, Brazil, Thailand, China, the US, Mexico, Russia, Pakistan, France, Australia) together accounted for nearly 70 per cent of global output (Anonymous, 2020).

Sugarcane plays a pivotal role in the agro-industrial economy of India. Sugarcane production for the year 2019-20 stood at 370 million tonnes from an area of 4.6 million hectares and productivity of 80.50 tonnes per hectare (Indiastat, 2020). India consumed about 27 million tonnes with per capita consumption of 19 kg and exported about 5.65 million tonnes of sugar during 2019-20 (Anonymous, 2020).

Karnataka is one among the major sugarcane and sugar-producing states in the country. It is being cultivated on large areas since many years for production of jaggery, khandsari and white sugar. It is also a major provider of livelihood to millions of agricultural families and their dependents in rural areas. In Karnataka, the sugarcane is cultivated over an area of 4.29 lakh ha with production 38.20 million tonnes of sugarcane and productivity of 89 tonnes per hectare during the year 2019-20 (Indiastat, 2020).

Sugarcane is the main source of sugar (80 %) globally and holds a prominent position as a cash crop. It is one of the main crops of earning foreign exchange. The main by-products of sugarcane industry are bagasse and molasses. Bagasse is mainly used as fuel,

besides its use for production of compressed fibre board paper, plastic and others, while molasses is used in distilleries for the manufacturing of ethyl alcohol, butyl alcohol, citric acid etc. Rum is the best potable spirit made from molasses. Molasses is also used as an additive to feeds for livestock. Press mud can be used as soil amendment in saline and alkali soils. Green tops of cane are good source of fodder for cattle.

Realizing the commercial importance of sugarcane with its wider uses of by products, there has been lot of focus on research and extension activities in sugarcane production in order to improve the production and productivity of sugarcane. All India Coordinated Research Project on Sugarcane is coordinating research work in the country since 1970 through a network of sugarcane research stations of ICAR (Indian Council of Agricultural Research), State Agricultural Universities, State Government Departments and Non-Government Organization (Shukla *et al.,* 2017). The main emphasis is laid on the development of new innovations in agriculture such as improved sugarcane varieties, crop production and protection technologies suited to commercial cultivation under different agro-climatic conditions of the country. These new technologies and interventions in agriculture that are developed by Government and private institutes, will help target farmers with primary objective of increasing agricultural production, productivity and profitability with the purpose of increasing agricultural income of farmers.

These technological interventions not only lead to the intended result, but also to unanticipated positive or negative effects. Therefore, to identify the consequences of the proposed action, impact assessment is done to ensure whether the intervention is technically feasible, economically viable, socially acceptable and environmentally sustainable.

With this backdrop the present study sheds light on the economic impact of technological innovations in sugarcane production by choosing the University of Agricultural Sciences, Bangalore (UAS-B) released variety of sugarcane *i.e.,* VCF 0517 for in-depth analysis. VCF 0517 sugarcane variety which was released in the year 2017 has occupied 80 per cent of the area in Southern Karnataka (Anonymous, 2019). The VCF 0517 is popularly called as 'Bahubali" because of its high cane yield, high sugar recovery, high jaggery yield and good quality sugar which was chosen for the study to estimate costs and returns, resource use efficiency over other popular check variety (Co 86032) in the study area. The study would help in assessing the performance of new innovation developed by the university and its impact on farmer's income. This would in turn help to advisethe farmer to adopt to such technologies with better production management practices and sustainable use of resources.

METHODOLOGY

Study Area, Sampling Framework and Sources of Data

The present study was undertaken in Mandya and Mysuru districts of Karnataka. These districts were purposively chosen based on the predominance of sugarcane area in the jurisdiction of UAS, Bengaluru. The respondents were chosen randomly from predominantly sugarcane growing villages in consultation with scientists and extension workers working in the study area. The data were collected from 100 sample farmers which constituted 50 farmers who adopted UAS, Bangalore released VCF 0517 sugarcane variety and 50 farmers who adopted a check variety (Co 86032).

The primary data pertaining to socio-economic characteristics, resources used, yield, price realized and other relevant information were collected from sample farmers related to the agriculture year 2020-21 using the pre-tested, well-structured interview schedule in selected villages of Mandya and Mysuru districts in Karnataka.

Analytical Tools

Estimation of Costs and Returns of Sugarcane Production

Cost of cultivation was estimated in terms of variable costs and fixed costs using information related to each of these standard cost concepts. In addition, interest

on working capital, different items of fixed costs like rental value of land, depreciation (straight line method was used), land revenue and interest on fixed capital were included. The gross returns from sugarcane cultivation, net returns over total cost and returns per rupee of expenditure were calculated.

Partial Budgeting

A simple yet powerful tool of partial geting technique was used to estimate the direct economic benefit (or loss) at farm-level by adoption of VCF 0517 variety over check variety. This technique focuses on the changes in income and expenses that would result from implementing an alternative practice or technology. All components of farm profits which remain unchanged by the decision were not considered. In this study, the impact of using VCF 0517 sugarcane variety on income of farmers was evaluated by considering the additional costs incurred in adoption of VCF 0517 sugarcane variety and decrease in gross returns (if any) were used under debit side of the Partial budgeting template. Decrease in cost if any by adoption of VCF 0517 sugarcane variety and incremental returns realized (if any) were taken on credit side as shown in following template. Sum of credits were subtracted from the sum of debit side to arrive at net gain or loss from the modification for the farm enterprise.

Partial Budgeting

Debit		Credit	
Increase in cost due to adoption of VCF-0517 variety	=A	Decrease in cost due to adoption of VCF-0517 variety	=C
Decrease in gross returns due to adoption of VCF-0517 variety	=B	Increase in gross returns due to adoption of VCF-0517 variety	=D
Total	=A+B	Total	=C+D

Credit-Debit = Net gain / loss

Resource Use Efficiency

The Cobb-Douglas type of production function as specified below was used to assess the resource use efficiency in sugarcane cultivation.

$$Y = a\ X_1^{bl}\ X_2^{b2}\ X_3^{b3}\ X_4^{b4}\ X_5^{b5} X_6^{b6} X_7^{b7} e^{u} \ldots\ldots\ldots (1)$$

Where,

Y = Yield of sugarcane (tonnes)

X_1 = Human labour (Man days)

X_2 = Bullock labour (Pair days)

X_3 = Machine labour (Tractor hours)

X_4 = Seed material (tonnes)

X_5 = Fertilizer (Rs.)

X_6 = Farm yard manure (Bullock loads)

X_7 = Plant protection chemical cost (Rs.)

a = Constant

u = random variable.

b_1 to b_7 indicate regression coefficients of respective inputs and implicitly represents the elasticity of production of respective inputs.

The Cobb-Douglas production function was converted into natural log linear form and estimated using the OLS technique. The log linear form of equation was

$$\ln Y = \ln a + b_1 \ln X_1 + b_2 \ln X_2 + b_3 \ln X_3 + b_4 \ln X_4 + b_5 \ln X_5 + b_6 \ln X_6 + b_7 \ln X_7 + u \ln e \ldots. (2)$$

Marginal Value Product (MVP): The estimated coefficients were used to compute the MVP. We can assess the relative importance of factors of production by studying the marginal value product. Marginal Value Product of X_i, *i.e.* for the i^{th} input, it is estimated by the following formula (equation 2)

$$MVP = bi \times \frac{GM(Y)}{GM(Xi)} \times P_y \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

GM (Y) and GM (Xi) represent the geometric means of output and input, respectively, b_i is the regression coefficient of i^{th} input and P_y is price of output. The efficiency of input use was estimated using the following equation 3.

$$r = MVP/MFC \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where, 'r' is the efficiency ratio, MVP is the marginal value product of variable input and MFC is the marginal factor cost (price per unit input).

Based on economic theory, a firm maximizes profits with regards to resource use when the ratio of the marginal return to the opportunity cost is one. The values of 'r' less than unity indicate excess use of resource (there exist scope for the reduction). If 'r' is greater than one, indicates underutilization of the resource (there is a scope to increase). If 'r' is equal to unity indicate optimum utilization of resource.

RESULTS AND DISCUSSION

Cost of Cultivation

The details on per hectare cost of cultivation of sugarcane of UAS-B released variety VCF 0517 and Check variety (Co 86032) during the crop year 2020-21 are given in Table 1.

Among the different items of cost, harvesting and marketing cost was found to be the prominent item of cost in the cultivation of both VCF 0517 (Rs.1,54,980)

TABLE 1

Cost incurred in cultivation of VCF 0517 and Co 86035 varieties of sugarcanein the study area

Particulars	VCF 0517				Check (Co 86032)			
	Quantity	Rate (Rs.)	Cost (Rs.)	Per cent	Quantity	Rate (Rs.)	Cost (Rs.)	Per cent
A Variable Cost (Rs.)			**243770**	**89.32**			**217809**	**88.20**
Human labour (md)	72	400	28800	10.55	89	400	35600	14.42
Sets (tons)	7.00	3000	21000	7.69	6.20	2500	15500	6.28
Tractor (hrs)	3.50	800	2800	1.03	5.00	800	4000	1.62
Bullock (Pair days)	7.41	700	5187	1.90	7.00	700	4900	1.98
Fertilizer (Rs.)			7125	2.61			8250	3.34
FYM (Cart loads)	7.20	400	2880	1.06	9.39	400	3750	1.52
Plant protection chemicals (Rs.)			1050	0.38			1280	0.52
Micro nutrient and Bio fertilizer (Rs.)			350	0.13			230	0.09
Irrigation charges (Rs.)			3650	1.34			4590	1.86
Harvesting &Marketing (Contract) (Rs.)		820	154980	56.79		820	125460	50.80
Interest on working capital @ 7 per cent			15948	5.84			14249	5.77
Fixed Cost (Rs.)			**29150**	**10.68**			**29151**	**11.80**
Land revenue			50.00	0.02			50.00	0.02
Depreciation cost			1450	0.53			1450	0.59
Rental value of land			25000	9.16			25000	10.12
Interest on fixed capital @ 10 per cent			2650	0.97			2650	1.07
Total Cost (Rs.)			**272920**	**100**			**246960**	**100**

and Check variety (Rs.1,25,460). Human labour cost was the second highest cost incurred by farmers with corresponding cost of Rs.28,800 (10.55 %) and Rs.35,600 (14.45 %). The cost of seed material was relatively higher for VCF-0517 farms (Rs.21000) compared to Check variety farms (Rs.15500). This higher seed cost was attributable to the use of more quantity of seed material by VCF 0517 growing farms. While, the fertilizer cost was higher (Rs.8,250) for check variety farms than VCF 0517 farms (Rs.7,125) as they have applied more quantity for chemical fertilizers. The cost of FYM (Farm Yard Manure) was also higher for check variety farms (Rs.3750) than that of VCF 0517 farms (Rs.2880). The similar trend was observed with respect to irrigation cost (water cess+Human labour) incurred in sugarcane cultivation, as farmers growing check variety farms incurred comparatively more cost (Rs.4590) than VCF 0517 growing farms (Rs.3650).

Proportion of working expenses was relatively more than fixed cost in the cultivation of both the VCF 0517 and Check variety farms, which accounted for 89.32 and 88.20 per cent, respectively. Respondents incurred a total cost of Rs.272920 and Rs.246960 in the cultivation of VCF 0517 and Check variety, respectively. The cost of cultivation was higher for VCF 0517 variety because of more number of labour use for crop maintenance and expenditure towards harvesting due to higher cane yield.

Yield and Returns

Yield and returns structure of sugarcane growing farmers is given in Table 2. The average per hectare yield realized on respondents' farms was higher (189 tonnes) in the case of VCF 0517 variety compared to check variety (Co 86032) farms (153 tonnes), thus they could able to realize higher gross returns from VCF 0517 variety (Rs.2,72,920) than from check variety (Rs.3,82,500). The differences gross returns were found statistically significant at ten per cent level of significance. Consequently, net returns from sugarcane cultivation from VCF 0517 variety were more (Rs.1,99,580) compared to check variety (Rs.1,35,540). These results are in line with study conducted by Raghupathi, *et al.* (2020) which revealed that, net returns from cultivation of Arka Kamini variety of China aster was the higher (Rs.1 69985 per acre) than that of check variety farms (Rs.142241 per acre), as an attempt to evaluate technology (variety) released from Indian Institute of Horticultural Research (IIHR).

This difference in returns between the two categories of farms can be attributed to the higher yield realization by the farmers cultivating for VCF 0517 (23.52 %) than that of Co 86032 farmers. This higher returns from sugarcane cultivation by VCF 0517 farms due to higher yield level subsumed their high cost of cultivation. The returns per rupee of expenditure for VCF 0517 farms and check variety farms were Rs.1.74

TABLE 2

Production and returns from VCF-0517 and Co-86035 varieties of sugarcanein the study area

Particulars	VCF-0517			Check variety (Co-86032)		
	Quantity	Price (Rs.)	Returns (Rs.)	Quantity	Price (Rs.)	Returns (Rs.)
Main product (Tons)	189	2500	472500	153	2500	382500
Gross returns (Rs.)			472500			382500
Net returns (Rs.)			199580			135540
Returns per rupee of expenditure (Rs.)			1.74			1.55
t-test for gross returns						t=1.42*

Note: * indicates significant at ten per cent probability level

TABLE 3

Relative benefit of VCF-0517 variety over check variety of sugarcane production (Rs/ha)

	Debit	Amt (Rs.)		Credit	Amt (Rs.)
A	Increase in Cost due to VCF 0517 variety		C	Decrease in cost due to VCF 0517 variety	
i	Bullock labour	287	i	Human labour	7600
ii	Micronutrients	60	ii	Machine labour	1000
iii	Harvesting and marketing	34650	iii	Fertilizer	1125
B	Decrease in returns due to VCF 0517 variety	0	iv	FYM (Bullock loads)	750
			v	PPC	200
	Total debits	34997	vi	Irrigation	1200
				Increase in returns due to VCF 0517 variety	90500
				Total credits	102375

Net gain per hectare (Total credits -Total debits) = Rs. 67378

Resource use efficiency in sugarcane production

and Rs.1.55, respectively. This indicated that, every rupee spent in sugarcane cultivation would fetch a net return of Rs.0.74 and Rs.0.55, respectively for farms growing VCF 0517 and Co 86032. These findings are in line with the study conducted by Raghupathi *et al.* (2021) on economic impact of research in French bean, which revealed that, the per acre gross returns realized by the Arka Sharath French bean variety (Rs.2,62,500) was 29 per cent higher (Rs.7,7510) than check variety Ashoka (Rs.1,84,990) in Karnataka.

Partial Budgeting Analysis

Partial budgeting technique was used to estimate the relative benefit of UAS-B released variety (VCF 0517) over the control variety in terms of output and income level of farmers in sugarcane cultivation. It is evident from Table 3 that, farmers realised net gain of Rs.67378 per hectare from VCF 0517 variety over check variety of sugarcane. The cultivation of UAS-B released variety VCF 0517 has given higher yield level and income level. The results obtained using partial budgeting indicated higher profitableness of UAS-B released variety of sugarcane. These findings are on par with the study conducted by Pramod and Mahadevaiah (2021) which revealed that, among various improved varieties and new crops introduced in the study area under the NAIP project, farmers have realized the highest additional returns in cultivation of cotton and redgram (BRG 2) which accounted to Rs.8000 per acre and Rs.5780 per acre, over their respective check varieties.

Resource Use Efficiency in Sugarcane Production

Resource use efficiency in agriculture plays an important role in determining the farm production and income. The size of farm income depends on the efficiency with which farmers are able to utilize the available resources. With higher efficiency in the use of scare resources, farmers can augment their income and savings. Therefore, besides estimating the superiority of UAS-B variety over check variety an attempt was also made to study the resource use efficiency in sugarcane production using the functional analysis presented in previous section. The estimates of Cobb-Douglas (CD) function are presented in Table 4. The estimated production function revealed that independent variables included in the model explained 85 per cent and 79 per cent of variation yield of VCF 0517 and check varieties of sugarcane.

The analysis of resource use efficiency on VCF 0517 variety cultivating farm revealed that the MVP to MFC

TABLE 4
Resource use efficiency in sugarcane production

Particulars	VCF-0517		Check (Co-86032)	
	Coefficients	MVP/ MFC	Coefficients	MVP/ MFC
Intercept	1.779 *		1.924 ***	
Human labour	0.183	1.050	0.072	0.296
	(0.026)		(0.091)	
Bullock labour	0.078	0.750	-0.028	-0.776
	(0.064)		(0.129)	
Machine labour	0.041	1.373	0.056	1.749
	(0.026)		(0.050)	
Seed material	0.387 ***	1.084	0.485 ***	2.941
	(1.084)		(0.065)	
Fertilizer	0.036	1.726	-0.041	-1.248
	(1.720)		(0.005)	
Farm Yard Manure	0.108 **	2.829	0.068	0.786
	(0.043)		(0.073)	
Plant Protection Chemicals	0.009 NS	4.859	0.003 ***	1.275
	(0.014)		(0.001)	
R^2	0.85		0.79	
F-value	28.63 ***		75.91 ***	

Note:

1. ***, ** and * indicates significant at one per cent, five per centand ten per cent probability level, respectively.
2. Figures in parenthesis indicate standard error values

ratio was less than one for bullock labour (0.750) indicating that bullock labour was over used in sugarcane production and there is a need to reduce the use of it to attain optimum sugarcane production. The MVP to MFC ratio was more than one for human labour (1.050), machine labour (1.373), seed material (1.084), fertilizer (1.762), FYM (2.829), PPC (4.859), which indicated underutilization of these resources. Thus results indicated scope for reallocation of expenditure among these resource and optimize sugarcane production.

While in the case of check variety growing farms, the MVP to MFC ratio analysis revealed that human labour (0.296), bullock labour (-0.776), fertilizer (-1.248) and FYM (0.786) resources were over used in sugarcane cultivation, as the ratio of MVP : MFC was less than unity. Use of these resources need to be reduced to attain optimum sugarcane production. The MVP to MFC ratio was more than one for machine labour (1.749), seed material (2.941) and PPC (1.275) indicating underutilization of these resources and there exist scope for higher use of these resources from their existing level to reach optimum production of sugarcane.

The study revealed that VCF 0517 sugarcane variety is performing well in field conditions and offering higher returns to farmers compared to the check variety. The VCF 0517 cultivating farms have realized 23.50 per cent higher yield and additional benefit of Rs.67378 per hectare over check variety. Therefore, the Department of Agriculture, Government of Karnataka and UAS-B can make further intensive efforts to popularize and encourage the widespread adoption of VCF 0517 variety to realize full potential of the crop productivity, for better resource use and higher farm income.

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Evaluation of Trend Analysis of Sericulture Resource Development in North Western Himalayan Region of Kashmir Valley, Jammu and Kashmir, India

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ABSTRACT

Sericulture is an agro cottage industry that plays a significant role for sustainable livelihood in rural and urban economy of Kashmir. It includes backward and forward linkage processes from mulberry plantation, silkworm rearing, reeling, silk textile weaving. The present study was conducted to examine growth in mulberry area, production and productivity of silk cocoons which was collected over the period of 30 years from 1990-2020 in Kashmir valley. To carry out the analysis, secondary data sources have been used by taking into consideration the compound annual growth rate, regression analysis and decomposition model to achieve objectives of the study. The perusal of results indicate that the trend of production and yield of silk cocoons witnessed an increase atthe rate of 1.59 and 2.79 from 1990-91 to 2019-20 and mulberry area shows signs of decreasing trend at the rate of -1.14 during the last three decades (1990-2020). The decomposition model analysis predicted that silk cocoon production is mainly contributed by yield effect (59.27 %) followed by interaction effect (46.10 %) and area effect (-5.37 %). Therefore, the need of sericulture policy interventions and supply chain collaborations by the Government and comprehensive strategic approach is required which is not only important from viewpoint of potential income generating activities but also as the key contribution to the GDP of the Jammu and Kashmir economy.

Keywords : Silk farming, Kashmir valley, CAGR, Regression analysis, Decomposition model, Sustainability

SILK farming comprises rearing of silk producing organisms and the word sericulture is derived from Greek word sericos meaning silk and English word culture means rearing. It broadly includes interrelation of activities such as cultivation of mulberry plant, silkworm rearing to produce the silk cocoons, cocoon reeling for untwisting silk filament, yarn making, weaving and silk fabric processing (Kumaresan *et al*., 2008). Sericulture involves raw silk production by raising silkworms which provides income generation round the year to farm families (Kamili *et al.,* 2000; Lakshmannan *et al.*, 2011). Mulberry silk is commonly known in the textile industry (Wang, 2010 and Babu, 2015). It is an important economic subsidiary income generating activity for rural people of mountainous regions and provides livelihood in industries being an important activity in urban economy and contributes sustainable development of region (Meneguim *et al.,* 2007).

Mulberry silk is obtained from silkworm (*Bombyx mori* L). Silkworm feeds on mulberry leaves and spins silk cocoon in about 28-30 days. Finally silk cocoons are sold to the reelers and convert them into silk yarn. Bivoltine silk of Jammu & Kashmir is of high quality which adds to the improvement of economic condition of the sericulture farmer and provides employment opportunities in pre-cocoon and post cocoon sector. Jammu & Kashmir could be converted into silkworm gene bank for sustaining sericulture of the whole world (Tazima, 1978).

In Kashmir valley silk is produced from almost all areas which includes Kupwara, Baramulla, Anantnag, Bandipora, Kulgam, Budgam, Ganderbal, Shopian and Srinagar shown in Fig 1. Introduced by Emperor Zain-ul-Abidin, silk industry plays an important role as a small and medium scale industry for sustainable livelihood of small and marginal families. Mulberry silk

cocoon in the study area yields a very fine fiber that can be compared with the best in the world. This region currently produces 805 metric tons of silk cocoon and generates five lakh man-days of employment annually. It engages around 22,000 farmers directly or indirectly with the industry (Anonymous, 2020). The present objective of the study was to find out sericulture scenario in Kashmir valley by exploring the data on trend of mulberry area, production and productivity of silk cocoons for time period from 1990 to 2020.

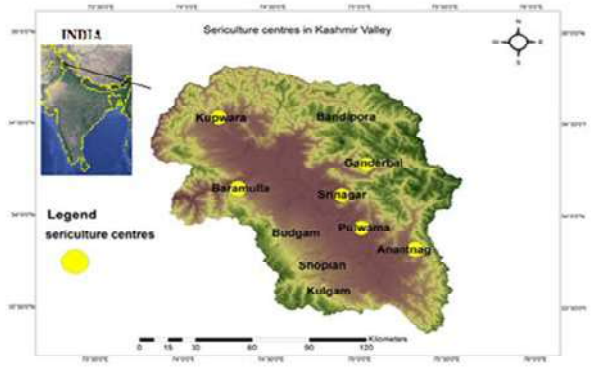

Fig. 1 : Sericulture pockets in Kashmir valley
(Source: Directorate of sericulture, Jammu &Kashmir, Srinagar)

Geographically, large chunk of silk in the world comes from Asia which contributes over 95 per cent of the total world output. China ranks firsts in term of silk production with an annual production of 142,005 metric tonnes in 2017 (Anonymous, 2017). Sericulture acts as an effective tool for poverty alleviation that contributes to sustainable development goals in many areas of developing countries which improve the livelihood for women empowerment and gender equality (Anonymous, 2017a) and is considered being a lucrative industry with high employment potential (Popescu, 2018). Karnataka is one of the leading mulberry sericulture producing states followed by Andhra Pradesh, Tamil Nadu, West Bengal and Jammu & Kashmir which collectively contributes for about 98.5 per cent of silk production in the country. In developed countries at present there is a huge consumption of silk products which leads to high demand in the global level market and plays an important role in foreign exchange earnings for developing countries in the world that have resulted in the transformation from sericulture sector to the manufacturing sector. Silk producing countries in the world are : China, followed by India, Uzbekistan, Thailand and Brazil (Anonymous, 2017b). Compound annual growth model was used to assess mulberry area and silk cocoon production in India from 1971-72 to 2008-09 (Manjunath *et al.*, 2015). Regression analysis aims to study the relationship between silk cocoon production and time periods and is used to estimate trends of silk growth in India (Bhat *et al*., 2014).

The silk industry of Kashmir gained a leading position on Europe silk route with which Kashmir had started its silk trade and exports silkworm seeds to Europe (Anonymous, 2013). Jammu and Kashmir produced about 801 metric tonnes of silk cocoons during 2018-19 with income generation under pre-cocoon and yarn production excluding value additions in silken fabric/ products sales (Anonymous, 2020a). In Jammu & Kashmir, mulberry is being cultivated in 7,064 hectares and produced 739 metric tonnes of cocoons and 112 metric tonnes of raw silk during the year 2009-10 (Trag *et al.,* 2011). Sericulture in Jammu & Kashmir having a temperate climate conditions for quality silk production, organized production system and supply of disease free laying eggs, value added products of sericulture activity, modernization of reeling sector, rationalization of silk cocoons marketing which gives a wonderful picture to the silk industry in the global silk markets (Bhat *et al*., 2020).

Silk Products have a ready market both at national and international levels; however this industry needs immediate attention by the Government to improve the socio-economic condition of weavers (Yousuf *et al.,* 2013). Silk Samagra was introduced by Central Silk Board Government of India for sericulture development in the Country including Jammu & Kashmir (J&K) with an objective to improve the quality and productivity of silk produced (Anonymous, 2019). A research study in Kashmir valley was conducted to assess the growth of sericulture which is not only an important income generating activities but also as the key contribution to the GDP of the union territory of J&K.

Material and Methods

Study Area

Kashmir lies in the north-western part of India which is located between Pir Panjal and Greater Himalayan ranges, a transverse valley and meso-geographical region in union territory of Jammu & Kashmir. According to census, 2011 the Population of Jammu & Kashmir is 1.25 crore people which accounts for about 1.04 per cent of the total population of the country with Literacy rate is 67.17 per cent. Nearly 70 per cent of population of J&K directly or indirectly depends on agriculture and allied activities like sericulture, apiculture that significantly contributes to the economy of J&K. Kashmir is well known for silk carpet weaving which is made up of both silk yarn and wool. Silk carpet design that attained great excellence due to superb artistry which inspired countries from central Asia. It led to the high demand in the international market and carpet weaving become a source of livelihood opportunity to the inhabitants of people of this region.

The present study is based on secondary sources of data which aims to examine time series data on mulberry area, production and productivity of silk cocoon in Kashmir valley from 1990-2020 which were collected from Directorate of Sericulture, Kashmir, Central Sericultural Research and Training Institute Pampore, Directorate of Economics and Statistics, Jammu and Kashmir and reports of Food and Agriculture Organization.

Sericulture development in Kashmir valley was evaluated through measuring growth in area of mulberry, production and productivity of silk cocoons. The compound annual growth rates (CAGR) of area under mulberry, production and productivity of silk cocoons were computed using the exponential growth function.

$$Y=\beta_0 \ \beta_0^t$$

$$\text{Log } Y= \log \beta_0 + \log \beta_1$$

Compound growth rate were calculated by using the following formula.

Where, CGR = Compound growth rate

t = time trend, denoting years

Y = Area/ production / productivity

β_0 = constant

β_1 = regression coefficient

Regression Model

To examine the impact of variation in time, taken as criterion variable on the outcome variables *viz.,* area of mulberry, production and productivity of silk cocoons, regression analysis was used to find the strength of association between dependent and independent variable which was used to find out trends and understand the relationship between variables. The variables considered for analysis are area of mulberry, production and productivity of silk cocoons. The dependent variable Y is area, production and productivity and Independent variable X is the time period (years). Among the models being fit the best model was selected on the basis of their goodness of fit of R^2 and significance of the coefficients.

Decomposition Analysis

To know the relative contribution of area and yield towards the total output, a decomposition model was used to examine the yield effect, interaction effect and area effect on the production of silk cocoons which enables to analyse the change in the production of a particular crop due to the increase of area or yield improvement (More *et al.,* 2015). The average area and productivity of first triennium was taken as a base and it was compared with the averages of last triennium in respective periods. In the decomposition analysis the total change in production was decomposed into three effects, yield effect, area effect and interaction effect due to change in yield and area by applying the function,

$$\Delta P = A_0 \Delta Y + Y_0 \Delta A + \Delta A \Delta Y$$

ΔP = Change in production.

A_0 = Area in the base year.

Y_0 = Yield in the base year.

Y_t = Yield in the current year.

A_t = Area in the current year

ΔA = Change in area ($A_t - A_0$)

ΔY= Change in the Yield ($Y_t - Y_0$)

Results and Discussions

Kashmir is one of the important silk cocoon producing union territory in India. Production and productivity of silk cocoons of Kashmir indicated accelerating linear trend when compared to trend of mulberry area. Area of mulberry shows decreasing trend in Kashmir valley which was 270 hectares in 1990-91 and reached 211 hectares in 2019-20. The production of silk cocoons in Kashmir which was 210 metric tonnes in 1990-91 reached 347 metric tonnes during the year 2019-20. The perusal of Table 1 shows that area under mulberry plantation has seen annual compound growth rate of -1.14 per cent from 1990-2020 which shows decelerating trend and negative growth rate. Production and productivity of silk cocoons has seen annual compound growth rate of 1.59 percent and 2.79 per cent indicating a positive growth rate from 1990-91 to 2019-20.

Table 1

Annual compound growth rate for Mulberry and Silk cocoons in Kashmir with respect to area of mulberry, production and productivity of cocoons from 1990-91 to 2019-20

Variable	CAGR (%)
Area of Mulberry	-1.14
Production of silk cocoons	1.59
Productivity of silk cocoons	2.79

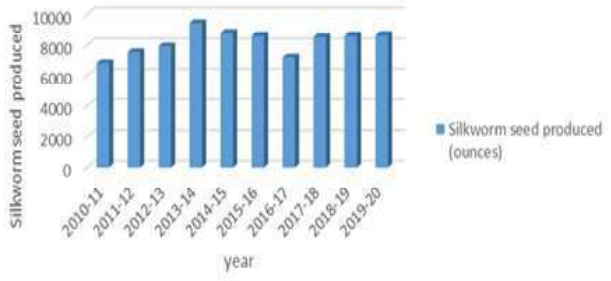

Fig 2 : Silk worm seed produced in Kashmir valley (Source: Directorate of sericulture, J&K)

The perusal of Table 2 reveals that silk cocoon production and productivity shows an increasing trend with respect to time and also indicates that there is significant relationship between time with production and productivity of silk cocoons which is significant at 0.05 level of significance. The results shows that 72.5 percent changes is explained by time variable in production of silk cocoons and 39.3 per cent changes is explained by time period in productivity of silk cocoons. It is observed that area of mulberry shows a decreasing trend with respect to time and also indicates that there is significant relationship between time and area of Mulberry and p-value was observed to be 0.012 which is less than 0.05 implying that there is significant relation between time period and area of mulberry and 14.2 per cent changes is explained by time variable.

Table 2

Regression analysis of Mulberry area, Production and Productivity of Silk cocoons in Kashmir valley

Independent Variable	Dependent Variable	R^2	Intercept	Slope of Regression line	P-value.
Time	Area of Mulberry	0.142	3.79	-2.62	0.012
	Silk cocoons production	0.725	1.42	6.26	0.035
	Silk cocoons productivity	0.393	0.30	0.03	0.028

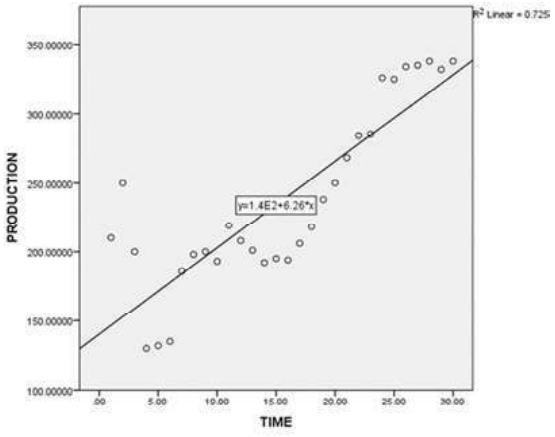

Fig 3: Trend in production of silk cocoons in Kashmir valley from 1990-2020

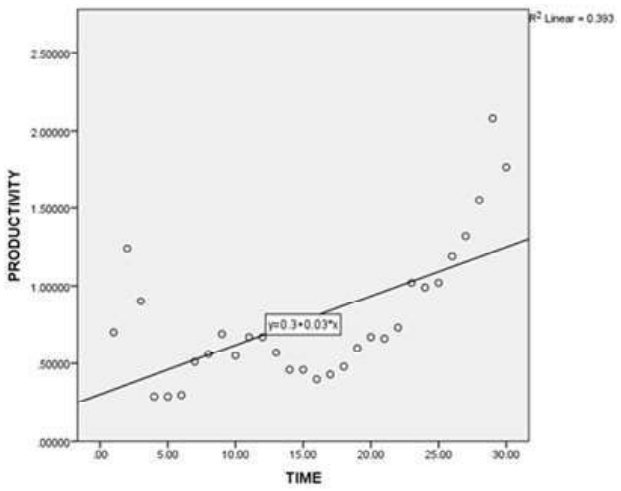

Fig 4 : Trend in productivity of silk cocoons in Kashmir valley from 1990-2020

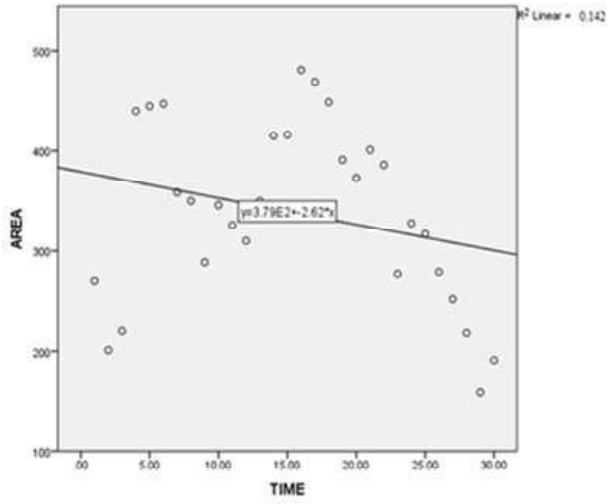

Fig. 5 : Trend in area under mulberry in Kashmir Valley from 1990 - 2020

The decomposition analysis of the silk cocoon production in the Kashmir valley is presented in Table 3. The perusal of the table reveals that increase in the production of silk cocoons is mainly due to the increase in yield from 0.77 in 1990 to 1.76 in 2020 having around (59.27 per cent) contribution to the total production of silk cocoons. The stagnation in area as discussed above is clearly reflected in model showing area has contributed only (-5.37 per cent) to the overall production of silk cocoons. The combined effect of the interaction between area and productivity has contributed (46.10 per cent) to the production of silk cocoons in Kashmir valley. The results clearly reveals that increase in yield of silk cocoons was the major factor in increased production of silk cocoons.

Increasing trend of silk cocoon production and productivity in Kashmir valley is due to high yielding varieties of mulberry, silkworm biovoltine hybrids, separate rearing sheds, effective management and implementation of training schemes and programmes (Hussain, 2002; Bhat *et al.*, 2020; Chauhan *et al.,* 2016 and Trag *et al.,* 2011). Mulberry area shows decelerating trend and negative growth rate due to improper plantation practices and land under horticultural and agriculture crop is under stress due to the reluctance of farmers towards growing of mulberry plants in their land. For this reason intercropping of mulberry with agriculture and horticulture crops for sustainable livelihood is the answer to address leaf shortage and to promote sericulture in Kashmir valley (Ahsan, 1989; Mir *et al.,* 2018 and Qadri *et al.,* 2021). Inadequate marketing of silk cocoons and poor extension support is one of the main cause which discourages the farmers to take or continue sericulture activities in Kashmir valley (Ganie *et al*., 2018 and Bhat *et al*., 2020) but now sericulture is in reviving phase of sericulture which encourage farmers and stakeholders to involve in this sector leading to sustainable development of sericulture (Anonymous, 2021).

TABLE 3

Decomposition analysis model of sericulture resource from 1990-2020 in Kashmir Valley

Variable	Base triennium	Ending triennium	Total value	% contribution prod	
Area of Mulberry (ha)	270	191	Area effect	-50305.1	-5.37
Silk cocoon Prod. (mts)	210	338	Yield effect	554742	59.27
Silk cocoon Yield (mts)	0.77	1.76	Interaction effect	431466	46.10

In 2010-11, union territory Govt. of J &K wanted up-gradation of departmental nurseries to improve mulberry saplings and leaf production which encouraged and supported the farmers stakeholders to take up sericulture and taking up multi-cropping. This was done by providing appropriate incentives and crafted public private partnership model to promote silk tourism. This is likely to support all the stakeholders in the value chain and play an important role for socioeconomic development of the study region (Anonymous, 2020).

Sericulture development in Jammu and Kashmir reveals that the production and productivity of silk cocoons has positive growth rate due to the plantation of improved mulberry varieties. Further Jammu & Kashmir sericulture is based on adaptation of technological innovations from different sericulture institutions and tree type mulberry plantations support the farmers to raise successful cocoon crop and produce silk yarn. Rearing kits should be provided to the farmers to help them conduct rearing on modern scientific lines and increase their average productivity per ounce of the seed. Apart from decreasing trend in the area under mulberry due to improper plantation practices, insufficient mulberry leaves, problems in marketing discourages the farmers to remain in sericulture. A strategic comprehensive approach and human resource development and effective supply chain collaborations is required at both pre-cocoon and post cocoon sectors which should be addressed simultaneously. Sericulture has the potential to provide viable and sustainable livelihood opportunities which includes a number of processes including backward and forward linkages which perfectly aligns with the National Goals and the sustainable development goals of United Nations that play an important role in poverty alleviation and inclusive sustainable growth. Mulberry plantations creates natural carbon sink which mitigates climate change and prevent environmental degradation and promotes sustainable livelihood. Therefore by effective management and need for formulation of area stabilizing policy is required for encouraging silk farming and sustain the livelihood of sericulturists.

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Isolation and *In-Silico* Analysis of A Novel *Cucumis sativus* Polyubiquitin Gene Promoter

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ABSTRACT

Transcriptional regulation is a dynamic process and the first level of gene expression control, largely governed by the gene promoters and their contributing cis-regulatory elements (CREs), the binding of which to the regulatory proteins and transcription factors (TFs) lead to the activation or repression of the genes. Strong constitutive promoters that drive higher expression levels have become a valuable tool in the genetic engineering of plants. Recently, the search for strong plant-derived constitutive promoters has expanded to several monocot and dicot species. In this study, we isolated a novel promoter of ~850 bp located in the upstream of a house keeping *Cucumis sativus* polyubiquitin gene (Ub) with an open reading frame (ORF) of 1374 bp. The conserved domain results of the Ub gene revealed the presence of a typical Ub like superfamily conserved domain and a k27 lysine residue involved in the chain linkage of Ub genes. The bioinformatics analysis of the cis-regulatory elements (CREs) using plant CARE and PLACE showed 22 functional classes in the Ub gene promoter, many of which are involved in the binding of transcription factors (TFs) for the expression during abiotic and biotic stresses. Therefore, it would be an ideal choice of plant-derived promoter for driving higher levels of transgene expression in dicots especially in cucurbits which needs further validation by gene expression and functional characterization studies.

Keywords : Cucumis sativus, CREs, *In silico*, Polyubiquitin, Promoter analysis

GENE promoters are the regulatory sequences located upstream of the gene coding regions involved in the transcriptional expression of the gene. They contain multiple cis-regulatory elements (CREs); their nature and organization has a major impact on the promoter strength and determines the specificity of binding to the trans-regulatory proteins; transcription factors (TFs) required for the initiation and regulation of the transcription process (Ho and Geisler, 2019).

The crop genetic improvement through 'green technology approaches' such as genetic engineering and genome editing techniques *via* TALENS, ZFNs and CRISPR require a strong and well-regulated promoter for driving higher expression levels of the foreign genes or utilization of cis-genic elements. Several types of promoters such as constitutive, inducible, tissue-specific, viral and synthetic are used in the plant genetic transformation. A constitutive promoter is the one which is able to drive gene expression in many or all tissues or throughout most of the lifecycle of the plant (Kummari *et al.,* 2020).

The most widely used is a viral based promoter Cauliflower Mosaic Virus (CaMV) 35S for directing strong constitutive expression in transgenic plants (Porto *et al.,* 2014). Apart from CaMV35S, peanut chlorotic streak caulimo virus (PC1SV) and figwort mosaic virus (FMV) have also been shown to be very useful for generating Genetically Modified (GM) plants. Previous research findings show evidence of the increased chances of transcriptional inactivation due to the overuse of CaMV35S promoter (Chen *et al.,* 2013). An earlier report has shown the silencing of bar transgene, a commercially important genetic trait in transgenic oilseed rape leading to the altering of the plant phenotype from herbicide resistance to susceptibility upon CaMV infection (Bak and Emerson, 2020). It is also not uncommon to find in the literature that CaMV 35S promoters used to drive two or more

chimeric genes in the same transformation vector. The CaMV 35S also gives rise to the gene silencing phenomenon. Therefore, to avoid the potential risk of gene-silencing associated with CaMV35S and to introduce multiple transgenes, it is important to isolate and characterize a wide range of novel plant-derived promoters driving higher expression in plants.

In monocot species, certain constitutive promoters of plant origin, such as rice actin promoter and maize ubiquitin promoter (Beringer *et al.,* 2017), have been isolated and are often used for transformation of grasses (Wang *et al.,* 2016). In dicot plants, although a number of endogenous constitutive promoters have been isolated, they are not widely used or tested in other species, particularly in legumes. Although a number of constitutive promoters have been isolated from plants and used for the generation of transgenic plants, there is still a great need for novel plant sequences that function as promoter elements for the high-level expression of transgenes.

With the availability of genome sequence information (Huang *et al.,* 2009) and development of genetic transformation protocols in the model plant *Cucumis sativus*, it is essential to explore, isolate and characterize several endogenous promoters to drive higher level of transgenic expression. With this in the view, we isolated a novel promoter from a regulatory polyubiquitin gene (Ub) from *C. sativus* and identified the presence of multiple CREs through bioinformatics analysis with the possibility of utilizing them as a constitutive promoter to drive higher levels of expression of genes under biotic and abiotic stresses. Further, functional characterization and gene expression studies are required to validate for its application as a strong promoter to drive high levels of transgene expression in cucurbits.

Material and Methods

Sample Collection and Extraction of Plant Genomic DNA

The *Cucumis sativus var* green long plants were maintained in the greenhouse under standard conditions and the leaf samples were collected for the genomic DNA isolation. The modified SDS protocol was adopted for the genomic DNA isolation and the pellet was air dried and 0.1X $T_{10}E_1$ buffer was added and stored at -20 °C until further use (Sahakar & Peter, 2015; Tak & Peter, 2016 and Xia *et al.*, 2019).

Quantity and Quality Assessment of the Genomic DNA

Isolated genomic DNA was quantified by Nanodrop spectrophotometer (Bio Spectrometer, Eppendorf, Germany). About 1-2 µl of DNA sample was kept in the nano drop spectrophotometer and the absorbance was read at 260 nm. An Optical Density (OD) of 1 at 260 nm correlates to a double stranded DNA concentration of 50 ng/µl. Assessment of DNA quality was carried out by resolving the genomic DNA using 0.8 per cent agarose gel electrophoresis, stained with ethidium Bromide (EtBr) and visualized under UV light. The purity and presence of intact DNA was checked prior to PCR analysis.

Retrieval of Upstream Sequences of Polyubiquitin Gene and Primer Designing

The sequences (1kb located upstream of the translation start site) of poly ubiquitin gene (Ub) (CsaV3_6G049240) was retrieved from the Cucurbit genomic database (http://cucurbitgenomics.org). The gene specific forward and reverse primers were designed using Primer3 tool (v. 0.4.0) and the following forward CP: 5' CATGTCCGTCTCGCTATCGTCT CCCAAACTCTAACA -3') and reverse CP 5' - CATGTCCGTCTCGatTCTGGAAGACAAAGGATTAGG -3'), respectively adhering to the basic principles governing the primer design**.**

PCR Amplification Conditions

The isolated genomic DNA was amplified using Ub promoter specific forward and reverse primers. The reaction was set up in a 25 µL final volume containing 25-30 ng DNA template, 14 µL deionized nuclease free water, 2.5 µL 10X PCR buffer with 15 mM MgCl2, 2.5 µL 2 mM dNTPs, 1.0 µL forward and reverse primer (each of 10 pmol/µL) and 1.0 µL *Taq* DNA

polymerase (1U/µL) (3B Biotech, India). The amplification was carried out using a GeneAmp PCR system 9700 thermal cycler (Bio-Rad laboratories, USA) with the following amplification conditions of initial denaturation at 94 ºC for 4 minutes, denaturation at 94 ºC for 45 seconds annealing at 60 ºC for 1 minute, extension at 72 ºC for 1 minute 30 seconds and final extension at 72 ºC for 8 minutes with 32 cycles of amplification.

Analysis of the PCR Products

The resulting PCR products (10µL) were mixed with 1.5µL of 6x loading dye (30 % (v/v) glycerol, 0.25 % (w/v) bromophenol blue and 0.25 % (w/v) xylene cyanol FF) and separated electrophoretically in 1 % agarose gel (3B low EE agarose) with 1X Tris Acetate EDTA (TAE) buffer (50x buffer: 242g Tris base, 57.1mL glacial acetic acid, 100mL 0.5M EDTA (pH 8.0) and dH_2O) along with 3 µL of 100bp standard size DNA ladder (Thermos Scientific, India) and run at 80v for 2 hours (Genei, Bangalore, India). Gel was stained with EtBr and the bands were visualized under UV A_{260}nm (Alpha Innotech, FlourChem SP imaging system, USA) and the banding pattern was observed. The amplicons were further purified according to manufacturer's instruction for sequencing (Thermos Scientific, India).

DNA Sequencing

Sequencing of the purified amplified product was done at a commercial facility (Scigenomics, Kerala, India). Both the forward and reverse sequences were assembled and aligned using Bio Edit sequence alignment software (v 7.1) followed by a similarity search with the BLAST feature in the Cucurbit genomics database.

Structural Analysis of Polyubiquitin Gene

The conserved domain of the Ub gene sequence retrieved from Cucurbit genomics database (Accession number: CsaV3_6G049240) was predicted using NCBI domain database (https://www.ncbi.nlm.nih.gov/Structure/cdd/wrpsb.cgi) (Marchler-Bauer *et al.,* 2017).

Analysis of CIS - Regulatory Elements (CREs**) of Ub Promoter**

The cis elements of *C. sativus* Ub promoter was predicted using the tools Plant Care (http://bioinformatics.psb.ugent.be/webtools/plantcare/html/) and PLACE (http://www.dna.affrc.go.jp/htdocs/PLACE/).

Results and Discussion

BLAST Analysis

Amplification of the isolated genomic DNA with Ub promoter specific primers yielded an amplicon size of ~900 bp (Fig. 1). The sequenced amplicon was subsequently analyzed in the cucurbit genomics database using the BLAST feature and the results revealed a sequence identity of 99.8 per cent with the scaffold02364 of *C. sativus* green long (Gy14) v2 genome, confirming it as the Ub promoter (http://cucurbitgenomics.org/blast). The sequenced promoter was submitted to NCBI with an assigned accession number: MN243922.1.

Structural Analysis of Ub Gene

The structural analysis of Ub gene showed the presence of a conserved domain; ubiquitin-like-fold superfamily domain characteristic of ubiquitin proteins and also a key conserved k27 amino acid residue; one of seven lysines involved in chain linkage in ubiquitin (K6, K11,

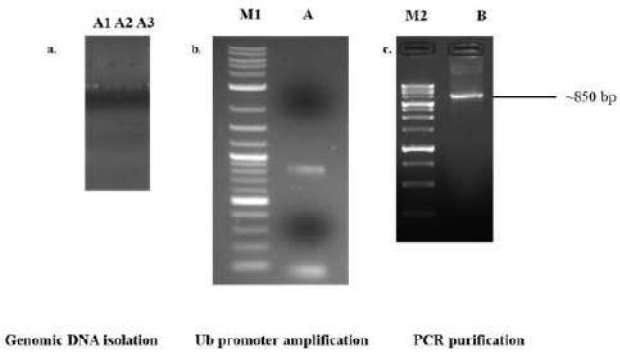

Fig. 1: The agarose gel electrophoretic images of a) *C.sativus* genomic DNA isolation, lanes A1, A2 and A3 specifying the isolated genomic DNAs. b) Polyubiquitin gene promoter, lane M1and M2- 100 bp DNA ladder (Thermo Scientific, India) and A- Ub promoter amplicon and c) PCR purified Ub promoter amplicon

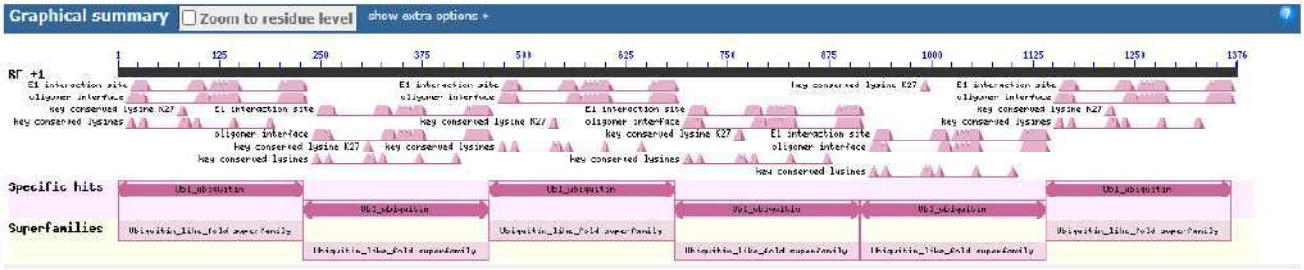

Fig. 2 : The conserved domains of *C. sativus* Ubi gene using CDD NCBI search

K27, K29, K33, K48 or K63, Ub numbering (Fig. 2). Ubiquitin is a protein modifier in eukaryotes that is involved in various cellular processes, including transcriptional regulation, cell cycle control, and DNA repair. Ubiquitination is comprised of a cascade of E1, E2 and E3 enzymes that results in a covalent bond between the C-terminus of ubiquitin and the epsilon-amino group of a substrate lysine (Tracz and Bialek, 2021). Ubiquitin-like (Ubl) proteins have similar ubiquitin beta-grasp fold and attach to other proteins in an Ubl manner but with biochemically distinct roles. Ubiquitin (Ub) and Ubl proteins conjugate and deconjugate *via* ligases and peptidases to covalently modify target polypeptides. Ub includes Ubq/RPL40e and Ubq/RPS27a fusions as well as homo polymeric multiubiquitin protein chains (Yi *et al.,* 2017). Our results were in accordance with the previous findings confirming the presence of Ub conserved domains in the polyubiquitin gene (Ub).

The analysis revealed a total of 22 Cis-regulatory elements (CREs) in the Ub gene promoter. The length of the CREs varied from 4 to 10 bp with an average range of 5-6 bp length in majority. The CREs were classified into different functional groups based on the data obtained and are summarized in Table 1. The functional classes were categorized into groups which included CREs involved in the normal cellular development process, stress responsiveness, hormonal regulation and some reported with unknown function. Majority of the CREs were observed in the 44-674 bp regions on the forward strand and 130-778 regions in the reverse strand. The CREs TATA and CAAT elements involved in the normal transcriptional control of gene were in predominantly higher frequencies covering about 61 per cent than the other functional classes. The role and importance of CREs involved in different functional classes are discussed below.

CREs in Stress Response

The CREs for stress response occupied 17 per cent of the promoter gene sequences comprising anaerobic induction response and light response elements (Fig. 3). AREs are Anaerobic Responsive Elements with AAACCA motif sequences (Table 1). The presence of AREs in the promoter region is known to play a significant role in acclimation to various stresses including oxidative and flooding stress. The interaction of AREs and transcription factors (TFs) is reported to regulate the transcriptional levels of genes involved in ATP production through the fermentation pathway during anaerobic energy metabolism under low oxygen concentrations. Similarly, both maize and *Arabidopsis* ADH1 promoters have a bipartite ARE element consisting of GT- and GC-motifs, which are crucial for gene expression under stress conditions (Kaur and Pati, 2016).

There are several light responsive elements present in the Ub gene promoter sequences including G-Box with 'CACGTT' sequence motifs, I-box with

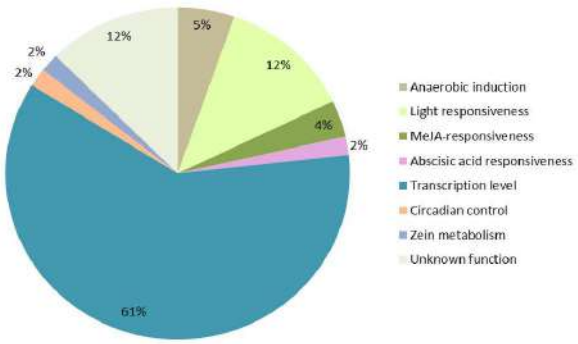

Fig. 3 : The pie chart distribution of various CREs of the *C. sativus* Ub gene according to their functional classes

TABLE 1

Details of the CREs extracted from plant CARE database for the *C. sativus* Ub gene promoter

Motif/ Cis element	Sequence	Motif function
ARE	AAACCA	Cis-acting regulatory element essential for the anaerobic induction
CGTCA-motif	CGTCA	Cis-acting regulatory element involved in the MeJA-responsiveness
TCA	TCATCTTCAT	-
CAAT-box	CAAAT	Common cis-acting element in promoter and enhancer regions
Unnamed__1	CGTGG	-
TATA-box	ATATAA and TATA	Core promoter element around -30 of transcription start
G-Box	CACGTT	Cis-acting regulatory element involved in light responsiveness
ERE	ATTTCATA	-
MYB-like sequence	TAACCA	-
ABRE	ACGTG	Cis-acting element involved in the abscisic acid responsiveness
MYB	TAACCA	-
Circadian	CAAAGATATC	*Lycopersicon esculentum* cis-acting regulatory element involved in circadian control
MYC	CATTTG	-
I-box	gGATAAGGTG	Part of a light responsive element
GATA-motif	AAGGATAAGG	Part of a light responsive element
STRE	AGGGG	-
AS-1	TGACG	-
AE-box	AGAAACT	Part of a module for light response
AAGAA-motif	GAAAGAA	-
TGACG-motif	TGACG	Cis-acting regulatory element involved in the MeJA-responsiveness
WRE3	CCACCT	-
O2-site	GATGA(C/T)(A/G)TG(A/G)	Cis-acting regulatory element involved in zein metabolism

gGATAAGGTG, GATA-motif AAGGATAAGG and AE-box AGAAACT modules respectively. Literature evidences suggest multiple roles of G-box elements in response to light, abscisic acid, methyl-jasmonate and anaerobiosis and also in ethylene induction as well as in seed specific expression (Ezer *et al.,* 2017). Earlier reports suggest the contribution of strong expression levels of Ub gene promoter mediated by a well conserved G-box like motif in the soybean Gmubi3 and Gmubi7, rice RUBQ2 andrubi3, maize Zmubi1, sunflower UbB1, switchgrass PvUbi1, and potato Ubi7 promoters (Liu *et al.,* 2016). Similarly, the occurrence of conserved tetramers of this element (ACGT) is observed in the isolated Ub promoter, suggesting their possible role in high expression levels.

CREs in Hormonal Regulation

CREs of this class contributes to 8 per cent of the total CREs with ABA, methyl jasmonate, and zein hormonal response elements. The results revealed the presence of a typical consensus ABRE motif ACGTG, which is also found in other species including rice and *Arabidopsis* that regulates dehydration and salinity responses. The ACGT core, characteristic of these cis-acting DNA elements is known to interact with a group of basic leucine zipper (bZIP) transcription factors for various physiological responses of many ABA-regulated genes in plants (Sarkar and Lahiri, 2013). Presence of another well characterized conserved motif sequence CGTCA involved in the

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Me-JA response was also observed. The jasmonic acid (JA) and its derivatives (JAs) serve as signaling molecules to regulate diverse aspects of plant life including leaf senescence, tuber formation, tendril coiling and filament elongation, biotic and abiotic responses (Wang *et al.,* 2011). Similar observations were made in the promoter sequences of JAZ family genes with several conserved motifs, such as G-box (CACGTG) and CGTCA-motif (CGTCA) related to jasmonate signaling. Similarly in *Poncirus trifoliate*, the promoter element of PtAO (Allene oxide) gene involved in JA biosynthesis typically comprised a CGTCA-motif element involved in MeJA responsiveness (Xiong *et al.,* 2020). The presence of another hormonal regulating Opaque2 (O2) motif sequences recognizing basic leucine (Leu)-zipper transcriptional activator controlling the gene expression of zein metabolism was also seen in the upstream Ub promoter sequences (Zhang *et al.,* 2015).

CREs in Cellular Development and Possible Role of CREs with unknown Function

The presence of CAAAGATATC motif involved in the circadian regulation accounted for 2 per cent of the total CREs. In addition to the other functional classes, there were also cis-elements with unknown function which constituted 12 per cent of the total CREs present in *C. sativus* Ub promoter region. Various elements such as ERE, Myb, Myc, STRE and as-1 element were observed. Their contribution in the plant stress and the relevant literature reported previously are discussed below.

The role of STRE elements in the regulation of gene expression during heat-stress conditions is reported in several research studies. For example: In Arabidopsis, it was demonstrated through deletion assay of AtHsp90–1 gene promoter. Similarly, it is also reported to occur as one of the heat shock element in Heat Shock Factor HsfA1a. An earlier study identified RSRE cis-elements (AAGGGG) resembling STRE in the promoters of diverse rapid wound responsive genes in Arabidopsis and functionally involved in stress responses, which is similar to the AGGGG motif sequence identified in this study. AGGGG (STRE) is a binding site for transcriptional activator, Msn2p/ Msn4p, identified in yeast and responsive to various stresses and also upon elicitor induction in wounding (WUN-motif, WRE3 and box S) (Montibus *et al.,* 2015).

The role of ethylene responsive elements (ERE), as a potential tool for rapid high-throughput analysis of in planta pathogen responses is previously reported (Hernandez-Garcia and Finer, 2014). Functional studies have shown that MYB is involved in plant secondary metabolism, hormone and environmental factor responses and plays an important regulatory role in cell differentiation, cell cycle and leaf morphogenesis (Sheshadri *et al.,* 2016 and Li *et al.,* 2019). The regulation of the expression of *CBF3*/ *DREB1A* by the binding of MYC-like bHLH (basic-helix-loop-helix) transcription factor in the canonical MYC *cis*-elements (CANNTG) is previously reported, the presence of such canonical sequences were also observed here with CATTTG motifs.

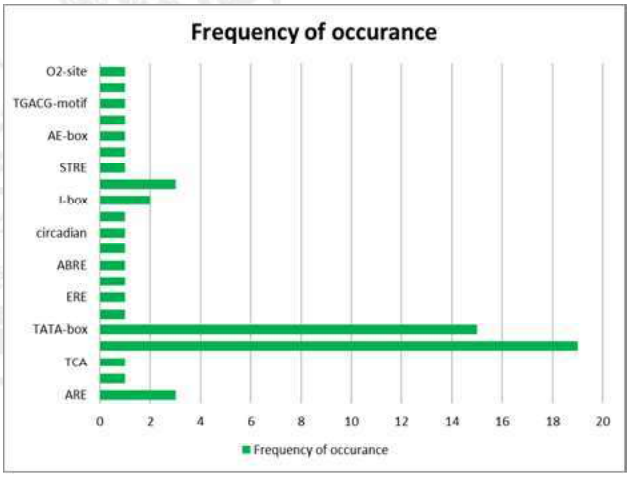

Fig. 4 : The frequency of the motifs found in the *C.sativus* Ub promoter using PLantCARE database.

Bioinformatics analysis of the upstream promoter elements comprising MYB and MYC elements along with ABRE (ABA responsive element), DRE/CRT (dehydration-responsive element/C-repeat, and the E-box elements have shown to exhibit a functional role possibly involved in the chilling or cold responses across different plant species (Ohta *et al.,* 2018).

Analysis of the promoter sequence alignments in peas (GCG 8.0, Genetics Computer Group, Madison, WI)

revealed three regions of identity namely WRE1 (wound-response element 1, AAATTTC motif), WRE2 and WRE3 (CCACCT) that are potentially involved during the common wound induction of the *CYP73A9v1* and *CYP82A1v1*. The occurrence of such WRE3-like CRE was observed in the upstream Ubi promoter sequence. The TGACG-box (TGACG) popularly known as 'as-1 motif', is another well characterized cis-element present in plants. TGACG motif is methyl jasmonate responsive element present among *A. thaliana* and *O. sativa* PR gene sequences (Wang *et al.,* 2012).

Promoters play an essential role in initiating and regulating the transcription, the first and the most important step of gene expression, their isolation and functional characterization is therefore important. High-expressing housekeeping genes that encode abundant proteins required for basic functions in plant cells are a good source of strong native plant-derived constitutive promoters. The endogenous promoter isolated in this study could emerge as a promising candidate promoter for genetic manipulation of abiotic and biotic stress tolerance in crops for high-level expression of transgenes after a thorough functional characterization and expression analysis studies.

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Documentation and Economic Analysis of Green Leafy Vegetables : A Study in Bengaluru District of Karnataka

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Abstract

The present study was carried out during 2019-20 at Bengaluru district. Bengaluru is located in South Eastern Karnataka, on the Deccan Plateau and it lies at an average elevation of 920 meters (3,018 feet) in the South Eastern part of Karnataka. The people of Bengaluru district mainly Urban and Rural population depend on green leafy vegetables as food supplements. This paper encompasses the information of 42 species of 42 genera of 31 families were tabulated as botanical name, local name, family and mode of consumption. Use of green leafy vegetables may act as alternative food resources other than cultivated vegetables, thus also acting as a multi-valued resource for health and wealth. The total sample size was 40 green leafy vegetable farmers/growers. Hence, an attempt was made to study the cost of cultivation, marketing costs and returns of growing green leafy vegetables. Results showed that, around 74.34 per cent of total cost of cultivation comprised of variable cost (Rs,12,003.11/acre) and fixed cost was 25.65 per cent (Rs.4,142.53/acre). The total cost of cultivation was Rs.16,145.64/acre, the net returns was Rs.45,932.61/acre and the magnitude of B:C ratio was 3.32:1. The marketing cost of green leafy vegetables in channel-II (produce – APMC – commission agent/traders – wholesalers – retailers – consumers) was Rs.269.76/1000 bundles, channel-II (producer – procurement centers – company retail outlets – consumers) was Rs.262.36/1000 bundles and in channel-III (producers – traders – wholesalers and retailers – consumers) was Rs.39.57/1000 bundles.

Keywords : Green leafy vegetables, Documentation, Bundles, Cost of cultivation, Marketing cost

Green leafy vegetables have played an important role in human life, since time immemorial. Millions of people do not have enough food to meet their daily requirements and are deficient in one or more nutrients and the similar situation is noticed in India with 70 per cent of rural population with rain fed agriculture dependent population. In India most urban and rural inhabitants depend on green leafy vegetables to meet their additional food requirements as they provide staple and supplement foods to urban and rural communities. The diversity in green leafy vegetables species offers variety in family diet and contributes to household food security. The nutritional value of green leafy vegetables is higher than several known common vegetables. India secured second position in the world next to china in vegetable production. However, this is much less than the recommended requirement of 300g/capita/day of vegetables for a balanced diet. Although, 175 major and minor vegetable crops are grown in India including 82 green leafy vegetables (Dey *et al.,* 2007). The World Health Organization (WHO) recommends a daily intake of more than 400g of green leafy vegetables per person to protect against diet related chronic diseases (Anonymous, 2004). Besides, green leafy vegetables are rich resource of carbohydrates, oils, proteins, minerals, ascorbic acid and the antioxidant phenols. Green leafy vegetables were largely transmitted through participation of individuals helps for future generation to obtain inexpensive food resource. Green leafy vegetables are largely ignored in land use planning and implementation, economic development and biodiversity conservation. Documentation of green leafy vegetables were limited compared to medicinal plants (Limo *et al.,* 2003).

India occupies a central position in rural life, with agriculture as its primary source of livelihood. The contribution of agriculture towards GDP is about 14

per cent in 2019-20 (MOSPI, 2019-20). Farming is the foundation of the Indian economy. Since agriculture is the backbone of the Indian economy, much more attention is needed to sustain agricultural industry. Development of allied agricultural sector, especially horticulture might be the best option for diverting resources from agriculture which ensures economic growth in large scale. A focused attention was adapted to horticulture development. Vegetable crops are of prime importance for nutritional needs of people. India has made tremendous progress in annual vegetable production of over 183.17 million tonnes and India is world's second largest producer of vegetables. The hybrid technology has revolutionized crop production of vegetables and continuously rising demand for hybrid seeds. The main advantages of hybrids are high production, short duration, superior quality, uniform production and resistance to biotic and abiotic stress.

Karnataka is India's seventh largest state, located in the tropical zone and enjoying warm climate year-round. The mean temperature ranges from 21.50 to 31.70 ^{0}C, the average state temperature is roughly 240 ^{0}C. The climatic condition is generally favourable for cultivating crops. Karnataka's geographical area is 190.50 lakh hectare of which an area of 121.82 lakh hectare is the cultivable area, making up 64 per cent of the geographical area. The normal state rainfall ranges between as low as 569 mm and as high as 4,029 mm. The average annual state rainfall is 1,354 mm. Most of the state's rainfall is provided from the South West monsoon, which begins the first week of June and lasts until the end of September. Almost all of the state contains red soils. Laterite soils tend to be found in the Western hilly and coastal areas. The Northern part of the state has black soils that have high potential for moisture.

Bengaluru lies at an average elevation of 920 meters (3,018 feet) in the South Eastern part of Karnataka. It is positioned at 12.97°N 77.56°E and covers an area of 2,190 km^2. Bengaluru has many lakes in it. Of these, the major is the Sankey lake, Ulsoor lake and Yediyur lake. Because of its elevation, Bengaluru enjoys a nice and unflappable environment across the year. The highest recorded temperature is 39 °C (102 °F) and the lowest temperature is 11 °C (52 °F). August, September and October are the wettest months; with a 180 mm is heaviest rainfall recorded in 24 hours period. Bengaluru is located in South Eastern Karnataka, on the Deccan Plateau. Bengaluru has an estimated 6.1 million metropolitan population making it the third-largest and fifth-largest metropolitan city in India. Ethno-botanical information was documented through semi structured questionnaires; Key informant interviews, frequent interactions and discussion with the local villager, farmers and retailers. The questions focused to be primarily on the local name of the plant, knowledge of the uses of plants in the past and present for consumption, collection and mode of food preparations.

Bengaluru was chosen as the study area to learn how green leafy vegetables are cultivated and marketed. Many retail companies come to Bengaluru to do business. Bengaluru has been chosen as the study location, as this city has been the center of the retail revolutions and has numerous food retail chains operating for a long time. Many new retail chains have also recently opened their stores in the city and several retail chains have made Bengaluru as the focal point of their managerial operations.

METHODOLOGY

In order to know regarding current cost of cultivation and marketing of green leafy vegetables in Bengaluru, the data was collected from 40 farmers belongs to different taluks of both Bengaluru Urban and Bengaluru Rural districts, were interviewed to know about quality of green leafy vegetables. To learn the optimum use of current resources and bottlenecks in cultivation and marketing of green leafy vegetables. The primary data forms an important component of any research investigation. The data pertaining to the source of seed materials, fertilizers, plant protection chemicals, finance, technology and information, etc., along with cultivation technology and marketing were collected from the farmers. Information pertaining to marketing channel, costs and financial sources was collected from market intermediaries such as commission agents, wholesalers and retailers, through

primary survey. Primary data was collected from 40 farmers, 20 retailers using a pre-structured questionnaire encompassing a number of variables which would help to arrive at the conclusions.

The present study was carried out with the following specific objectives they are;

1. To document the green leafy vegetables
2. To document the major green leafy vegetables marketed in Bengaluru
3. To assess the cost of cultivation and returns in green leafy vegetables by farmers
4. To assess the cost of marketing, margins and price spread of green leafy vegetables by farmers

Analytical tools and techniques employed are;

Depreciation :

$$\text{Annual depreciation} = \frac{\text{Purchase value} - \text{junk value}}{\text{Useful life of the asset}}$$

Gross returns: Gross returns (GR) = Yield *Price

Net returns: Net returns = Gross returns - Total costs

Price spread: The difference between retail price paid by the consumer and that received by the grower/ farmer for an equivalent quantity.

Results and Discussion

To Document the Green Leafy Vegetables

The study provides empirical evidence green leafy vegetables. The study area is floristically rich and includes various green leafy vegetables (Aberoumand, *et al.,* 2009). The present survey encompasses 42 green leafy vegetable species belonging to 31 family and 42 genera tabulated with botanical name, local name, family and mode of consumption of green leafy vegetables. (Table 1). The documentation on green leafy vegetables are tabulated (Arora and Pandey, 1996). More number of green leafy vegetables are documented they are amaranths, spinach, fenugreek, coriander, cabbage, cauliflower, moringa leaves, curry leaves, gongura leaves, mint leaves, lettuce leaves and dill etc.

To Document the Major Green Leafy Vegetables Marketed in Bengaluru

The documentation on major green leafy vegetables marketed in Bengaluru are tabulated in the Table 2. In Bengaluru major green leafy vegetables marketed are amaranths, spinach, fenugreek and coriander.

Cost and Returns of Cultivation from Selected Green Leafy Vegetables

The total cost of cultivation for all the green leafy vegetables was assessed by estimating per acre variable and fixed costs as shown in the Table 3. Among the different green leafy vegetable crops, the total variable cost incurred per acre in amaranths, coriander, dill, fenugreek and spinach crop cultivation was Rs.12,033.11/acre accounting 74.34 per cent (Gurikar, 2014).

The average cost of FYM was the highest *i.e.,* Rs.2105.26/acre with accounting for 13.03 per cent compared to other costs of materials. The average cost of green leafy vegetable seeds was Rs.1,609/ acre and accounts for 9.96 per cent, miscellaneous cost was around Rs.404.85/acre and its per cent is 2.50. Hence, the total material cost was about Rs.4,119.42/acre with 25.51 per cent. In machinery and labourers cost of ploughing and harrowing cost was Rs.1740.89/acre with 10.78 per cent and its cost was high as compared to other costs, then the loading and transportation of FYM costs about Rs.809.71/acre and its percentage is 5.01, the spreading of FYM was less cost that was Rs.485.82/acre with per cent 3.00 as compared to other costs and then the total labour cost was Rs.7,883.69/acre with 48.82 per cent, it was height cost as compared to the material cost of the green leafy vegetables.

Finally, the variable cost of green leafy vegetables was height *i.e*., Rs.12,033.11/acre with 74.34 per cent as compared to fixed cost was around Rs.4,142.53/acre with 25.65 per cent and the total cost of cultivation was Rs.16,145.64/acre. The analysis of gross returns for green leafy vegetable crops (Table 4) indicated

TABLE 1

Documentation on green leafy vegetables

Botanical name	Family	Common name	Local name	Mode of consumption
Achyranthes aspera L.	Amaranthaceae	Prickly chaff flower	Uttarani	Young leaves and shoots are collected, roasted then eaten.
Allium cepa L.	Amaryllidaceae	Onion leaves	Eerulli soppu	Young leaves are mixed with flour of Ragi or rice to prepare rotti.
Allmania nodiflora	Amaranthaceae	Node flower	Hasirubudde soppu	Leaves are cooked as vegetable
Anethum graveolens	Apaiaceae	sabbasige	sabbasige soppu	Leaves are cooked as vegetable
Amaranths blitum L.	Amaranthaceae	Purple amaranths	Chilakarive	Leaves and young shoots is used to prepare curry and leaves are also used to prepare palyam
Amaranths caudatus L.	Amaranthaceae	Foxtail amaranths	Chilike soppu	Leaves and young shoots is used to prepare curry and leaves are also used to prepare palyam
Amaranths cruentus L.	Amaranthaceae	Red amaranths	Rajagiri	Leaves and young shoots is used to prepare curry and leaves are also used to prepare palyam
Amaranths dubius L.	Amaranthaceae	-	Mulladantu	Leaves and young shoots is used to prepare curry and leaves are also used to prepare palyam
Amaranths gangeticus L.	Amaranthaceae	Amaranths	Dantu soppu	Leaves and young shoots is used to prepare curry and leaves are also used to prepare palyam
Amaranths polygonoides L.	Amaranthaceae	Amaranths	Chikkire soppu	Leaves and young shoots is used to prepare curry and leaves are also used to prepare palyam
Amaranths roxburghianus L.	Amaranthaceae	Amaranths	-	Leaves and young shoots is used to prepare curry and leaves are also used to prepare palyam
Amaranths spinosus L.	Amaranthaceae	Amaranths	Mullu harave soppu	Leaves and young shoots are cut into small pieces, cooked with salt and chilly and then eaten.
Amaranths tricolor L.	Amaranthaceae	Jacob's coat	Dantina soppu	Leaves and young shoots is used to prepare curry and leaves are also used to prepare palyam
Amaranths viridis L.	Amaranthaceae	Green amaranths	Nayi harive soppu	Leaves and young shoots is used to prepare curry and leaves are also used to prepare palyam
Basella alba L.	Basellaceae	Indian spinach	Basale soppu	Stem and leaves are used to prepare curry.
Beta vulgaris var. Bengalensis L.	Chenopodiacee	Palak	Palak soppu	Young leaves are boiled in water and mixed with flour of Ragi to prepare rotti.

Botanical name	Family	Common name	Local name	Mode of consumption
Boerhavia diffusa L.	Nyctaginaceae	Horse purslane	Odakalu soppu	Tender leaves and young shoots are collected, fried/ roasted then eaten.
Brassica juncea (L) Czern. & Coss.	Brassicaceae	Indian mustard.	Sasive soppu	Yung leaves are used to prepare curry
Cardiospermum helicacabum L.	Sapindaceae	Baloon vine	Agnibali	Cooked as vegetable
Cassia fistula	Fabaceae	Golden shower	Kakke soppu	Cooked as vegetable
Celosia argentea L.	Portulaceae	Red spinach	Anne soppu	Young leaves and shoots are collected, roasted then eaten.
Centella asiatica (L.) Urban	Apiaceae	Indian pennywort	Ondelga soppu	Leaves and young shoots are collected, roasted then eaten.
Chenopodium album L.	Chenopodiaceae	Chenopod	Sakothina soppu	Cooked as vegetable
Cleome gynandra L.	Cleomaceae	African cabbage	Kadu sasive	Leaves and young shoots are collected, roasted then eaten.
Cleome viscosa L.	Cleomaceae	Yellow spider flower	Nayibela	Leaves and young shoots are collected, fried/ roasted then eaten.
Commelina communis L.	Commelinaceae	Asiatic day flower	Kanne soppu	Cooked as vegetable
Coriandrum sativum	Apaiaceae	dhanya	Kothamberi soppu	Cooked as vegetable
Digera muricata L.	Amaranthaceae	False amaranths	Chenchali soppu	Cooked as vegetable
Eclipta alba L.	Asteraceae	Bhringaraj	Garuga Soppu	Cooked as vegetable
Lathyrus sativus L.	Papilionaceae	Lathyrus	Kesari	Cooked as vegetable
Merremia emarginata (Burm. f) Hallier f	Convolvulaceae	Kidney Leaf Morning Glory	-	Cooked as vegetable
Moringa oleifera L.	Moringaceae	Drumstick	Nugge soppu	Leaves are eaten after frying or roasting.
Oxalis corniculata L.	Oxalidaceae	Indian Sorrel	Huli soppu	Leaves are plucked, and Eaten as raw.
Phyllanthus amarus L.	Euphorpiaceae	Carry Me Seed	Nela nelli	Eaten as raw
Portulaca oleracea L.	Portulaceae	Purslane	Nelabasale soppu	Cooked as vegetable
Portulaca quadrifida L.	Portulaceae	Chicken leaf	Goni soppu	Tender leaves and shoots are collected, roasted then eaten.
Raphanus sativus L.	Brassicaceae	Radish	Mulangi soppu	Cooked as vegetable
Sesbania grandiflora (L.) Pers.	Fabaceae,	West Indian Pea	Agase soppu	Cooked as vegetable
Spinacia oleracea	Amaranthaceae	Pinni Palak	Palak soppu	Cooked as vegetable
Solanum nigrum L.	Solanaceae	Black nightshade	Kachi soppu	Cooked as vegetable
Trianthema portucastrum L.	Aizoaceae	Desert horse purslane	Sambar soppu	Cooked as vegetable
Trigonella foenumgraecum L.	Apaiaceae	Methi	Menthya soppu	Fresh leaves used for pulav preparations

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TABLE 2

Documentation on major green leafy vegetables marketed in Bengaluru district

Botanical name	Family	Common name	Local name	Mode of consumption
Amaranths gangeticus L.	Amaranthaceae	Amaranths	Dantu soppu	Leaves and young shoots is used to prepare curry and leaves are also used to prepare palya
Spinaciaoleracea	Amaranthaceae	Pinni Palak	Palak soppu	Cooked as vegetable
Trigonella foenum graecum L.	Apaiaceae	Methi	Menthya soppu	Fresh leaves used for pulav preparations
Coriandrumsativum	Apaiaceae	dhanya	Kothamberi soppu	Cooked as vegetable

TABLE 3

Cost of cultivation of green leafy vegetables

(Rs./acre)

Particulars	Costs	Percentage
A. **Variable costs**		
1. *Material costs*		
a. FYM and fertilizers	2,105.26	13.03
b. Seeds	1,609.31	9.96
c. Miscellaneous	404.85	2.50
Total material costs (A)	4,119.42	25.51
2. *Labour and machinery costs*		
a. Ploughing & harrowing	1,740.89	10.78
b. Loading & transportation of FYM	809.71	5.01
c. Spreading of FYM	485.82	3.00
d. Sowing	623.48	3.86
e. Fertilizer application	1,170.04	7.24
f. Irrigation	506.07	3.13
g. Weeding	728.74	4.51
h. Harvesting	971.65	6.01
3. *Marketing expenses*	728.74	4.51
4. *Interest on working capital @ 4 %*	118.55	0.73
Total labor costs (2+3+4)	7,883.69	48.82
Total variable costs (1+2+3+4)	12,003.11	74.34
B. **Fixed costs**		
a. Land revenue	45.00	0.27
b. Maintenance of farm equipment's	2,186.23	13.54
c. Depreciation	89.44	0.55
d. Rental value of land	1,821.86	11.28
Total fixed cost (B)	4,142.53	25.65
Total cost of cultivation (A+B) (Avg. of 40 farmers)	**16,145.64**	**100.00**

Note : 1+2+3+4= variable costs / paid out costs

Table 4

Cost and returns of green leafy vegetables production

Particulars	Green leafy vegetables
Avg. total cost of cultivation/ha (Rs.)	16,145.64
Avg. yield of good quality leaves (Bundles/acre)	12,415.65 (3.33/bundle)
Gross returns (Rs./acre)	62,078.25
Net returns (Rs./acre)	45,932.61
B:C ratio	3.32:1

that the gross returns obtained per acre was Rs.62,078.25 based on per acre yield of good quality marketable leaves. With respect to net returns, it was Rs.45,932.61/acre (Jaffer and Namasivayam, 2005).

Thus, cultivation of green leafy vegetables in the study area was found to be profitable as revealed by the net returns. The analysis of returns and cost were used to compute the benefit cost ratio and it resulted into a profitable benefit cost ratio in respect of all the green leafy vegetables. The magnitude of B:C ratio was 3.32:1 there by indicated higher returns for every rupee invested in the green leafy vegetables production in the study area (Kaur Harshimranjeet and Singh, 2007).

Cost of Marketing, Margins and Price Spread of Selected Green Leafy Vegetables

The major marketing channels identified in the study area adopted by the respondents, are given below.

Channel-I: Producer – APMC – Commission agent / trader – Wholesalers – Retailers – Consumers

Channel-II: Producer – Procurement centers – Company retail outlets - Consumers

Channel-III: (On farm sales) Producer – Traders - Wholesaler and Retailer – Consumers

The marketing costs involved in the marketing of selected green leafy vegetables was presented in the Table 5. The total marketing cost in channel-I was Rs.269.76/1000 bundles and here marketing takes place from producer to APMC market next sells to commission agent / traders next sells to wholesalers next sells to retailers next sells to consumers and marketing cost was more in this channel. The total marketing cost in channel-II was Rs.262.36/1000 bundles and here the marketing takes place from producer to procurement centers next sells to company retail outlets next sells to consumers. The total marketing cost in channel-III was Rs.39.57/1000 bundles and here the marketing cost was low because the traders will only take the produce from farm itself and next sells to wholesalers and retailers and finally sells to consumers (Thorat and Bhujbal, 2010).

TABLE 5

Cost of marketing of green leafy vegetables

(Rs./1000 bundles)

Particulars	Channel-I	Channel-II	Channel-III
Assembling/preparing	40.32	40.41	39.57
Packing	81.56	80.06	-
Loading/uploading	27.01	30.01	-
Transport	50.97	50.97	-
Tax/market fee	45.81	-	-
Spoilage loss etc.	8.62	20.91	-
Others	15.47	40.00	-
Total marketing cost	269.76	262.36	39.57
Farmer selling price	5,000.00	8,000.00	5,000.00
APMC selling price	6,000.00	-	-
Procurement centers selling price	-	10,000.00	-
Commission agent / trader selling price	8,000.00	-	8,000.00
Wholesalers selling price	10,000.00	-	10,000.00
Retailers selling price	12,000.00	14,000.00	10,000.00
Consumer purchase price	12,000.00	14,000.00	10,000.00
Price spread	7,000.00	6,000.00	5,000.00

Note:

Channel-I : Producer – APMC – Commission agent / trader – Wholesalers – Retailers - Consumers

Channel-II : Producer – Procurement centers – Company retail outlets – Consumers

Channel-III: (On farm sales) Producer – Traders - Wholesaler and Retailer –Consumers

The marketing costs and margin in channel-I adopted in the distribution of green leafy vegetables showed the producers selling price was Rs.5,000/1000 bundles and the ultimate price paid by the consumer was Rs.15,000/1000 bundles. It was found that farmer as a producer played a limited role as marketer and his role was only to the extent of preparing and sells the produce to APMC market. In this channel, there was an intervention of middlemen in the marketing of green leafy vegetables. Hence, the price spread in this channel-I was Rs.7,000/1000 bundles.

The marketing costs and margin in channel-II adopted in the marketing of green leafy vegetables showed that the producers' selling price was Rs.8,000/1000 bundles and the ultimate price paid by the consumer was [1]Rs.14,000/1000 bundles. It was found that farmer as a producer played a limited role as marketer and his role was only to the extent of preparing the produce and sells to the procurement centers. In this channel, there was an intervention of middlemen in the marketing of green leafy vegetables. Hence, the price spread in this channel-II was [1]Rs.6,000/1000 bundles.

The marketing costs and margin in channel-III adopted in the marketing of green leafy vegetables showed that the producers' selling price was Rs.5,000/1000 bundles and the ultimate price paid by the consumer was Rs.10,000/1000 bundles. It was found that farmer as a producer played a limited role as marketer and his role was only to the extent of preparing the produce for the traders. In this channel, there was an intervention of middlemen in the marketing of green leafy vegetables. Hence, the price spread in this channel-III was Rs.5,000/1000 bundles and in this channel less price spread is observed, respectively.

Hence, by accounting the marketing cost incurred by producer in channel-I he actually received a net price of Rs.5000/1000 bundles. The share in price spread by APMC comprising the cost incurred profit margin was Rs.1000/1000 bundles and commission agent / traders, wholesalers and retailers comprising the cost incurred profit margin was Rs.2,000/1000 bundles from each one. In channel-a! the producer share in price spread by procurement centers comprising the cost incurred profit margin was Rs.2000/1000 bundles and company retail outlets comprising the cost incurred profit margin was Rs.4000/1000 bundles. In channel-III the producer share in price spread by traders comprising the cost incurred profit margin was Rs.3000/1000 bundles and wholesalers and retailers comprising the cost incurred profit margin was Rs.2000/1000 bundles. From the above analysis, it was observed that the retailers of green leafy vegetables added more price to the consumers' price when compared to the others in marketing of green leafy vegetables.

The people of Bengaluru district have rich knowledge on use of green leafy vegetables. Uses of green leafy vegetables provide seasonal, staple foods and important alternative to the agriculturally cultivated crops. The study revealed that the distribution and importance of green leafy vegetables utilization in the past and present in Bengaluru district. It shows that green leafy vegetables use is influenced by culture and socio-economic conditions. Many valuable green leafy vegetables are familiar to certain areas or to certain communities but are unknown to others. Green leafy vegetables are not only sources of food and nutrients to the local communities, but could also be means of income generation and managed sustainably. Several green leafy vegetables can benefit local people not only as food, but also with their medicinal properties. These multi-valued resources are threatened by several anthropogenic and natural causes such as land-use change, unscientific harvesting, over-grazing, and invasive species. Therefore, sustainable management of these resources for the wellbeing of the local and urban communities as well as to conserve biodiversity is of the at most importance and could also contribute to preserve cultural and genetic diversity.

Green leafy vegetables were grown by the farmers in study area with an anticipation of good profits due to higher yields in short duration and its volatility in prices. Thus, the different green leafy vegetable crops the average cost of cultivation was Rs.16,145.64/acre in that the variable cost was Rs. 12,033.11/acre accounting 74.34 per cent and fixed cost was Rs.4,142.53/acre accounting 25.65 per cent, respectively. The magnitude of B:C ratio was 3.32:1 there by indicated higher returns for every rupee invested in green leafy vegetable cultivation in study area. The average marketing cost of green leafy vegetables like amaranths, fenugreek, spinach, coriander and dill was Rs.269.76/1000 bundles and for channel-I, in channel-II the marketing cost was Rs.262.36/1000 bundles and in channel-III the marketing cost was Rs.39.57/1000 bundles, respectively. In this study the retailers of green leafy vegetables added more price to the consumers' price when compared to the others in marketing of green leafy vegetables.

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Why do Farm Households Migrate? Evidence from Rural-Urban Interface of Bengaluru

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ABSTRACT

The study empirically assesses various factors affecting internal out-migration among farm households across rural urban interface of North Bengaluru. The study draws on both qualitative and quantitative information gathered through in-depth interviews of farm households in the context of internal out-migration. The data was collected from randomly selected 260 farm households (60 from urban and 100 each from transition and rural gradients). To identify the significant factors causing migration, Probit regression was used. results showed that education level of the migrant, household size, farm gross income, non-farm income and debt outstanding of the family were major influencing factors in shaping the out-migration among farm households. Study confirm the hypothesis that migrant and non-migrant farm households differ significantly in livelihood activities including farm income, non-farm income, household size, per capita land availability and outstanding debt of the household. The study also identifies various push and pull factors which causes out migration among the farm households and it was observed that major push factor were lack of employment and job opportunities at the origin. Prospects of higher wages, better employment opportunities were some of the critical pull factors for migration. This study underlines the need to have suitable policy and programmes to reduce rural-urban disparities and help prevent the large scale migration thereby reducing the stress on urban cities which might have impeding effects.

Keywords : Migration, Rural-urban interface, Push and pull factors, Urbanization, Probit model

In recent decades, India and other developing countries are experiencing rapid urbanization along with rapid economic growth. Urbanization is the redistribution of population from rural to urban settlements with the passage of time. Most urbanization is the result of net rural to urban migration (Satterthwaite *et al*, 2010). As agriculture in India is becoming non-remunerative compared to other sectors of the economy, specially the farm households are moving away from agricultural areas and making their way towards urbanized cities nearby. Migration is an expression of the human aspiration for dignity, safety and a better future and it is part of the social fabric, part of our very make-up as a human family. Migration in India is influenced by major differences in the patterns of social and economical development. The development policies of the central and state governments have not been able to check the process of migration and this uneven development is the main cause behind migration. Predominantly, migration in India is of short distances with around 60 per cent of the migrants changing their residence within their district of birth and 20 per cent within their state, while the rest move across the state boundaries (Thorat *et al*., 2007). Internal migration occurs in the form of rural-urban migration, transition-urban migration, and resettlement policies (Zenaselase, 2015). Barrios *et al.* (2006) reported that rural poverty is one of the main contributors to migration and rapid urban growth.

Bengaluru is one of the fastest growing cities in the world and is globally known for its development in terms of information technology, biotechnology, real estate and its diversity (Harishkumar and Chinnappa Reddy, 2017). Bengaluru is the capital city of Indian state of Karnataka which has a population of over twelve million, making it a megacity and the third-most populous city and fifth-most populous urban agglomeration in India. Table 1 shows the population growth of the city over the years. More than 50 per cent of the total population of the city are migrants and among them two third of the share is from internal

TABLE 1

Population growth of Bengaluru city (Urbanization trend)

Census Year	Population (in numbers)	Percentage changein Population (%)
1941	406,760	—
1951	778,977	91.5
1961	1,207,000	54.9
1971	1,654,000	37.0
1981	2,922,000	76.7
1991	4,130,000	41.3
2001	5,101,000	23.5
2011	8,425,970	65.2
2021	12,764,935 *	51.5%

Source : Compiled from Census of India reports
*Note : Estimated values of UN World Urbanization (Prospects, 2019)

migration (inter-state migration). Unsurprisingly, most of the migrants are from villages in and around Bengaluru city (Census of India, 2011). Bengaluru city has emerged as the hotspot for ample of job opportunities. Bhagath (2005), in his study on migration cited that predominance of non-agricultural activities and better provision of social amenities like health and educational infrastructure emerged as distinguishing features of settlements. The past literature and history on migration confirm that areas with urban centres, administrative headquarters and business sectors attract the migrants from backward areas, where employment opportunities are very less. Certainly, migration is not the way to urbanize as there are many undesirable outcomes that have resulted in rural as well as urban areas from the migration. Rural areas stand to lose from the out-migration of skilled residents (Sridhar *et al.,* 2012). Understanding the rural to urban migration has always been an inherent part of the economic development process, but its impacts are poorly understood, and are often feared by governments, which has led to policies that either attempt to explicitly or implicitly hinder migration. A major concern is that rural-urban migration can threaten increasing slums in the urban areas, food security through reductions in agricultural production. Todaro and Smith (2003) opine that the movement of population from rural to urban centers is because of high income differentials between stagnant rural sectors and developing urban sectors.

Thus, it is very essential to understand why the farm households decide to migrate or actually what compels them to move away from their origins. Hence, this study intends to understand and explore various determinants which affect the farm households across rural-urban interfaces to migrate to urban city. The study also makes an attempt to assess the various push and pull factors to understand the reasons behind migration which help in evolving appropriate policy measures.

With this backdrop, the study was conducted with the following specific objectives:

1. Identifying the factors affecting migration
2. Exploring various Pull and Push factors for migration

METHODOLOGY

The study was carried in rural-urban interface of North Bangalore in Karnataka (Fig. 1). North transect was further divided into three parts namely urban, transition (peri-urban) and rural gradients. The distinction of this transact into rural, transition and urban gradient was made based on the survey stratification index (Ellen *et al*., 2017) developed by considering percentage of built-up area and its linear distance from the city centre

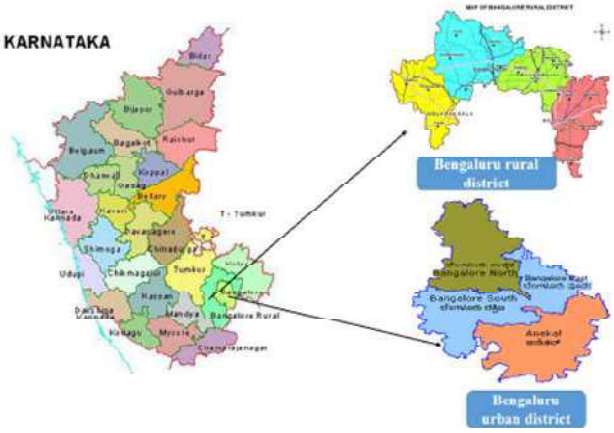
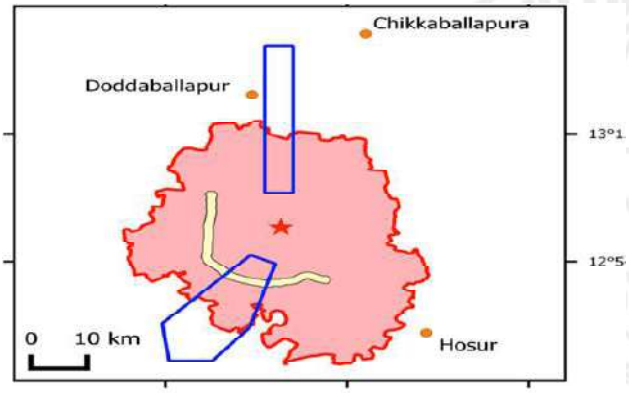


Fig 1 . Map of Karnataka showing Rural and Urban Bangalore regions.

(Fig. 2). *Vidhana Soudha*, the building of the state legislature, was used as the reference point to measure the distance. Up to about 20 to 25 km away from the city centre building density was strongly correlated to distance (the closer to the city, the higher the percentage of built-up area). Beyond that, however, the two parameters were negatively correlated (Udaykumar and Umesh, 2019).

The red area in the Fig. 2 corresponds to the districts under Bangalore's administrative authorities. The Outer Ring Road is shown in yellow. The blue contours indicate the Northern and Southern research transects, the star marks the reference point *(Vidhana Soudha)* in the city centre.



Source: Ellen, M. and co-workers

Fig. 2: Bangalore and its rural–urban interface.

The villages were selected randomly across all the three transacts. The random sampling method was adopted for the selection of farm households. The sample frame consisted of 260 farm households representing 60 from urban and 100 each from the transition and rural gradients. Pre-tested well-structured schedule was used for data collection through personal interviews. Through the interviews, data regarding age, education, farm and non-farm income of the family, cropping pattern, land holdings, family size, number of migrants in the family, reasons behind migration etc were collected. The data was collected in 2020 and the farm households were asked to give information of all the households who have migrated to city and not living with them from last 12 months to consider them as migrants.

Analytical Tools

Migration : Is defined as a move from one defining area to another (a move of some specified minimum distance) that may involve permanent shift in the residence of the people. United Nations defines migration as 'permanent change of residence' lasting for more than one year. In present study, the household members who are away from the family from last 12 months are only considered as migrant. While collecting data, we have only considered movement of household members who migrated to Bangalore city only for employment and economical purpose and we ignored migration of marriage and educational purpose as the main focus of the study was to identify the economic aspects of the migration across the rural-urban interface.

Migrant farm household : In areas of origin, migrant households are those with at least one member of the family is out migrated to Bangalore city for various reasons, while those without anyone of the family member migrated to Bangalore are non-migrant households.

Internal Migration : Movement of people from one place to another place has been broadly categorised into internal and international migration. International migration is the movement of people from one country to another country (usually crossing international borders). According to United Nations, internal migration is defined as the movement of people within the country or movement of people over short distances. Since this study is concerned about the out migration of people within short distances (the sample villages are within 50 km of city centre Bangalore), migration has been considered as internal migration.

Out migration : Movement of people out of their region (out of their original residence) to new settlement region is called as out migration. In this study, out migration means movement of people from their origins (resident areas) to Bangalore city.

Intra-Migration : Migration within the same transact (urban to urban / rural to rural). In this study, urban to

urban migration within the same city has been considered identified as intra migration.

Push & pull factors : Push and pull factors of migration help to understand why the migration actually happens and why people decide to move. Push factors (pushing away from the origin) explains about the conditions of the rural areas which compel people to move away from their origin settlement areas. Pull factors (attract people towards) help us to understand the different conditions of the cities or urban areas which attract the people towards it.

Many migration studies and literature works consider some of the major push factors for migration as lack of suitable employment opportunities and educational facilities, lack of infrastructure, health facilities, business opportunities, conflicts, and death of family members. In the same way, major pull factors observed in the studies were access to basic facilities, better employment or business opportunities, proximity to village, presence of social networks like friends, family members or relatives, and secured job in cities.

Probit model : Probit model is also called as probit regression and it is used to model dichotomous or binary outcome variables. Probit model is a statistical probability model which have two categories in the dependent variable (Liao, 1994). Probit analysis is based on the cumulative normal probability distribution. The binary dependent variable, y, takes on the values of zero and one (Aldrich and Nelson, 1984). The Probit analysis provides statistically significant findings of which factor increase or decrease the probability of migration.

In this study, migrating family was taken as 1 and non-migrated family was taken as 0. It is assumed that if there is at least one migrant in the family, such household is considered as a migrant household and if there are no migrant in the family, such household is considered as non-migrant. In view of the fact that the there were both migrant and non-migrant farm households in the sample, Probit model was used to find the important factors affecting the migration. Probit regression commands in the Stata 14.2 version software were used to find the maximum likelihood estimation of the independent variables.

$$Pr(y=1) = \Phi\ (\beta'x)$$

Where Pr denotes probability and Φ is the cumulative density function of the standard normal distribution with $\varepsilon \sim N\ (0, 1)$, which gives us the likelihood for both cases y=0 and y =1. Here, $\beta'x$ denotes the probit score/index. The inference will be like a one-unit

TABLE 2

Selection of variables and their meanings (n=260)

Variable	Mean	Std. Dev.	Meaning
Education	9.115	4.378	Education of the respondent (in years)
Age	33.638	7.786	Age of the respondent (in years)
HH size	4.773	2.378	Total number of household members
Land	2.315	2.466	Landholding of the household (in Acres)
Farm income	78018.3	134703	Gross farm income of the household per year (in Rs.)
Non-farm Income	16155.38	22302.21	Total non-farm income of the household per month (in Rs.)
Debt	0.265	0.442	"Debt=1" if family having debt outstanding; "Debt=0" if family having no debt outstanding
Commercial crops	0.184	0.388	"Comm=1" if the family growing commercial crops; "Comm=0" if family not growing commercial crops
R_ T _ UR (rural) T (Transition) U (urban)	0.403	0.491	"R_T_U=1" if the household is in urban area; "R_T_U=2" if the household is in transition area; "R_T_U=3" if the household is in rural area.

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change (either increase or decrease) in the x coefficient leads to a change in the probit score/index by β standard deviations.

$$y_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9 + \mu_i$$

Where,

X_1 = Age of the respondent (years)

X_2 = Education of the respondent (years of schooling)

X_3 = Size of the houshehold (numbers)

X_4 = Total land holding (acres)

X_5 = Gross farm income of the household (Rs.) per annum

X_6 = Non-farm income of the household per month (Rs.)

D_1 : Dummy variable as '1 0' for household having any outstanding debt

D_2 : Dummy variable as '1 0' for household growing commercial crop

D_3 : Dummy variable as '1 2 3': '1' for urban farm household, '2' for transition farm households and '3' for rural farm households.

μ_i : Error term

$b_1, b_2, \ldots\ldots b_6$ are the regression co-efficient for the variables $X_1, X_2, \ldots\ldots X_6$, respectively. b_7, b_8 and b_9 are the regression coefficients for dummy variables D_1, D_2 and D_3 , respectively.

Results and Discussion

Characteristics of Migrating and Non-Migrating Households

As mentioned in the methodology section, in a family, if at least one person is migrated such family/household is considered as migrant and otherwise. Table 3, shows the distinctive general characteristics of the migrant and non-migrant households. To know whether there was significant difference between the characteristics of the migrant and non-migrant households, t-test has been conducted and the difference was significant. It was evident from the table that education level of the migrant family, household size, dependent household members on working members of the family, non-farm income have more mean value in migrated households compared to non-migrant households. Whereas, age, farm income and land holding mean values of non-migrated families were more than the migrated families. Hence, it is clearly understood that, education level, less farm income, more non-farm income, more household size, more number of dependent family members, less land holding and less land per capita were the characteristics of the migrant households and these can be taken as influencing factors for migration.

Factors Influencing Migration

This study attempts to identify the factors influencing the farm households to migrate by using Probit analysis. The selection of variables and their respective meanings are provided in Table 2. In this study, the dependent variable considered was migrant and non-migrant household. Qin (2010), in his study to identify different factors of migration has used the same approach taking dependent variable as migrant and non-migrant households. The results of the Probit regression (Table 3) analysis indicated that, independent variables like education (total number of schooling years), household size, farm income, non-farm income, total outstanding debt of the household and rural farm household were significantly affecting the probability of the farm household migrating. It was observed that among the significant factors, education, household size, non-farm income of the household and outstanding debt had positive effect while, farm income alone had negative effect on the probability of household migration. Results confirm the hypothesis that migrant and non-migrant households differ significantly in livelihood activities including education, household size, farm income, non- farm income and location of the household (urban/transition/rural). The results are in line with the study by Unal (2018). It was observed that as the education of the household member increases, there is more probability that the household will migrate because households having better-educated individuals move to find better jobs. Related relationship between education of the households and migration was found in the study on migration by Agnes and Scott (2005).

TABLE 3

Descriptive statistics of migrated households and non-migrated households

Variables	Migrated Household (n=105)			Non migrated household (n=155)		
	Mean	S.D.	C.V.	Mean	S.D.	C.V.
Age (years)	33.304	7.271	52.867	36.609	9.870	97.426
Education (years)	10.123	3.618	13.090	8.185	4.620	21.352
HH size (numbers)	6.161	3.168	10.040	4.635	1.899	3.606
Dependent HH*	5.257	3.110	9.673	2.682	1.196	1.431
Land (in acres)	1.508	1.088	1.184	2.576	2.482	6.162
Land/capita* (acre)	0.290	0.244	0.059	0.611	0.634	0.401
Farm income (Rs.)	33985.97	28509.86	81300	99567.75	155529.7	24200
Non-farm income(Rs.)	26629.32	26980.12	72800	9365.56	14942.55	22300

* (Dependent HH= No. of dependent persons on working members of a family; Land/capita= per capita availability of land per person in the household)

Further, the study showed that the rural households have more probability of migrating than the urban and transition households, since the urban and transition households are near to the Bengaluru city and had more job opportunities compared to the rural households. Similar observations were made by Roopa and Chinnappa Reddy (2016) on urbanization effect in Bengaluru, which showed that, there had been industrialization at the fringes of Bengaluru city which attracts rural people to work there. These results were analogous to the results of the study conducted by Pandey and Singh (2003) in which they concluded that vicinity of urban areas facilitates the growth and development of non-farm sector. The households having lesser farm income had higher probability of migrating. The results were similar to the results Mazambani (1990); Rozelle *et al.* (1999) and Schmook & Radel (2008). This indicates that it is a depressed, rather than a prosperous agriculture sector that ultimately leads to higher migration and higher urbanization (Tripathy and rani, 2017).

Thorat *et al.* (2007) also observed very similar results on farm and non-farm income and concluded that there is a negative relationship between migration of family members and income from agriculture and as off-farm income of a household increases, the probability of migration of its family member decreases. The remaining variables like age, land holding of the household and the households growing commercial crops did not have any significant effect on the migration. To know the extent of changes in the household decision to migrate because of the respective factors, marginal effects have been estimated (Table 4).

Push and Pull Factors

Another way of determining the factors responsible for the households to migrate is looking at different pull and push factors. As the words themselves reveal the meanings, push factors push people away from their hometowns (village), whereas, pull factors pull people (attract) to a new destination (*i.e.,* city like Bengaluru in this study). The reasons people migrate are usually economic, political, cultural, or environmental. Many migration studies identified various push and pull factors at both origin and destination of migration. Since, the present study was limited to the farm households, the factors considered were from the origin side of the migration but not at the destination side. Lee (1966) determines push (unemployment, lower income, little access to basic public services, conflicts in rural areas) and pull (employment opportunities, higher incomes, better

TABLE 4

Probit regression analysis results for identifying the factors of migration (n=260)

Explanatory variables	Coef.		Robust Std.error	P>|z|	dy/dx(Marginal effect)
R_T_U					
R_T_U 2	0.065		0.262	0.804	0.014
R_T_U 3	0.459	*	0.261	0.079	0.099
Education	0.053	**	0.023	0.023	0.011
Age	-0.017	0.012	0.183	-0.003	
HH size	0.333	***	0.064	0	0.070
Land		0.024	0.050	0.639	0.005
Farm income	-0.0001	***	0.000	0	-0.000
Non-farm Income	0.00001	***	0.000	0	0.001
1.Debt	0.806	***	0.234	0.001	0.188
1.Commrcial crops	-0.363	0.413	0.378	-0.076	
_Cons	1.81999	0.64824	0.005		

(Note:*, **, *** means P < 0.1, P < 0.05 and P < 0.01 respectively)

provision of basic public services in urban areas) factors causing rural-urban migration.

In most of the migration studies, the major motivation behind migration is economic factors. In developing countries like India, low or marginal agricultural income, agricultural unemployment and less job opportunities are considered as basic push factors. In the same manner, Table 5 illustrates various push and pull factors and it was seen that low agricultural income/ agricultural unemployment/ low wages were the major push factor with 52 per cent followed by lack of employment and business opportunities (20.95 %). Brauw (2017) study also describes that in most of the world a rural urban labour productivity gap exists, and urban labourers obtain roughly twice the return to their labour that rural labourers do.

Thus, it was evident that more wages in the urban areas is one of the pull factors. Among the pull factors, more employment and business opportunities (33.33 %) followed by prospects of high wages (29.52 %) were the major pull factors. Since Bengaluru city is near to the study area, about 12 per cent of the migrant households expressed that it is also one of the pull factors for them to migrate.

TABLE 5

Various Push and Pull factors for migration (n=105)

Various push factors	Frequency	Percentage
Low agricultural income / agricultural Unemployment / low wages	55	52.38
Lack of employment and business opportunities	22	20.95
Lack of suitable jobs	18	17.14
Lack of educational and health facilities	7	6.66
Family / social conflicts	3	2.85
Various Pull factors		
More employment and business opportunities	35	33.33
Prospects of higher wages	31	29.52
Promise for better life and better standard of living	26	24.76
Near to their home town	13	12.38

The study identifies major factors affecting migration using Probit regression analysis. Results of the analysis clearly showed that, migrant households and non-migrant households differ significantly in many socio-

economic characteristics. The important and significant factors among many factors of migration were households having outstanding debt followed by household size. It was not surprising that, the results were in line with the hypothesis that, as the households have more members in the family, have outstanding debt to be paid and less farm income then the probability that the household moving to the migrant household category is also more. Further, the results also showed that, the rural household have more probability to migrate compared to the transition and urban. It means that rural households migrate more than that of transition and urban households as they are deprived of better employment and better living standard opportunities compared to the latter.

Meanwhile, the study also helped in identifying various important push and pull factors of migration and listed them according to their importance and it was pretty clear that better employment and job opportunities and prospects of higher wages in urban areas that made the households to migrate towards Bengaluru city.

These outcomes of the study have implications for designing development policy strategies to reduce rural-urban gaps and migration including basis for future research works. The study also helps in improving our understanding about the various factors of internal out migration as the concept of urbanization and migration are often complex and examining the characteristics of the migration is very essential for the policy makers. Especially, developing countries like India, where getting exact and accurate data related to migration is a hardship and a difficult task. This study is a modest attempt to understand and find out various significant factors affecting migration in the rural-urban interface opening up of plethora of opportunities for further research in this area.

Policy Recommendations

Based on the outcome of the study few policy inputs can be drawn for the policy makers and rural-urban development institutions.

1. Encouraging youths in villages to take up agriculture seriously and providing required and essential investment and capital factors for making agriculture remunerative for them. Thus, realising the importance of rural youth in agricultural development especially from the point of view of food security of the country, ICAR's programme on "Attracting and Retaining of Youth in Agriculture (ARYA)" can be implemented in rural areas.

2. Ensuring that farmers have timely access to seeds, fertilizers etc at competitive rates and also availability of credit at low interest rates. Further, ensuring that people also have easy access to loans or credits to start small and petty businesses in their own areas.

3. Establishment of skill development institutes and training centres in rural areas for the capacity and skill development of unemployed youth is the need of the hour.

4. Setting up of new small and medium industries in rural and transition areas which will reduce the number of migrants who migrate to cities in search of jobs and also reduce the pressure on urban cities.

5. Setting up of a data management organisation where correct/reliable data and details of migrants can be recorded from time to time for better management of migrants at the destination.

It is very clear from the above discussion that migration is an inevitable part of any economy which undergoes economic development but regulating it in a proper and gradual manner will be a better option for both rural and urban areas. Controlling this transition from rural to urban using both central and state policies and powers would make migration not a bane but a boon for further economic progress of a prosperous nation. Implementation of Provision of Urban Amenities to Rural Areas (PURA) strategy, a concept as given by former president Dr. A.P.J. Abdul Kalam can also be done which proposes that urban infrastructure and services be provided in rural hubs to create economic opportunities outside of cities. Thus, coordinating with all the stakeholders to make it

a controlled and gradual transition will bring better opportunities for all.

Limitations of the Study

1. The most critical limitation of this study was finding the farmers in the urban area of Bengaluru with at least one member migrated to compare with the non-migrant, so the sample in urban area was limited to 60 while in transition and urban, the sample size was 100 each.

2. It would have been easy if the secondary data was available to compare the percentage of migrants from each transect to Bengaluru.

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Awareness of Crisis Management Among the Sugarcane Growers of Northern Karnataka

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ABSTRACT

The present study was conducted in Belagavi and Bagalkot districts of Karnataka during 2020-21 to know the awareness of sugarcane growers about crisis and crisis management. Data was elicited from 80 head reach, 80 mid reach and 80 tail end sugarcane growers constituting to a total sample size of 240. The results revealed that 47.50 per cent of head reach sugarcane growers belongs to good awareness category followed by poor (30.00 %) and better (22.50 %) awareness categories. Similarly, 38.75 per cent of mid reach sugarcane growers belongs to good awareness category followed by poor (33.75 %) and better (27.50 %). 36.25 per cent of tail end sugarcane growers belongs to good awareness category followed by poor (33.75 %) and better (30.00 %) awareness category. With respect to overall sugarcane growers' awareness, significant percentage of sugarcane growers belongs to good awareness category with 40.83 per cent followed by poor (30.42 %) and better (28.75 %) awareness categories. With respect to statement wise awareness of sugarcane growers about crisis and its management the results revealed that crisis management means aftermath rehabilitation (32.92 %), crisis management was a concern of government (38.75 %), Television was major source of crisis information (25.83 %), agricultural crisis management is concerned with providing relief by government agencies (25.83 %), storing adequate fodder for livestock crisis management (28.33 %) and creating awareness and providing technical help is role of government in crisis management (30.00 %). Floods was major crisis faced (40.00 %), delay in payments was cause of price crisis (34.17 %), planned planting of cane as flood management in sugarcane (27.92 %), acute water shortage was cause of lower sugarcane productivity (27.50 %) and governments role is to take actions against factories for delayed payments (40.00 %).

Keywords : Crisis, Crisis management, Awareness, Head reach, Mid reach and Tail end sugarcane growers

CRISIS is extremely harmful to people whose survival solely depends on agriculture and cause considerable loss to national economies. It is a highly familiar fact that today's crisis and disasters are often due to human activities (Anonymous, 2011) causing to change the natural balance of the universe. Agriculture is one of the sectors that was most affected by crisis. In agriculture, crisis is defined as an unforeseen situation that endangers the viability of agricultural holdings, in the form of low crop prices and low farm income, either at localized level/ whole sector of production / wider geographical level (Anonymous, 2005). It may be caused by natural disasters like floods, drought, diseases and pests, economic factors and unforeseeable disruption of market access caused. Agriculture underpins the livelihoods of over 2.5 billion people worldwide (Anonymous, 2021). With agriculture sector's innate interactions with the environment. Disasters and crisis don't just have immediate, short-term effects, they diminish livelihoods and national development gains that took years to build (Anonymous, 2016). In coastal area, shift in the timing of rainfall season is due to crisis of climate change (Vinaykumar and Shvamurthy, 2015). Crisis and disasters disrupt livelihoods and add risk, damage and stress of crisis to farmers' livelihoods (Anonymous, 2018). India's geo-climatic conditions as well as its high degree of socio-economic vulnerability, makes it one of the most crisis prone country in the world (Anonymous, 2011).

Sugarcane is an important commercial crop cultivated in around seventy-nine countries. Today sugarcane cultivation and sugar industry stand as supporting pillars

of Indian agriculture economy. India holds second position in both area and production of sugarcane with an area of 5.06 lakh hectare and 341.20 million tonnes of production with the productivity of 70 to 75 tonnes/ ha, only after Brazil followed by China, Pakistan and Thailand. Among 20 sugarcane cultivating states, Karnataka stands third position in both area and production with 3.70 lakh ha under sugarcane and 299.02 lakh tonnes of production with productivity of 95 tonnes/ha, only after Uttar Pradesh and Maharashtra (Anonymous, 2020). Belagavi is the leading producer of sugarcane in Karnataka with an area of 1,20,762 hectares and 90.67 lakh tonnes of production with productivity of 75.08 tonnes/ha followed by Bagalkot (58,913 ha; 45.90 lakh tonnes; 78.08 tonnes/ha), Mandya (28,847 ha: 14.47 lakh tonnes 110.30 tonnes/ha) and Vijayapur (22,734 lakh ha; 14.47 lakh tonnes; 63.60 tonnes/ha). Lack of awareness of farmers about environment friendly practice like carbon sequestration was also indirectly contributing to crisis (Suresh and Shivamurthy, 2017).

When we compare the productivity of Karnataka, it is observed that there was a decline in the productivity of the state from 105-110 tonnes/ha (2006-07) to 90-95 tonnes/ha (2020). In recent years, country has witnessed the price crisis across sugarcane growing states of India. Along with price crisis, sugarcane farmers are facing various crisis like floods, droughts, hike in input cost, pest and disease outbreak, severe usage of chemical fertilizers & other inputs, prolonged irrigation led to the decrease in cane yield, problems in export policy which have affected the farming community mentally, financially, socially and their coping capacities. As a testimony to these farmers suicides were more in the sugarcane growing areas like Belagavi and Mandya (Anonymous, 2019). By definition, crisis is unforeseen and may exceed individual coping capacity and significant negative impact on economic viability and livelihood security of whole communities. The growing frequency and intensity of crisis are jeopardizing production system. Thus, in order to reduce the vulnerability and negative effects of crisis on sugarcane growers' lives, understanding and awareness about crisis and crisis management in general agriculture and specifically in sugarcane farming is of utmost importance. Awareness about crisis and crisis management helps in improving crisis preparedness, mitigation, response and recovery through formulation of location specific and suitable strategies (Anonymous, 2021).Integrating agriculture, livelihoods and environmental issues into crisis management efforts and risk reduction strategies is particularly important for poor farming communities, which are at greatest risk of natural crisis. Therefore, it is imperative to know the awareness level of sugarcane growers. Keeping all this in view, the present study was planned to assess the awareness of sugarcane growers about crisis and crisis management in agriculture and sugarcane farming.

METHODOLOGY

The study was carried out in two purposively selected districts of northern Karnataka region namely Belagavi and Bagalkot districts as these two districts are major sugarcane growing districts in Karnataka with contribution of 45.67 per cent to total Karnataka's sugarcane production and 48.56 per cent of Karnataka's total sugarcane area. Further, more yield gap of nearly 21 per cent in sugarcane production was observed in Belagavi and Bagalkot districts. Ex-post facto research design was used in the present study as crises like drought, flood, price, production, financial, pest and disease outbreak and livestock were already experienced by farmers *i.e.,* the event has already happened. Simple random sampling technique was used in the study. From each district, two blocks were selected based on maximum area under sugarcane and crisis prevalence. From each block two head reach (0-4 km), two mid reach (4-8 km) and two tail end (8-12 km) villages were selected based on their distance from river basin as followed by Somashekhar (2010). From each village ten sugarcane growing farmers were randomly selected thus constituting a total sample of 240. A set of statements reflecting crisis and crisis management in agriculture and sugarcane farming were identified and developed into a structured schedule through thorough review of the literatures available. The sugarcane growing farmers' responses to the crisis management statements in sugarcane cultivation were documented through

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personal interview method using the structured pre-tested interview schedule. The collected data were analyzed with descriptive statistics, percentage, frequency, mean and standard deviation.

Results and Discussion

Statement Wise Awareness of Head Reach, Mid Reach and Tail End Sugarcane Growers about Crisis and Crisis Management in Agriculture

Table 1 represents the statement wise awareness of head reach, mid reach and tail end sugarcane growers about crisis and crisis management in agriculture. The results of head reach sugarcane growers revealed that more than one-third of respondents expressed that crisis management means activities taken during crisis occurrence followed by 30.00 per cent of them opined that crisis management means prior planning along with activities taken during crisis occurrence and aftermath rehabilitation measures. The probable reason is that their exposure to crisis was comparatively more mainly to floods and further they believed that activities carried out during floods as the crisis management activity. Two-fifth of the respondents opined that crisis management is an activity of concern of government followed by less than one-fourth of them (23.75 %) expressed that it is a concern of community. The probable reason as expressed by respondents was that the effects of crisis cannot be overcome by individuals alone and it requires government's involvement to

Table 1

Statement wise awareness of crisis and crisis management in agriculture among head reach, mid reach and tail end sugarcane growers.

Statements	Head rich (n=80)		Mid rich (n=80)		Tail end (n=80)	
	F	%	F	%	F	%
Crisis management means						
Prior planning	12	15.00	08	10.00	15	18.75
Activities during crisis occurrence	27	33.75	21	26.25	12	15.00
Aftermath rehabilitation measures	17	21.25	35	43.75	27	33.75
All the above	24	30.00	16	20.00	26	32.50
Crisis management is an activity of concern to						
Individual	11	13.75	08	10.00	09	11.25
Community	19	23.75	14	17.50	21	26.25
Government	32	40.00	34	42.50	27	33.75
NGOs	06	07.50	06	07.50	07	08.75
All of them	12	15.00	18	22.50	16	20.00
Major source of information about crisis is						
Radio	0	0	0	0	00	00.00
Television	23	28.75	21	26.25	18	22.50
Newspapers	06	7.50	08	10.00	10	12.50
Government agencies	15	18.75	16	20.00	14	17.50
NGOs	08	10.00	05	06.25	08	10.00
Neighbours and friends	18	22.50	19	23.75	16	20.00
Others (Mobiles & social media)	10	12.50	11	13.75	14	17.50
Crisis management in agriculture according to your opinion is						
Contingency crop planning	13	16.25	22	27.50	12	15.00
Relief by government agencies	21	26.25	19	23.75	22	27.50
Insuring crops	16	20.00	04	05.00	21	26.25
Compensation for crop loss	09	11.25	15	18.75	12	15.00
All the above	21	26.25	20	25.00	13	16.25
Crisis management measures in livestock according to your opinion is,						
Shifting cattle to safe and food accessible places immediately	26	32.50	16	20.00	18	22.50
Keeping buffer stock of medicines & concentrated feeds	08	10.00	09	11.25	11	13.75
Storing adequate fodder	15	18.75	25	31.25	28	35.00
Insuring cattle	03	03.75	09	11.25	04	05.00
All the above	28	35.00	21	26.25	19	23.75
The role of government in crisis management in agriculture is						
Kept stock of all inputs for sowing post crisis	13	16.25	09	11.25	07	08.75
Prior planning of farming systems	21	26.25	18	22.50	11	11.25
Creating awareness & providing technical assistance	23	28.75	23	28.75	26	32.50
Providing timely relief measures	18	22.5	19	22.50	27	33.75
Training farmers about crisis management activities	05	6.25	11	13.75	09	11.25

recover quickly. More than one-fourth of the respondents (28.75 %) expressed that television (TV) was major sources of information about crisis followed by neighbours and friends (22.50 %). The probable reason is that respondents have habit of regularly watching TV to get information about crisis and the same is disseminated to other fellow farmers. Critical notice has showed that NGOs are the major sources than newspaper because very few / none of the farmers (in some villages) had access and subscribed to newspapers and NGOs are providing information about crisis management. With the penetration of smart phones in to rural areas, sugarcane growers have no idea about how to access the crisis related information as most of them are using them for entertainment purpose due to their poor awareness about the sources providing information. More than one-fourth of the respondents (26.25 %) equally opined that providing relief by government agencies and insuring crops, contingency crop planning, relief and compensation for crop losses are major measures to manage crisis effectively in agriculture followed by insuring crops (20.00 %). This might be due to the reason that farmers expect relief measures from government as they invested more in crop production which includes investments for critical inputs and expect government to carry out rehabilitation measures as well as contigency crop planning. Nearly one-third of the respondents (32.50 %) expressed that shifting cattle to safer and food accessible places, keeping buffer stocks of medicines & concentrated feed, storing adequate fodder and insuring cattle are major livestock management measures during crisis period followed by shifting cattle to safer and food accessible places (18.75 %) and storing adequate fodder (18.00 %). As per the discussion with farmers it was found that based on their previous experiences, they take precautions to protect livestock during crisis period.Further, significant percentage of respondents irrespective of head reach, mid reach and tail end are not aware about crisis management measures with respect to livestock enterprises. More than one-fourth of respondents expressed that creating awareness and providing technical assistance (28.75 %) followed by prior planning of farming systems (26.25 %) are the major roles of government to manage crisis effectively. The reasons quoted by farmers were that they will be deprived of government compensations because of poor awareness and lack of knowledge about taking situation specific measures immediately to save crop.

With respect to mid reach sugarcane growers from Table 1, it can be observed that more than two-fifth of respondents (43.75 %) opined that crisis management means taking aftermath rehabilitation measures followed by more than one-fourth of them (26.25 %) expressed that it is an activity taken during crisis occurrence. The probable reason is that the severity of crisis faced by them is relatively low and as a result, they believe that crisis management means aftermath rehabilitation measures. More than two-fifth of respondents (42.50 %) are aware about crisis management is a concern of government followed by all stakeholders like government, community, individual and NGOs (22.50 %). This might be due to reasons that government involvement in crisis management along with local communities enhances their coping capacity to crisis and take appropriate measures more effectively. More than one-fourth of the respondents (26.25 %) opined that television is the major source of crisis information followed by neighbours & friends (23.75 %). This is due to the fact that they watch the television regularly related to weather and rainfall updates along with entertainment and disseminate the same among peer farmers to take activities and also consult their neighbours and friends to get crisis information. More than one-fourth of respondents (27.50 %) were aware that contingency crop planning is the major agriculture crisis management measure followed by relief by government agencies (23.75 %). The reason is that the cropping intensity of these farmers was more compared to head reach farmers and they are conscious about the planning for crops based on prevailing situation. Less than one-third (31.25 %) of respondents opined that storing of adequate fodder is the livestock management measure during crisis followed by more than one-fourth of them (26.25 %) expressed that shifting cattle to safer and food accessible places, keeping buffer stocks of medicines & concentrated feed, storing adequate

fodder and insuring cattle are livestock management measures during crisis period. This might be due to fact that they traditionally store dry fodder of maize and brought chaffed fodder from Yadavad factory to use during crisis. With respect to role of government in agriculture crisis management, more than one-fourth of respondents (28.75 %) opined that government should create awareness & provide technical help during crisis period followed by timely relief measures and prior planning of farming systems equally (22.50 %). This is due to their poor awareness and they were deprived of government facilities. With respect to mid reach farmers, awareness about meaning of crisis, major source of information and crisis management measures significant farmers are not aware about this. Hence efforts should be made by concerned organizations to create awareness among sugarcane growers. With respect to major source of information about crisis and its management, none of the respondents indicated radio as major source of information about crisis irrespective of head reach, mid reach and tail end sugarcane growers. The possible reason for non-use of radio could be the easy accessibility to the television, smart phones and web-based platforms penetration into the rural areas. Apart from this interesting thing is that majority of farmers opined that they don't know about the crop and livestock insurances. This was mainly due to the fact that the farmers are even not aware about the cattle insurance except very few and the people who know about the crop insurance are mainly due to their loans in the banks where farmers have been informed about that by bank officials.

With respect to tail end sugarcane growers, from Table 1, it is observed that more than one-third of respondents (33.75 %) opined that crisis management means aftermath rehabilitation and nearly one-third of them (32.50 %) expressed it as prior planning, activities during crisis occurrences & post crisis rehabilitation activities collectively. This might be due to their less exposure to crisis, good literacy and good extension contacts. In general, significant proportion of them do not possesses adequate knowledge about crisis and its management along with roles to be played by government agencies. More than one-third of respondents (33.75 %) expressed that crisis management is an activity of concern of government followed by community (26.25 %). This might be due to their poor exposure to natural crisis and if any damage occurs, the government came forward to help the farmers and some saints in the area inspired locals to provide basic facilities to the flood victims which initiated community action. Less than one-fourth of respondents (22.50 %) expressed that television was major source of crisis information followed by neighbours and friends (20.00 %) and local government agencies (17.50 %) & other sources like mobiles, social media (17.50 %). More than one-fourth of respondents (27.50 %) opined that providing relief by government agencies is a crisis management strategy in agriculture followed by insuring crops (26.25 %). This might be due to reason that the farmers believe strongly that whatever assistance provided was the governments' duty and further literate farmers contacted the extension personnel to grow alternate crops in case the earlier crop failed due to crisis. More than one-third (35.00 %) of respondents expressed that storing of adequate fodder was livestock crisis management measure followed by shifting cattle to safe and food accessible places, keeping stocks of medicines, storing adequate fodder and insuring cattle (23.75 %). This might be due to the reasons that most of the tail end farmers grow maize as livestock feed after turmeric harvest and they store it as dry fodder to use in crisis and rainy seasons. More than one-third of respondents (33.75 %) opined that government's role is to provide timely relief measures followed by creating awareness & providing technical help (32.50 %). This might be due to the fact that government relief amount was released lately to victims and few victims could not get government assistance due to their poor knowledge about submitting documents in time and use of crop survey app at appropriate time and difficulty of its operation.

Statement wise Awareness of Overall Sugarcane Growers about Crisis and Crisis Management in Agriculture

Fig. 1 indicates the statement wise awareness of overall sugarcane growers about crisis and crisis

management in agriculture. Nearly one-third of respondents opined that crisis management means aftermath rehabilitation activities followed by more than one-fourth of them (27.50 %) expressed that crisis management includes prior planning, activities during crisis occurrences & post crisis rehabilitation activities. Nearly two-fifth of respondents (38.75 %) expressed that crisis management is the concern of government followed by community (22.50 %) and nearly one-fifth of them expressed as it is a concern of individual, community, NGOs and government (19.17%). More than one-fourth of respondents expressed television as major source of crisis information followed by neighbours and friends (22.08 %) and local government bodies (18.75 %). Interestingly nobody has identified radio as source of crisis information because almost no farmer has been using radio now days with the penetration of electronic gadgets like smart phones/ cell phones with vast options of entertainment along with memory cards. More than one-fourth of respondents (25.83 %) expressed that crisis management in agriculture is providing relief by government agencies followed by 22.50 per cent of them expressed it as insuring crops, contingency crop planning, relief and compensation to crop losses.

More than one-fourth of respondents were equally aware about storing adequate fodder and shifting cattle to safe and food accessible places, keeping stocks of medicines, storing adequate fodder & insuring cattle as major crisis management measures in livestock. With respect to role of government during agriculture crisis period, less than one-third of respondents (30.00 %) expressed that government should provide timely relief measures followed by creating awareness and providing technical help (26.67 %) and prior planning of farming systems (20.83 %). The overall sugarcane growers awareness about crisis and its management in agriculture are in congruence with the findings of Aravind (2011) and Meludu (2011).

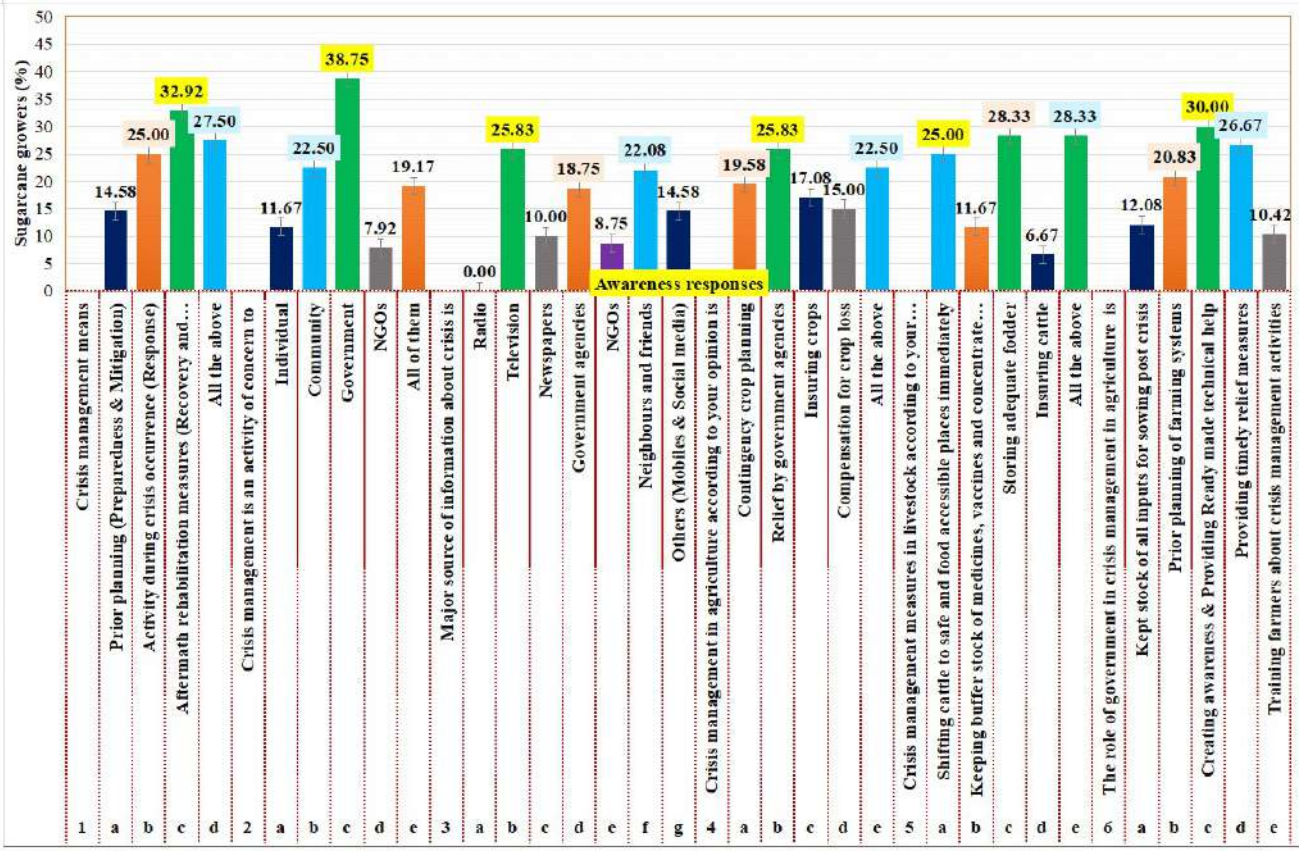

Fig. 1: Graphical representation of distribution of sugarcane growers based on their awareness about crisis and crisis management in agriculture (n=240)

Statement wise Awareness of Head Reach, Mid Reach and Tail end Sugarcane Growers about Crisis and Crisis Management in Sugarcane

Table 2 represents the statement wise awareness of head reach, mid reach and tail end sugarcane growers about crisis and its management in sugarcane farming. With respect to head reach sugarcane growers, more than half of the head reach sugarcane growers expressed that flood is the major type of crisis faced in sugarcane farming followed by price crisis (28.75 %). This is mainly because of the reasons that sugarcane growers are the frequent victims of floods and sugarcane arrears in the area. Two-fifth of respondents opined that delayed in payment is the major reason for price crisis in sugarcane farming followed by one-fifth of them expressed that they are not getting fixed prices for sugarcane. This was due to the fact that farmers were not receiving their payments for years from factories which in turn made the farmers to be in debt at bank as well as money lenders to carry out their farm activities. More than one-third of respondents (36.25 %) expressed that planned planting to reach advanced growth stage before flood occurrence is the major flood management strategy in sugarcane farming followed by draining out water from field to avoid crop loss (22.50 %). Based on their previous experiences about floods and droughts most of the farmers prefer to plant in October/November so that by monsoon season crop will be six to eight months old which can tolerate water stagnation as well as drought condition. With respect to reasons for lower productivity of sugarcane crop nearly one-third of growers (32.50 %) opined that acute shortage of water at critical stages is the main reason followed by imbalanced use of fertilizers (21.25 %) and improper selection of inter crops (16.25 %). This was mainly because of reason that drying up off rivers during summer as river was their major sources of irrigation. If they get good monsoons also it has led to floods and in-turn it reduced the yield. In order to balance yield, farmers are using more than recommended fertilizers. With respect to role of government in sugarcane crisis period, less than half of respondents (45.00 %) expressed that government should fix uniform prices for sugarcane like minimum support price instead of

TABLE 2
Distribution of respondents based on their awareness about crisis and crisis management in sugarcane

Statements	Head rich (n=80)		Mid rich (n=80)		Tail end (n=80)	
	F	%	F	%	F	%
Major type of crisis in sugarcane faced by you is						
Price crisis	23	28.75	33	41.25	31	38.75
Drought	06	7.50	09	11.25	19	23.75
Floods	43	53.75	31	38.75	22	27.50
Pest and disease outbreak	03	3.75	04	5.00	08	10.00
Others (Salinity, wetlands formation)	05	6.25	03	3.75	00	0.00
Price crisis in sugarcane is due to						
Over production	09	11.25	13	16.25	10	12.50
Delay in payments	32	40.00	21	26.25	29	36.25
No fixed prices	16	20.00	04	05.00	17	21.25
Fluctuations in weighing at factory	11	13.75	19	23.75	13	16.25
All the above	12	15.00	23	28.75	11	13.75
Flood management in sugarcane is mainly concerned with						
Conserving the soil from erosion	09	11.25	11	13.75	21	26.25
Drain out water from field to avoid crop loss	18	22.50	15	18.75	27	33.75
Slashed the crop to allow ratooning if damage was severe	11	13.75	05	6.25	3	3.75
Taking actions based on severity of floods	13	16.25	23	28.75	17	21.25
Planned planting to reach advanced growth stage before flood occurrence	29	36.25	26	32.5	12	15.00
Lower productivity of sugarcane is caused by						
Acute shortage of water	26	32.50	23	28.75	17	21.25
Frequent &faulty irrigation scheduling	12	15.00	10	12.50	08	10.00
Imbalanced application of fertilizers	17	21.25	21	26.25	27	33.75
Improper selection of inter-crops	13	16.25	16	20.00	15	18.75
All the above	12	15.00	10	12.50	13	16.25
The role of government in crisis management in sugarcane is to						
Take strict actions against factory for delayed payments	27	33.75	36	45.00	33	41.25
Fixing uniform prices for sugarcane like MSP instead of FRP	36	45.00	26	32.50	22	27.50
Framing of proper policies for sugarcane (Export, import etc)	13	16.25	16	20.00	21	26.25
All the above	04	05.00	02	2.50	04	5.00

fair and remunerative prices followed by taking strict actions against factory for delayed payments (33.75 %).

With respect to mid reach sugarcane growers, from Table 2 it is observed that more than two-fifth of respondents (41.25 %) expressed that price crisis is the major crisis faced by tail end sugarcane growers followed by floods (38.75 %) and drought (11.25 %). Most of these farmers dependent mainly on factories and they were also exposed to floods. With respect to price crisis in sugarcane farming, more than one-fourth of mid reach farmers (28.75 %) opined that over production, delayed payments, no fixed prices & weighing fluctuations were major reasons for price crisis in sugarcane farming followed by delay in payments (26.25 %). Nearly one third of respondents (32.50 %) expressed that planned planting to reach advanced growth stage before flood occurrence was the major flood management strategy in sugarcane farming followed by taking actions based on severity of floods (28.75 %). This might be due to their previous experiences of gambling with monsoons farmers prefer to take actions based on severity otherwise it will be burden for farmers. More than one-fourth of respondents expressed that acute shortage of water during critical stages (28.75 %) and imbalanced use of fertilizers (26.25 %) are the major causes for lower productivity in sugarcane farming. With respect to role of government during sugarcane crisis period, less than half of respondents (45.00 %) expressed that government should take strict actions against factory for delayed payments followed by fixing uniform prices for sugarcane (32.50 %) to manage sugarcane crisis effectively. This might be due to the burden they faced because of delayed payments and farmers observed price fluctuations in factories where farmers get better prices in cooperative factories compared to private factories of same taluk.

With respect to tail end sugarcane growers, from Table 2 it is observed that less than two-fifth of respondents (38.75 %) expressed that price crisis is the major crisis faced in sugarcane farming followed by floods and drought equally with 23.75 per cent. Because of their high dependency on sugarcane and political attachment to leaders made them to send their cane to private factories owned by politicians. As a result they are not getting good prices for their produce. More than one-third of respondents (36.25 %) expressed that delay in payments is the major reason for price crisis in sugarcane farming followed by 21.25 per cent of them opined that they are not getting fixed prices for sugarcane. More than one-third of respondents (33.75 %) expressed that draining out flooded water from field was the major flood management measure in sugarcane farming followed by conserving soil from erosion (26.25 %). This might be due to their experience in farming and least exposure to severe floods. Based on their experience due to heavy rains / overflow of stream into field, the water accumulated was drained out to avoid crop damage. With respect to lower productivity of sugarcane, more than one-third of growers (33.75 %) expressed that imbalanced use of fertilizers is the reason for lower sugarcane productivity followed by acute shortage of water during critical growth stages (21.25 %). The main reason is that most of the farmers extensively use fertilizers to get higher yield as they were cultivating more than three crops at a time believing that it requires more inputs. Further, they also use micro irrigation especially drip which reduced their water shortage in tail end areas. With respect to governments role during crisis period, more than two-fifth of tail end sugarcane growers (41.25 %) were opined that government should take strict actions against factory for delayed payments followed by fixing uniform prices for sugarcane (27.50 %) and should frame proper policies for sugarcane (26.25 %) production.

Statement Wise Awareness of Overall Sugarcane Growers about Crisis and Crisis Management in Sugarcane

Fig. 2 indicates the distribution of overall sugarcane growers based on their awareness about crisis and crisis management in sugarcane. It is observed that two-fifth of respondents (40.00 %) expressed that flood was major crisis faced in sugarcane farming followed by price crisis (36.25 %). With respect to price crisis in sugarcane, more than one-third of the

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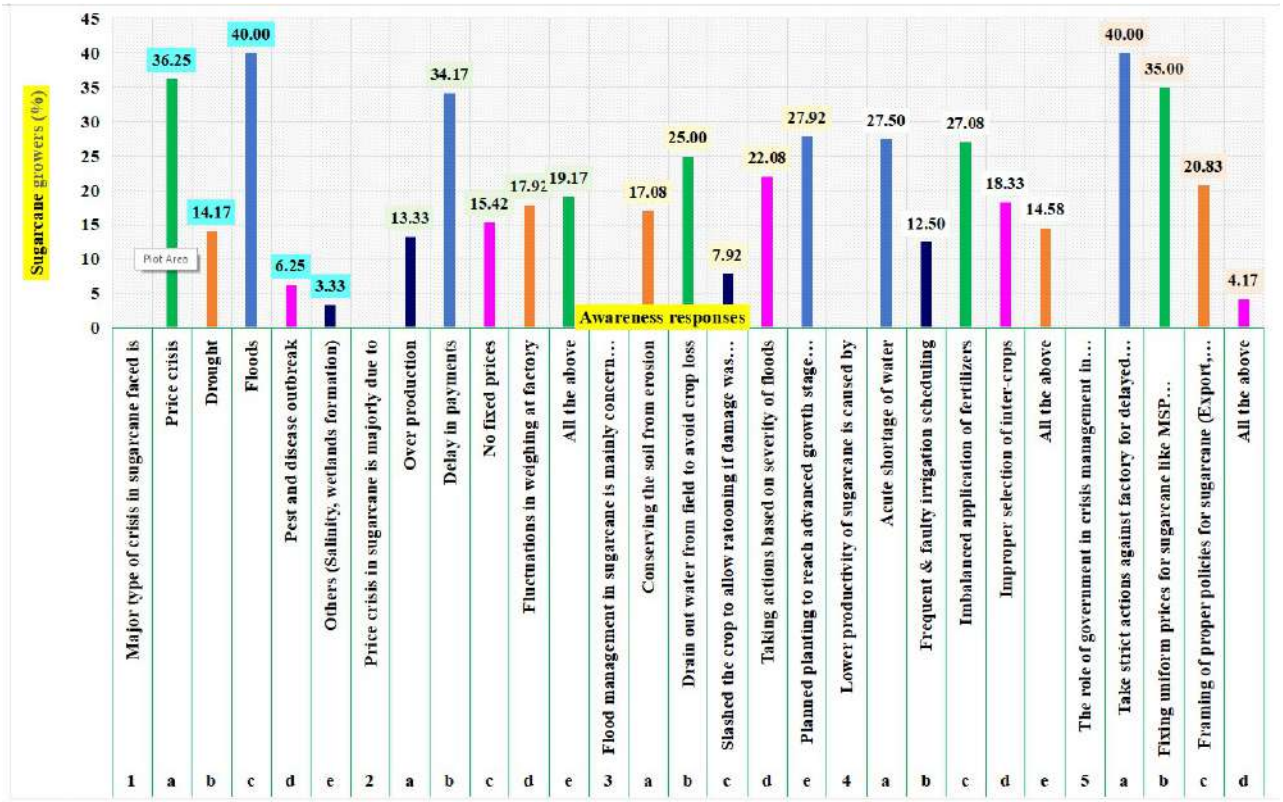

Fig. 2: Graphical representation of respondents based on their awareness about crisis and crisis management in sugarcane (n=240)

respondents (34.17 %) expressed that price crisis in sugarcane is due to delay in payments followed by over production, no fixed prices and fluctuations in weighing at factories (19.17%). More than one-fourth of sugarcane growers opined that flood management in sugarcane farming involves planned planting to reach advanced growth stage before flood occurrence (27.92 %) followed by drain out flooded water from field (25.00 %). With respect to lower productivity, more than one-fourth of the respondents expressed that acute shortage of water (27.50 %) and imbalanced use of fertilizers (27.08 %) were the major causes for lower productivity in sugarcane farming followed by improper selection of inter crops (18.33 %). With respect to role of government in sugarcane crisis management, two-fifth of the respondents expressed that government should take strict actions against factory for delayed payments and more than two-third of them expressed to fix uniform prices for sugarcane like minimum support price instead of fair and remunerative prices (35.00 %).

Overall Awareness of Sugarcane Growers about Crisis and Crisis Management

Table 3 represents the overall awareness of sugarcane growers about the crisis and its management in sugarcane farming. With respect to head reach sugarcane growers less than half of the respondents (47.50 %) belongs to average awareness category followed by poor (30.00 %) and better (22.50 %) awareness categories. Similarly, among mid reach sugarcane growers it was noticed that less than two-fifth of respondents (38.75 %) belongs to average awareness category followed by poor and better awareness categories with 33.75 per cent and 27.50 per cent, respectively. Among tail end sugarcane growers, 36.25 per cent of sugarcane growers belongs to the good awareness category followed by poor and better awareness category with 33.75 per cent and 30.00 per cent respectively. More tail end sugarcane growers belong to the better awareness category compared to head reach sugarcane growers because

TABLE 3

Overall awareness of sugarcane growers about crisis and crisis management

Statements	Head rich (n=80)		Mid rich (n=80)		Tail end (n=80)		Overall (n=240)	
	F	%	F	%	F	%	F	%
Poor (<13.92)	24	30.00	22	27.50	27	33.75	73	30.42
Average (13.92 to 18.50)	38	47.50	31	38.75	29	36.25	98	40.83
Better (>18.50)	18	22.50	27	33.75	24	30.00	69	28.75

Mean = 16.20833 SD : 4.5845

of the fact that tail end sugarcane growers possessed the good contacts with extension professionals and there was surety of getting returns if taken crisis management activities properly. Head reach farmers were mostly affected by the floods which cannot be prevented which in turn reduced their information seeking about the crisis management leading to poor awareness. In total, significant percentage of sugarcane growers belongs to the average awareness category with 40.83 per cent followed by poor and better awareness category with 30.42 per cent and 28.75 per cent respectively. The results are in congruence with the findings of Aravind (2011).

From the results it can be interpreted that most of the sugarcane growers belongs to average to better awareness category (69.58 %) and more than one fourth of them had poor awareness about crisis management which was mainly due to the fact that farmers what they know and take the crisis management actions based on their exposure, severity and frequency of crisis in their condition. Crisis cannot be controlled / prevented but it can be managed effectively if sugarcane growers aware about the crisis and its management. Hence, there is a need for improving the awareness level of sugarcane growers about crisis management by adopting suitable extension strategies during crisis period. It is imperative to devise suitable extension interventions like awareness campaigns, training to enhance coping capacities of sugarcane growers, planning farming systems, demonstrations, simulation exercises, etc., for updating their knowledge and create awareness about crisis management activities to facilitate better and holistic management of crisis to reduce its impact and faster recovery from its losses, rather than taking measures after crisis occurrence.

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Studies on Influence of Organic Sources on Growth and Yield of Maize in Maize-Cowpea Cropping Sequence

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Abstract

A field experiment was conducted at research and demonstration block of Research Institute on Organic Farming, UAS, GKVK, Bengaluru during 2020-21 to study the influence of organic sources on growth and yield of maize in maize-cowpea cropping sequence. The experiment was laid out in factorial randomised block design with three replications. The experiment consists of 15 treatment combinations of three levels of N equivalent and five organic sources along with absolute control and UAS-B package. The experimental soil was red sandy loam having low organic carbon (0.45 %) and medium in N (289.4 kg ha^{-1}), P_2O_5 (28.6 kg ha^{-1}) and K_2O (235.2 kg ha^{-1}) content. The experimental results indicated that application of bio-compost at 125 % N equivalent resulted in higher plant height (221.5 cm), leaf area (7949 cm^2 plant^{-1}), total dry matter accumulation (201.1 g plant^{-1}) and kernel (107.47 q ha^{-1}) and stover yield of maize (154.60 q ha^{-1}) followed by poultry manure at 125 per cent N equivalent and found significantly superior over other treatments in the studies. However, UAS-B package (150:75:40 kg N: P_2O_5: K_2O ha^{-1}) recorded significantly higher plant height (229.9 cm), leaf area (8197 cm^2 plant^{-1}), total dry matter accumulation (213.6 g plant^{-1}) and kernel (111.96 q ha^{-1}) and stover yield (161.13 q ha^{-1}) and was on par with application of bio-compost at 125 per cent N equivalent.

Keywords : Maize-cowpea cropping sequence, Organic sources, Bio-compost, Poultry manure, N equivalent

Maize (*Zea mays* L) is one of the most versatile crops grown throughout the tropical as well as temperate regions of the world. Globally, maize is known as 'Queen of cereals' because it has the highest genetic yield potential among the cereals. In India, it is cultivated in an area of 9.56 million hectare with a production 28.76 million tonnes and productivity of 3006 kg ha^{-1}.Karnataka alone contributes 14.88 per cent of the total maize production with an area of 1.42 million hectare and production of 4.4 million tonnes (Anonymous, 2021). About 85 per cent of the maize produced is consumed as human food and animal feed including poultry. Maize-cowpea cropping system has several advantages, such as improves of soil fertility, increase soil organic carbon (SOC), humus content, nitrogen and phosphorus availability, suppress weed growth through smothering effects, increase production per unit area, enhance land use efficiency, reduce runoff and soil loss, etc. Inclusion of legume provides sustainability to non-legume cereal component by enriching soil fertility and increasing system productivity and returns. Pulses are considered the key crops for intensification of rice and maize-fallows due to their short-duration, hardy and low-input requiring nature, hence offers a tremendous opportunity to utilize residual soil moisture and nutrients.

Over the years, health of Indian soils has deteriorated resulting in decline of organic carbon content, soil biodiversity and soil physico-chemical properties and build-up of multi-nutrient deficiencies over large area due to reduction in addition of organic manures, imbalanced use of fertilisers and mono cropping. It is reported that plant nutrient removal from soils by different crops annually is 10-12 million tonnes higher than addition from various sources, resulting in negative nutrient balance. Considering these disadvantages and escalation of fertiliser costs there is a paradigm shift from inorganic to organic farming. To sustain soil health addition of organic matter as source of nutrients is pivotal and in such situation organic agriculture plays

a crucial role in Indian farming. Organic agriculture is a production system which avoids or largely excludes the use of synthetically compounded fertilisers, pesticides, growth regulators and livestock feed additives. To the maximum extent possible, organic farming system relies on crop rotations, crop residues, animal manures, legumes, green manures, on-farm organic wastes and aspects of biological pest control to maintain soil productivity and health. Keeping these points in view, the investigation was carried out at UAS, GKVK, Bengaluru to study the influence of organic sources on growth and yield of maize in maize-cowpea cropping sequence.

Material and Methods

Field experiment was conducted at organic farming research and demonstration block of Research Institute on Organic Farming (RIOF), Gandhi Krishi Vignan Kendra (GKVK), University of Agricultural Sciences, Bangalore. It is situated in Eastern Dry Zone of Karnataka at latitude of 13° 09' North, longitude of 77° 57' East and an altitude of 924 m above mean sea level (MSL). Studies were conducted to know the influence of organic sources on growth and yield of maize during summer 2020 and to assess the residual effect on growth and yield of cowpea during *kharif* 2020 and the same sequence was followed during *rabi* 2020 and summer 2021. The experiment consists of 15 treatment combinations of three levels of N equivalent (N_1: 75 % N equivalent; N_2: 100 % N equivalent and N_3: 125 % N equivalent) and five organic sources [F_1: Farm Yard Manure; F_2: Bio compost; F_3: Vermicompost; F_4: Poultry Manure (pre cured); F_5: Jeevamrutha] along with absolute control and UAS-B package was laid out in factorial randomised block design with three replications. The experimental soil was red sandy loam with initial organic carbon content of of 0.45 per cent, medium in N (289.4 kg ha^{-1}), P_2O_5 (28.6 kg ha^{-1}) and K_2O (235.2 kg ha^{-1}) content. The average rainfall received during crop growth period was 331.5 mm. The nutrient composition of organic manures used in the experiment is presented in Table 1.

Table 1

Nutrient composition of organic manures

Organic manures	N (%)	P_2O_5 (%)	K_2O (%)
Farm yard manure	0.98	0.71	0.78
Bio-compost	2.03	1.57	1.84
Vermicompost	1.20	0.70	0.80
Poultry manure	2.23	1.77	0.57
Jeevamrutha	0.71	0.48	0.30

Maize hybrid MAH-14-5 was sown with a spacing of 60 x 30 cm and followed agronomic practices for raising crop. Nutrient sources *viz.,* bio-compost, poultry manure, vermicompost, farm yard manure and jeevamrutha were applied on N equivalent basis after analysing the nutrient content. Application of 10 t FYM ha^{-1} is common for all the treatments as per package of practice except absolute control. Half the dose of N was supplied as basal through organic sources and remaining 50 per cent of recommended N was supplemented through jeevamrutha in equal splits at 30 and 60 DAS. Neem oil (10 ml l^{-1}) spray was taken against fall army worm in maize as and when noticed. Manual weeding at two times (at 20 and 45 DAS) and earthing up (at 30 DAS) were practiced to maintain weed free condition. Cowpea crop (KBC 9) was sown after harvesting maize at a spacing of 45 x 10 cm and crop was raised without application of organic nutrient sources following crop management practices. Neem oil (10 ml l^{-1}) was sprayed to control aphid infestation in cowpea during crop growth stages.

Biometric observations on growth parameters were recorded randomly on selected five plants at 30, 60, 90 days after sowing and at harvest in the net plot. Data related to yield was recorded at the time of harvest of the crop. Based on the observations, data were subjected to statistical analysis as per the procedure outlined by Gomez and Gomez (1984). To know the effect of individual factors and to compare treatment combinations with control treatments, statistical procedure of factorial randomised complete block design and randomised complete block design were followed, respectively.

RESULTS AND DISCUSSION

Plant Height (cm)

The pooled data of two seasons pertaining to plant height at different growth stages of maize as influenced by application of organic sources in maize-cowpea cropping sequence is presented in Table 2. Plant height of maize varied significantly at 30, 60, 90 DAS and at harvest as influenced by organic sources. Application of organic sources at 125 per cent N equivalent recorded significantly higher plant height (42.5, 110.2, 176.6 and 188.2 cm at 30, 60, 90 DAS and at harvest, respectively) followed by 100 per cent N equivalent (33.5, 86.4, 139.4 and 148.5 cm at 30, 60, 90 DAS and at harvest, respectively) and 75 per cent N equivalent (26.1, 67.0, 108.5 and 115.6 cm at 30, 60, 90 DAS and at harvest, respectively). Among organic sources, application of bio-compost resulted significantly higher plant height (39.9, 103.1, 166.0 and 176.9 cm at 30, 60, 90 DAS and at harvest, respectively), followed by poultry manure (36.5, 94.3, 151.8 and 161.7 cm at 30, 60, 90 DAS and at harvest, respectively), vermicompost (33.1, 85.6, 137.9 and 146.9 cm at 30, 60, 90 DAS and at harvest, respectively) and jeevamrutha (31.0, 80.1, 128.9 and 137.4 cm at 30, 60, 90 DAS and at harvest, respectively) and lower plant height was recorded in farm yard manure (29.5, 76.3, 122.9 and 130.9 cm at 30, 60, 90 DAS and at harvest, respectively) applied plots.

Interaction effect between organic sources and levels of nitrogen was found to be significant. Application of bio-compost at 125 per cent N equivalent recorded higher plant height (50.0, 129.7, 207.9 and 221.5 cm at 30, 60, 90 DAS and at harvest, respectively) which was on par with UAS-B package *i.e.*, 150:75:40 kg N: P_2O_5: K_2O ha^{-1} (51.9, 134.6, 215.8 and 229.9 cm at 30, 60, 90 DAS and at harvest, respectively). Lower plant height was observed in absolute control plot of no application of organic manures (21.4, 55.6, 87.2 and 90.3 cm at 30, 60, 90 DAS and at harvest, respectively). Bio-compost contains higher amount of nutrients and addition of jeevamrutha as top dress has enhanced in nutrient release from organic sources. Jeevamrutha is a rich source of beneficial microorganisms and contains growth promoting

TABLE 2

Plant height (cm) of maize at different growth stages as influenced by organic sources (pooled data of two seasons)

Treatments	30 DAS	60 DAS	90 DAS	At harvest
Nitrogen equivalent levels (N)				
N_1 - 75 % N equivalent	26.1	67.0	108.5	115.6
N_2 - 100 % N equivalent	33.5	86.4	139.4	148.5
N_3 - 125 % N equivalent	42.5	110.2	176.6	188.2
S. Em ±	0.60	1.55	2.48	2.65
C.D. (p=0.05)	1.69	4.38	7.03	7.49
Organic sources (F)				
F_1 – Farmyard manure	29.5	76.3	122.9	130.9
F_2 – Bio-compost	39.9	103.1	166.0	176.9
F_3 - Vermicompost	33.1	85.6	137.9	146.9
F_4 – Poultry manure	36.5	94.3	151.8	161.7
F_5 - Jeevamrutha	31.0	80.1	128.9	137.4
S. Em ±	0.77	2.00	3.21	3.42
C.D. (p=0.05)	2.19	5.66	9.08	9.67
Interaction (NxF)				
N_1F_1	22.5	57.9	93.8	99.9
N_1F_2	30.5	78.3	126.7	135.0
N_1F_3	26.0	66.7	108.0	115.1
N_1F_4	27.8	71.5	115.8	123.3
N_1F_5	23.6	60.7	98.3	104.8
N_2F_1	29.1	75.0	121.0	128.9
N_2F_2	39.3	101.4	163.4	174.1
N_2F_3	32.8	84.5	136.3	145.2
N_2F_4	35.9	92.6	149.3	159.1
N_2F_5	30.5	78.7	126.9	135.2
N_3F_1	37.0	96.1	153.9	164.0
N_3F_2	50.0	129.7	207.9	221.5
N_3F_3	40.7	105.7	169.4	180.5
N_3F_4	45.7	118.7	190.2	202.6
N_3F_5	38.9	100.9	161.7	172.2
T_{16}	21.4	55.6	87.2	90.3
T_{17}	51.9	134.6	215.8	229.9
S. Em ± 1.34	3.47	5.56	5.93	
C.D. (p=0.05)	3.78	9.79	15.71	16.74

substances such as auxins, gibberlins, cytokinins apart from having lower concentration of both macro and micro nutrients. This is in conformity with Devakumar *et al*. (2008 and 2011).

Leaf Area (cm^2 plant^{-1})

Leaf area of maize differed significantly due to influence of organic sources in maize-cowpea cropping sequence (Table 3). Significantly higher leaf area was recorded with application of 125 per cent N equivalent (2480, 5407, 6895 and 6201 cm^2 plant^{-1} at 30, 60, 90 DAS and at harvest, respectively) followed by 100 per cent N equivalent (1682, 3666, 4675 and 4204 cm^2 plant^{-1} at 30, 60, 90 DAS and at harvest, respectively) and lower leaf area was observed in 75 per cent N equivalent (1371, 2990, 3813 and 3429 cm^2 plant^{-1} at 30, 60, 90 DAS and at harvest, respectively). Among organic sources, bio-compost application recorded significantly higher leaf area (2256, 4918, 6272 and 5640 cm^2 plant^{-1} at 30, 60, 90 DAS and at harvest, respectively) followed by poultry manure (1950, 4251, 5421 and 4875 cm^2 plant^{-1} at 30, 60, 90 DAS and at harvest, respectively) and found significantly superior over other treatments. However, lower leaf area of maize was recorded with application of farm yard manure (1560, 3400, 4336 and 3899 cm^2 plant^{-1} at 30, 60, 90 DAS and at harvest, respectively).

Interaction effect between organic sources and levels of nitrogen was found to be significant for leaf area. Application of bio-compost at 125 per cent N equivalent recorded higher leaf area (3180, 6932, 8840 and 7949 cm^2 plant^{-1} at 30, 60, 90 DAS and at harvest, respectively) which was on par with UAS-B package *i.e*., 150:75:40 kg N: P_2O_5: K_2O ha^{-1} (3279, 7148, 9115 and 8197 cm^2 plant^{-1} at 30, 60, 90 DAS and at harvest, respectively). Lower leaf area was recorded in absolute control plot (1091, 2378, 3033 and 2728 cm^2 plant^{-1} at 30, 60, 90 DAS and at harvest, respectively). Increased availability of nutrients in soil due to mineralization of organic nutrient sources could have triggered cell elongation and multiplication resulting in high growth rate of shoot in turn increase in leaf area of maize compared to control. The results are in line with Ashwini *et al.* (2015).

TABLE 3

Leaf area (cm 2 plant-1) of maize at different growth stages as influenced by organic sources (pooled data of two seasons)

Treatments	30 DAS	60 DAS	90 DAS	At harvest
Nitrogen equivalent levels (N)				
N1 - 75 % N equivalent	1371	2990	3813	3429
N2 - 100 % N equivalent	1682	3666	4675	4204
N3 - 125 % N equivalent	2480	5407	6895	6201
S. Em ±	58	126	161	145
C.D. (p=0.05)	164	357	456	410
Organic sources (F)				
F1 - Farmyard manure	1560	3400	4336	3899
F2 - Bio-compost	2256	4918	6272	5640
F3 - Vermicompost	1835	4001	5102	4588
F4 - Poultry manure	1950	4251	5421	4875
F5 - Jeevamrutha	1621	3535	4507	4053
S. Em±	75	163	208	187
C.D. (p=0.05)	212	461	588	529
Interaction (NxF)				
N1F1	1174	2560	3265	2936
N1F2	1629	3552	4530	4074
N1F3	1383	3015	3844	3457
N1F4	1455	3173	4046	3639
N1F5	1215	2648	3377	3037
N2F1	1504	3279	4182	3761
N2F2	1959	4271	5447	4898
N2F3	1659	3618	4613	4149
N2F4	1823	3973	5067	4556
N2F5	1463	3190	4068	3658
N3F1	2000	4360	5560	5000
N3F2	3180	6932	8840	7949
N3F3	2463	5370	6848	6158
N3F4	2572	5607	7151	6430
N3F5	2186	4766	6077	5465
T16	1091	2378	3033	2728
T17	3279	7148	9115	8197
S. Em ±	153	333	425	382
C.D. (p=0.05)	432	941	1200	1079

Total Dry Matter Accumulation (g plant^{-1})

Significantly higher total dry matter accumulation of maize (Table 4) was recorded with application of organic sources at 125 per cent N equivalent (8.15, 72.1, 118.1 and 150.7 g plant^{-1} at 30, 60, 90 DAS and at harvest, respectively) followed by 100 per cent N equivalent (5.32, 48.1, 77.1 and 98.4 g plant^{-1} at 30, 60, 90 DAS and at harvest, respectively) and 75 per cent N equivalent (4.10, 36.9, 59.5 and 75.9 g plant^{-1} at 30, 60, 90 DAS and at harvest, respectively). Significantly higher dry matter accumulation of maize was recorded in bio-compost applied plot (7.27, 65.0, 105.5 and 134.6 g plant^{-1} at 30, 60, 90 DAS and at harvest, respectively) and was found to be statistically superior over poultry manure (6.48, 58.0, 94.0 and 119.9 g plant^{-1} at 30, 60, 90 DAS and at harvest, respectively), vermicompost (5.86, 52.4, 85.0 and 108.5 g plant^{-1} at 30, 60, 90 DAS and at harvest, respectively), jeevamrutha (5.09, 45.5, 73.7 and 94.1 g plant^{-1} at 30, 60, 90 DAS and at harvest, respectively) and farm yard manure (4.57, 40.9, 66.3 and 84.6 g plant^{-1} at 30, 60, 90 DAS and at harvest, respectively).

Dry matter accumulation was found to be significant for the interaction between nitrogen equivalent levels and organic sources. Bio-compost application at 125 per cent N equivalent resulted significantly higher dry matter accumulation (10.87, 96.2, 157.6 and 201.1 g plant^{-1} at 30, 60, 90 DAS and at harvest, respectively) compared to other treatments and was on par with UAS-B package *i.e.*, 150:75:40 kg N: P_2O_5: K_2O ha^{-1} (11.55, 103.5, 167.5 and 213.6 g plant^{-1} at 30, 60, 90 DAS and at harvest, respectively). Lower dry matter accumulation was observed in absolute control plot of no organic manure application (4.06, 36.5, 58.8 and 75.0 g plant^{-1} at 30, 60, 90 DAS and at harvest, respectively). This is in conformity with Vishwajit and Devakumar (2018). Total dry matter production is a result of dry matter accumulation in plant parts, which depends on uptake of nutrients like N, P and K. Increase in dry matter was mainly due to increase in number of leaves produced per plant and better uptake of nutrients. Application of organic manures and jeevamrutha has increased biological efficiency and greater sink capacity in the crop which might have

TABLE 4

Total dry matter accumulation (g plant-1) of maize at different growth stages as influenced by organic sources (pooled data of two seasons)

Treatments	30 DAS	60 DAS	90 DAS	At harvest
Nitrogen equivalent levels (N)				
N1 - 75 % N equivalent	4.10	36.9	59.5	75.9
N2 - 100 % N equivalent	5.32	48.1	77.1	98.4
N3 - 125 % N equivalent	8.15	72.1	118.1	150.7
S. Em ±	0.13	1.18	1.92	2.45
C.D. (p=0.05)	0.37	3.34	5.44	6.93
Organic sources (F)				
F1 - Farmyard manure	4.57	40.9	66.3	84.6
F2 - Bio-compost	7.27	65.0	105.5	134.6
F3 - Vermicompost	5.86	52.4	85.0	108.5
F4 - Poultry manure	6.48	58.0	94.0	119.9
F5 - Jeevamrutha	5.09	45.5	73.7	94.1
S. Em±	0.17	1.52	2.48	3.16
C.D. (p=0.05)	0.48	4.31	7.02	8.95
Interaction (NxF)				
N1F1	3.86	34.8	56.0	71.5
N1F2	4.42	39.8	64.1	81.8
N1F3	3.74	33.6	54.2	69.1
N1F4	4.19	37.7	60.7	77.4
N1F5	4.30	38.7	62.3	79.5
N2F1	3.28	29.7	47.6	60.8
N2F2	6.53	59.1	94.6	120.8
N2F3	5.65	51.1	81.9	104.5
N2F4	6.18	56.0	89.7	114.4
N2F5	4.96	44.9	71.9	91.7
N3F1	6.57	58.1	95.3	121.5
N3F2	10.87	96.2	157.6	201.1
N3F3	8.20	72.6	119.0	151.8
N3F4	9.08	80.3	131.7	168.0
N3F5	6.01	53.1	87.1	111.1
T16	4.06	36.5	58.8	75.0
T17	11.55	103.5	167.5	213.6
S. Em ±	0.29	2.60	4.21	5.37
C.D. (p=0.05)	0.82	7.35	11.89	15.17

helped in higher photosynthetic efficiency and absorption of nutrients (Roopashree *et al*., 2019).

Kernel and Stover Yield (q ha^{-1})

Kernel and stover yield of maize (Table 5) differed significantly due to influence of organic sources in maize-cowpea cropping sequence. Significantly higher kernel and stover yield of maize were obtained with application of 125 per cent N equivalent (89.36 and 129.37 q ha^{-1}, respectively) followed by 100 per cent N equivalent (71.22 and 98.28 q ha^{-1}, respectively) and lower yield was observed in 75 per cent N equivalent plots (63.19 and 75.23 q ha^{-1}, respectively). Among organic sources, application of bio-compost produced higher kernel and stover yield (84.29 and 113.87 q ha^{-1}, respectively) followed by poultry manure (79.17 and 106.61 q ha^{-1}, respectively), vermicompost (74.10 and 99.47 q ha^{-1}, respectively), jeevamrutha (68.06 and 92.95 q ha^{-1}, respectively) and lower kernel and stover yield was obtained in farm yard manure (67.34 and 91.90 q ha^{-1}, respectively).

Application of bio-compost at 125 per cent N equivalent (107.47 and 154.60 q ha^{-1}, respectively) recorded significantly higher kernel and stover yield and was on par with UAS-B package *i.e*., 150:75:40 kg N: P_2O_5: K_2O ha^{-1} (111.96 and 161.13 q ha^{-1}, respectively). Lower kernel and stover yield was recorded in absolute control plot wherein no organic manures were applied (25.82 and 30.57 q ha^{-1}, respectively). The results are in line with Ananda and Sharanappa (2017). The increase in yield is mainly attributed to higher yield parameters like number of kernel rows, number of kernels per row and test weight. Combined application of manures and jeevamrutha ensure the release of readily available nutrients in adequate quantity to promote early growth as compared to sole organic manuring treatments, in which nutrients are available slowly over a long period of time. Higher growth and yield parameters could be attributed to availability of macronutrients and micronutrients from organic manure, which is very essential for plant growth and development (Boraiah *et al*., 2017). The lower grain yield due to reduced availability of nutrients for the crop during early growth

TABLE 5

Kernel and stover yield of maize as influenced by organic sources (pooled data of two seasons)

Treatments	Kernel yield (q ha^{-1})	Stover yield (q ha^{-1})
Nitrogen equivalent levels (N)		
N_1 - 75 % N equivalent	63.19	75.23
N_2 - 100 % N equivalent	71.22	98.28
N_3 - 125 % N equivalent	89.36	129.37
S. Em±	1.35	1.99
C.D. (p=0.05)	3.83	5.63
Organic sources (F)		
F_1 – Farmyard manure	67.34	91.90
F_2 – Bio-compost	84.29	113.87
F_3 - Vermicompost	74.10	99.47
F_4 – Poultry manure	79.17	106.61
F_5 - Jeevamrutha	68.06	92.95
S. Em±	1.75	2.57
C.D. (p=0.05)	4.95	7.27
Interaction (N x F)		
N_1F_1	60.02	72.90
N_1F_2	67.22	80.01
N_1F_3	62.30	71.36
N_1F_4	65.91	78.59
N_1F_5	60.52	73.29
N_2F_1	65.81	91.50
N_2F_2	78.17	107.01
N_2F_3	71.00	97.98
N_2F_4	74.92	102.72
N_2F_5	66.20	92.21
N_3F_1	76.19	111.29
N_3F_2	107.47	154.60
N_3F_3	89.02	129.07
N_3F_4	96.68	138.53
N_3F_5	77.46	113.35
T_{16}	25.82	30.57
T_{17}	111.96	161.13
S. Em± 2.88	4.28	
C.D. (p=0.05)	8.14	12.07

stages (vegetative period) and thus the crop might have starved of nutrients during later stage (reproductive stage), which might have affected the grain and stover yield (Urkurkar *et al.*, 2010).

Based on these studies it could be concluded that application of bio-compost at 125 per cent N equivalent resulted in better growth parameters, yield components and yield of maize and was on par with UAS-B package *i.e.*, application of 150:75:40 kg N: P_2O_5: K_2O ha^{-1}.

Available Nitrogen, Phosphorous and Potassium

Application of organic sources at 125 per cent N equivalent recorded significantly higher available nitrogen (kg ha^{-1}), phosphorus (kg ha^{-1}) and potassium (kg ha^{-1}) in soil (332.83, 34.20 and 237.51 kg ha^{-1}, respectively) after harvest of maize (Table 6) followed by 100 per cent N equivalent (309.50, 31.12 and 222.27 kg ha^{-1}, respectively) and 75 per cent N equivalent (267.07, 26.99 and 195.26 kg ha^{-1}, respectively). Significantly higher available nitrogen, phosphorus and potassium in soil after harvest of maize was recorded in bio-compost applied plot (321.60, 32.88 and 229.69 kg ha^{-1}, respectively) and was found to be statistically superior over poultry manure (309.98, 31.65 and 223.37 kg ha^{-1}, respectively), vermicompost (302.28, 30.51 and 220.81 kg ha^{-1}, respectively), jeevamrutha (292.96, 29.69 and 212.26 kg ha^{-1}, respectively) and farm yard manure (288.85, 29.12 and 205.62 kg ha^{-1}, respectively).

Available nitrogen, phosphorus and potassium in soil after harvest of maize were found to be significant for the interaction between nitrogen equivalent levels and organic sources. Bio-compost application at 125 per cent N equivalent resulted significantly higher available nitrogen, phosphorus and potassium in soil after harvest of maize (358.44, 36.06 and 246.16 kg ha^{-1}, respectively) compared to other treatments and was on par with UAS-B package *i.e.*, 150:75:40 kg N: P_2O_5: K_2O ha^{-1} (357.58, 36.56 and 249.36 kg ha^{-1}, respectively). Lower available nitrogen, phosphorus and potassium in soil after harvest of maize was observed in absolute control plot (213.33, 22.25 and 153.97 kg ha^{-1}, respectively).

TABLE 6

Available nitrogen, phosphorus and potassium content of soil after harvest of maize as influenced by organic sources (pooled data of two seasons)

Treatments	Available N (kg ha^{-1})	Available P_2O_5 (kg ha^{-1})	Available K_2O (kg ha^{-1})
Nitrogen levels (N)			
N_1	267.07	26.99	195.26
N_2	309.50	31.12	222.27
N_3	332.83	34.20	237.51
S. Em±	1.14	0.18	1.05
C.D. (p=0.05)	3.22	0.50	2.96
Organic sources (F)			
F_1	288.85	29.12	205.62
F_2	321.60	32.88	229.69
F_3	302.28	30.51	220.81
F_4	309.98	31.65	223.37
F_5	292.96	29.69	212.26
S. Em±	1.47	0.23	1.35
C.D. (p=0.05)	4.16	0.65	3.82
Interaction (N x F)			
N_1F_1	247.14	24.38	178.65
N_1F_2	287.47	30.17	214.54
N_1F_3	264.26	26.32	192.31
N_1F_4	280.11	28.96	202.36
N_1F_5	256.38	25.14	188.44
N_2F_1	296.35	30.38	215.49
N_2F_2	318.88	32.43	228.37
N_2F_3	315.30	30.74	221.46
N_2F_4	318.81	31.43	224.80
N_2F_5	298.16	30.63	221.22
N_3F_1	323.07	32.61	222.71
N_3F_2	358.44	36.06	246.16
N_3F_3	327.27	34.47	248.64
N_3F_4	331.02	34.56	242.96
N_3F_5	324.34	33.29	227.12
T_{16}	213.33	22.25	153.97
T_{17}	357.58	36.56	249.36
S. Em±	3.44	0.47	2.49
C.D. (p=0.05)	9.72	1.32	7.03

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The reason for increase in available NPK may be due to the effect of different nutrient sources and jeevamrutha that might have increased the activity of beneficial micro-organisms which in turn enhanced the decomposition of organic matter fraction supplied through different organic manures and as a consequence there was higher availability of N, P and K in soil. Increase in available nitrogen in soil was due to mineralization of organic manures by the increased activity of soil micro organisms and reduced nitrogen loss from the soil. Higher available soil phosphorus could be attributed to increased solubility of native phosphorus due to release of organic acid during the decomposition of organic manures. The increase in available potassium might be due to release of potassium from organic sources and solubilisation of mineral bound K or native K (Singh and Chauhan, 2002).

Nitrogen, Phosphorous and Potassium Uptake

Nitrogen, Phosphorous and potassium uptake (kg ha^{-1}) by maize at harvest differed significantly due to influence of organic sources in maize-cowpea cropping sequence (Table 7). Significantly higher nitrogen, phosphorous and potassium uptake was recorded with application of 125 per cent N equivalent (175.8, 26.79 and 194.2 kg ha^{-1}, respectively) followed by 100 per cent N equivalent (114.8, 17.5 and 126.8 kg ha^{-1}, respectively) and lower nitrogen, phosphorous and potassium uptake was observed in 75 per cent N equivalent (88.5, 13.49 and 97.8 kg ha^{-1}, respectively). Among organic sources, bio-compost application recorded significantly higher nitrogen, phosphorous and potassium uptake (157.0, 23.92 and 173.4 kg ha^{-1}, respectively) followed by poultry manure (139.9, 21.32 and 154.6 kg ha^{-1}, respectively) and found significantly superior over other treatments. However, lower nitrogen, phosphorous and potassium uptake by maize was recorded with application of farm yard manure (98.7, 15.04 and 109.0 kg ha^{-1}, respectively).

The nitrogen, phosphorous and potassium uptake was found to be significant in interaction effect between organic sources and levels of nitrogen. Application of bio-compost at 125 per cent N equivalent recorded

TABLE 7

Nitrogen, phosphorus and potassium uptake by maize at harvest as influenced by organic sources (pooled data of two seasons)

Treatments	N uptake (kg ha^{-1})	P_2O_5 uptake (kg ha^{-1})	K_2O uptake (kg ha^{-1})
Nitrogen levels (N)			
N_1	88.5	13.49	97.8
N_2	114.8	17.50	126.8
N_3	175.8	26.79	194.2
S. Em ±	2.86	0.44	3.16
C.D. (p=0.05)	8.09	1.23	8.94
Organic sources (F)			
F_1	98.7	15.04	109.0
F_2	157.0	23.92	173.4
F_3	126.5	19.28	139.8
F_4	139.9	21.32	154.6
F_5	109.8	16.73	121.3
S. Em±	3.69	0.56	4.08
C.D. (p=0.05)	10.44	1.59	11.54
Interaction (N x F)			
N_1F_1	83.4	12.71	92.1
N_1F_2	95.5	14.55	105.5
N_1F_3	80.6	12.29	89.1
N_1F_4	90.3	13.77	99.8
N_1F_5	92.7	14.13	102.4
N_2F_1	70.9	10.80	78.3
N_2F_2	140.9	21.47	155.6
N_2F_3	121.9	18.58	134.7
N_2F_4	133.4	20.33	147.4
N_2F_5	107.0	16.30	118.2
N_3F_1	141.8	21.61	156.6
N_3F_2	234.6	35.75	259.2
N_3F_3	177.1	26.98	195.6
N_3F_4	196.0	29.87	216.5
N_3F_5	129.6	19.75	143.2
T_{16}	87.5	13.34	96.7
T_{17}	249.2	37.98	275.4
S. Em ±	6.27	0.95	6.92
C.D. (p=0.05)	17.69	2.70	19.55

higher nitrogen, phosphorous and potassium uptake (234.6, 35.75 and 259.2 kg ha^{-1}, respectively) which was on par with UAS-B package *i.e*., 150:75:40 kg N: P_2O_5: K_2O ha^{-1} (249.2, 37.98 and 275.4 kg ha^{-1}, respectively). Lower nitrogen, phosphorous and potassium uptake was recorded in absolute control plot (87.5, 13.34 and 96.7 kg ha^{-1}, respectively). Increase in uptake of NPK might be due to increased mineralisation, higher nutrient availability and release of nutrients which cope up with crop demand and combined application of organic manures and jeevamrutha acted as slow release nutrient sources. Such property of nutrient sources facilitates greater uptake of nutrients by the crop as reported by Latha and Sharanappa, 2014.

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Identification of Causes for Seed Dormancy and Its Safe Removal in Sponge Gourd (*Luffaa egyptiaca*) and Snake Gourd (*Trichosanth escucumerina*)

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Abstract

The Cucurbit species of sponge and snake gourds have hard seed coat dormancy and viable seeds cannot germinate even in favourable environments. Consequently, the present study was carried out with the objective, to identify the causes and to break the dormancy in the seeds of sponge gourd and snake gourd with two different lots. Seeds were soaked in distilled water for 24h and 48h. After pre-soaking, the observations were recorded as number, weight and percentage of imbibed and intact (non-imbibed) seeds. It was observed that about 50 per cent seeds remained hard even after 24h of imbibition, but on the other hand even after 48 hours of imbibition, only 57 to 68 per cent of seeds imbibed water properly and 32 to 43 per cent seeds remained hard. From these observations, it was found that the seeds of sponge and snake gourd showed physical dormancy due to hard seed coat. Hard seed dormancy is a common phenomenon with sponge and snake gourd seeds and therefore, scarification, chemical and dry heat treatments were used to break dormancy in the selected gourd seeds. Manual scarification followed by chemical (GA_3@100 ppm, KNO_3@ 0.5 %) treatments, mere water soaking and dry heat treatments were also adopted. After these dormancy breaking treatments, seed germination results showed that scarified seeds treated with KNO_3@ 0.5 per cent for 18h gave the higher germination in sponge gourd (78, 80 %) and snake gourd (79, 78 %) followed by scarified seeds treated with GA_3 @100ppm for 18 h (74, 74 %) and (75,72 %) in two different lots, respectively. Seeds without scarification recorded on par results with control, which exhibited very low germination (63, 61, 65 and 63%) in both the seed lots.

Keywords : Sponge gourds, Snake gourds, Cucurbits, Seed dormancy imbibition, Radicle emergence, Mean germination time, Growth regulators

Cucurbits (*Cucurbitaceae*) are among the most important plant families supplying humans with edible products and useful fibres. Plants of this family are very similar in the above ground development, but they have high genetic diversity for fruit shape and other fruit characteristics, resulting in a variety of uses. The Cultivated cucurbits have spread through trade and exploration from their respective old and new world centres of origin to the six arable continents and are important in local, regional and world trade. Cucumber, melon, pumpkin, squash, gourd and watermelon comprise the major cucurbits. Bitter gourd, bottle gourd, wax gourd, sponge, ridge gourd and snake gourd are minor cucurbits from a global perspective that are of import to small shareholder farmers, mostly in Asia. The FAO estimates that cucurbits in India are grown on about 4,290,000 ha with a productivity of 10.52 t/ha. Thus, cucurbits cultivation accounts for about 5.6 per cent of India's total vegetable production. Cucurbits can play an important role in dietary health. They are low in nutritional value, but can be significant dietary sources of vitamins and minerals. Some cucurbits, such as bitter gourd, have medicinal properties. Cucurbits are generally valued for their delicious fruits, which can be sweet, bitter or aromatic, and may be highly perishable or stored for months with little change in quality. The seeds are good sources of vegetable oil and protein. Gourd shells may be used for storage containers, or as musical instruments. The cultivated cucurbits have been greatly improved by plant breeders using conventional plant breeding techniques for more than 100 years. Rapidly advancing molecular technologies are being applied to cucurbits to ensure sustainable production, improve fruit quality

and shelf life, and develop novel fruit types. Considering the importance of these crops, sustainable supply of quality seeds at affordable cost is pivotal to cope up with their production, productivity and supply to meet the ever growing demand of these crops. However, the vegetable seed industry is facing recurrent problem on seed quality of these crop plants due to their immaturity, ill-filling, hard seed coat etc., causing poor germination and seedling vigour which leads to poor plant establishment in field.

Luffa cylindrica (L.) M., commonly called smooth loofah or sponge gourd is a member of the *Cucurbitaceae* family. The plants are economically important in many parts of the world for instance, in China, Korea, Japan, India, Central America, as well as in Thailand for their young fruits, while ripening fruits are used to produce consumer goods such as cleaning materials and engine oil filters (Oboh and Aluyor, 2009). The seeds are composed of 46 per cent oil and 40 per cent protein (Siemonsma and Piluek, 1993). *Trichosanthes cucumerina* (Snake gourd) is a monoecious annual vine which grows in subtropical or tropical conditions. In Asia, people usually eat immature fruit of snake gourd as vegetable. Mature fruit pulp is too bitter, and it is used as an economical substitute of tomato. Snake gourd seeds are well adapted to the adverse environmental conditions. These cucurbit species have severe problems with seed dormancy and viable seeds that cannot germinate even in favourable environments because of seed coat impermeability which is considered as one of the major mechanisms causing hard seed coat dormancy (Bradbeer, 1988 and Anoop Badoni, 2018). To identify the problem of dormancy in these seeds, imbibitions process may play a major role, although the published information on the identification of causes for seed dormancy through imbibitions is not available much on sponge and snake gourd. It would also be useful to increase the germination rate of these seeds, especially for those interested in commercial production of the crop. Therefore, the study was undertaken with main emphasis on to identify the causes of dormancy in both sponge and snake gourd seeds by using imbibition process.

These gourd seeds are considered hard-seeded with its thick seed structure and a hard seed coat moreover, phenolic compounds including pectin or suberin on the surface of the seed coat restrict water uptake into the seed during germination process (Doijode, 2001). Physical dormancy is caused by one or more water-impermeable layers of palisades (Baskin *et al.,* 2004 and Gowthami *et al.,* 2016). In addition, Singh and Dathan (1998) found that the seed coat of gourds is characterized by upright epidermal cells with rod-like thickenings and narrow, palisade-like osteosclereids which cause physical dormancy of gourd seeds. Seed dormancy is the most important factor limiting germination and there are various ways to break hard seed coat such as clipping, scarifying, and dry heat (Bradbeer, 1988). One such technique that has been widely and successfully used for breaking hard seed dormancy is scarification, which involves removing the seed coat or rubbing it with sandpaper or subjecting it to different chemical treatments (Bradbeer, 1988). Loyma *et al*. (2009) reported that removing the seed coat of wax gourd seeds increased radicle emergence with scarification of‘ Feang’ and ‘Fakkheaw’ seeds. Removing the outer and inner testa, significantly improved radicle emergence to 96.0 and 99.5 per cent, respectively, of ‘Feang’ seeds and to 93.0 and 95.5 per cent, respectively, of ‘Fakkheaw’ seeds, compared to the un-scarified seeds (83.0 per cent for ‘Feang’ and 80 per cent for ‘Fakkheaw’). Another technique for breaking hard seed coat dormancy is dry heat, which causes seed coat and perisperm dehydration and allows water and gases to enter the seed more quickly (Khan, 1980 and Thananthika, 2015). Hence, the secondary goal of this study was to determine the suitability of various techniques for breaking the dormancy of sponge and snake gourd seeds.

Material and Methods

Seed Materials

Sponge and Snake gourd seeds of two different lots were obtained from a Private Company in Bengaluru. Seeds were harvested and processed during October and November 2020. The study was conducted in ISTA member laboratory at Seed Technology

Research Centre, National Seed Project (Crops), University of Agricultural Sciences, GKVK, Bengaluru. The initial seed quality parameters were recorded as per the Seed Testing Rules of ISTA (2013).

Imbibition Studies

To conduct the experiment on seed imbibitions, four replications of 50 seeds each were taken and weighted separately. Seeds were then soaked in distilled water for two selected durations of 24h and 48h. After pre-soaking, the observations were recorded as number, weight and percentage of imbibed and hard (non-imbibed) seeds.

Methods of Breaking Seed Dormancy

Seeds were subjected to scarification followed by different chemical treatments to study methods of breaking dormancy. The experiment was arranged in a completely randomized design with eight treatment combinations. It consisted of two methods for breaking dormancy. The first method involved manual scarification by rubbing with sand paper for few seconds and second method was chemical treatment with GA_3 and KNO_3. Seeds after subjecting to dormancy treatments were tested for germination as per ISTA (2013). First and final counts were recorded at 4, 14 in sponge gourd and 4, 8 in snake gourd days respectively after putting for germination in between paper method and sand method.

Treatment Combinations

T_0 : Control

T_1 : Scarification (Mechanical)

T_2 : Scarification + GA_3 @100ppm for 18 h

T_3 : Scarification + KNO_3@ 0.5 % for 18 h

T_4 : Scarification + Water soaking for 18 h

T_5 : Scarification + Dry heat @ 70 ^{0}C for 3 h

T_6 : GA_3 @ 100 ppm for 18 h without scarification

T_7 : KNO_3@ 0.5 % for 18 h without scarification

T_8 : Water soaking for 18 h without scarification

Mean Germination Time

The number of normal seedlings was counted from the day of first count up to the day of final count. The mean germination time (MGT) was calculated using Equation below (Ellis and Roberts, 1981).

$$MGT = \Sigma nD/\Sigma n$$

Where, n= number of seeds newly germinated (2 mm, radicle emergence) at time D at 25 °C, D=days from the beginning of the germination test, Σn=final germination.

Radicle emergence was tested by removing the seed coat of the gourd seeds by soaking the seeds in water for 24h under room condition and incubation of them in the petri plates at 30 °C.

Results and Discussion

Germination and seedling establishment are critical stages in the plant life cycle. In crop production, stand establishment determines plant density, uniformity and management options. In arid and semi-arid environments, the water needed for germination is available for only a short period, and consequently, successful crop establishment depends not only on the rapid and uniform germination of seed, but also on ability of seed to germinate under low water potential. However, if the stress effect can be alleviated at the germination stage, chances for attaining a good crop with higher production would be possible. The initial seed quality parameters recorded is depicted in Table 1.

The results on seed imbibition studies depicted in Table 2, suggested that even after 48h of imbibition, only 57 to 60 and 64 to 68 per cent seeds were imbibed water adequately and remaining 40 to 43 and 32 to 36 per cent seeds were hard in sponge and snake gourd of two seed lots, respectively.

Similarly, According to reviews the main reason for germination failure was the inhibition of seed water uptake due to a high salt concentration, whereas others have suggested that germination was affected by salt toxicity in the soil water (Thananthika *et al*., 2015). However, the results of present study indicated that more than 40 per cent of sponge gourd and 35 to 40 per cent of snake gourd seeds did not imbibe water and due to non-imbibition, embryos of the seeds

TABLE 1

The initial seed qualities parameters of Sponge and Snake Gourds

Seed quality parameters	Sponge gourd			Snake gourd		
	L_1	L_2	Mean	L_1	L_2	Mean
Seed moisture content (%)	9.30	10.0	9.65	7.5	7.5	7.50
1000 seed weight (g)	80.0	83.0	81.5	215	212	213.5
Seed viability (%)	95.0	97.0	96.0	100	100	100.00
Germination (%)	63.0	61.0	62.0	65.0	63.0	64.00
Hard seeds (%)	26.0	25.0	25.50	28.0	27.0	27.50

TABLE 2

Effect of different durations of soaking in sponge and snake gourds

Crop	Lot	Average initial weight of four replications		Seed Imbibition (hours)							
				24				48			
				Imbibed		Hard seed (Non-imbibed)		Imbibed		Hard seed (Non-imbibed)	
		No.	Wt. (g)	No.	Wt. (g)	No.	Wt. (g)	No.	Wt. (g)	No.	Wt. (g)
Sponge gourd	Lot-1	50	4.02	27.5	3.33	22.5	1.76	30.0	4.27	20.0	2.84
	Percentage (%) of Imbibed and Hard Seeds			55	45	60	40				
	Lot-2	50	4.35	25.0	3.28	25.0	2.17	28.5	4.68	21.5	3.53
	Percentage (%) of Imbibed and Hard Seeds			50	50	57	43				
Snake gourd	Lot-1	50	12.57	29.5	11.35	20.5	7.92	32.05	12.34	18	6.93
	Percentage (%) of Imbibed and Hard seeds			59	41	64	36				
	Lot-2	50	14.17	28.5	11.0	21.5	8.30	34.00	13.12	16.00	6.17
	Percentage (%) of Imbibed and Hard Seeds			57		43		68		32	

remains dry; which directly affect the metabolic activities of the seeds during germination process. Therefore, it is concluded that the seeds of sponge and snake gourd shows physical dormancy mainly due to hard seed coat permeability.This physical dormancy is caused by one or more water-impermeable layers of palisades according to Baskin and Baskin (2004).

The effectiveness of dormancy breaking methods in sponge and snake gourd seeds is shown in Table 3 & 4. There was a significant difference in seed germination among the treatments. The seeds scarified and treated with KNO_3 @ 0.5 per cent gave the highest germination (78, 80 %) and vigour index-I (2828, 2839) in sponge gourd and snake gourd (79, 78 per cent & 3697, 3572) in two different lots, respectively followed by seeds scarified and treated with GA_3 @100ppm [(74, 74 %), (2445, 2455) and (75, 72 %), (3195, 3060), respectively). Seed scarified and treated with KNO_3@

TABLE 3

Effect of different dormancy breaking methods on germination (%) and number of hard seeds in sponge gourd and snake gourds

Treatments	Sponge gourd						Snake gourd					
	Germination (%)			Hard seed (%)			Germination (%)			Hard seed (%)		
	L_1	L_2	Mean	L_1	L_2	Mean	L_1	L_2	Mean	L_1	L_2	Mean
T_0	63	61	62.0	26 * (31)	25 * (30)	25.5 * (30.5)	65	63	64.0	28 * (32)	27 * (31)	27.5 * (31.5)
T_1	68	66	67.0	24 (29)	24 (29)	24.0 (29)	68	65	66.5	24 (29)	26 (31)	25.0 (30)
T_2	74	74	74.0	18 (25)	17 (24)	17.5 (24.5)	75	72	73.5	18 (25)	18 (25)	18.0 (25)
T_3	78	80	79.0	14 (22)	13 (21)	13.5 (21.5)	79	78	78.5	15 (23)	16 (24)	15.5 (23.5)
T_4	68	69	68.5	20 (27)	20 (27)	20.0 (27)	64	63	63.5	18 (25)	19 (26)	18.5 (25.5)
T_5	67	66	66.5	19 (26)	18 (25)	18.5 (25.5)	69	68	68.5	19 (26)	20 (27)	19.5 (26.5)
T_6	63	66	64.5	25 (30)	22 (28)	23.5 (29)	67	64	65.5	24 (29)	24 (29)	24.0 (29)
T_7	65	66	65.5	23 (29)	24 (29)	23.5 (29)	65	67	66.0	23 (29)	26 (31)	24.5 (30)
T_8	65	65	65.0	25 (30)	23 (29)	24.0 (29.5)	66	65	65.5	24 (29)	24 (29)	24.0 (29)
Mean	67.89	68.00	67.9	21.56 (27.6)	21.00 (26.8)	21.3 (27.2)	68.67	67.22	67.9	21.44 (27.4)	22.22 (28.1)	21.8 (27.7)
	SEm±	CD (0.05P)		SEm±	CD (0.05P)		SEm±	CD (0.05P)		SEm±	CD (0.05P)	
Lots (L)	0.191	0.543		0.163	0.465		0.192	0.545		0.192	0.545	
Treatments (T)	0.382	1.086		0.327	0.929		0.384	1.091		0.384	1.091	
L x T	0.540	1.536		0.462	1.314		0.542	1.542		0.542	1.542	
CV (%)		2.17			4.41			1.59			4.03	

* Figures in the parentheses are arcsine transformed values

T_0 : Control
T_1 : Scarification (Mechanical)
T_2 : Scarification + GA_3 @100ppm for 18 h
T_3 : Scarification + KNO_3@ 0.5 % for 18 h
T_4 : Scarification + Water soaking for 18 h
T_5 : Scarification + Dry heat @ 70 ^{0}C for 3 h
T_6 : GA_3 @ 100 ppm for 18 h without scarification
T_7 : KNO_3@ 0.5 % for 18 hrs without scarification
T_8 : Water soaking for 18 hrs without scarification

0.5 per cent and GA_3@100ppm recorded 15 to 20 per cent higher germination over control (Fig. 1 & 2). However, hard seeds were found minimum when scarified seeds were subjected to chemical treatments (13 %) over non-scarified seeds with or without chemical treatments (26 %). Besides, scarified seeds soaked in water and dry heat treatments showed slightly improved germination and less number of hard

TABLE 4

Effect of different dormancy breaking methods on seedling vigour index-I in sponge gourd and snake gourds

Treatments	Seedling vigour index-I					
	Sponge gourd			Snake gourd		
	L_1	L_2	Mean	L_1	L_2	Mean
T0	1339	1355	1347	2002	1802	1902
T1	1646	1645	1645	2326	2113	2219
T2	2445	2455	2450	3195	3060	3128
T3	2828	2839	2834	3697	3572	3635
T4	1690	1733	1711	2208	2218	2213
T5	1829	1924	1876	2498	2441	2470
T6	1501	1510	1506	2184	2016	2100
T7	1612	1755	1684	2191	2318	2254
T8	1676	1742	1709	2303	2321	2312
Mean	1841	1884	1862	2512	2429	2470
	SEm±	CD (0.05P)		SEm±	CD (0.05P)	
Lots (L)	9.45	10.51		9.56	10.24	
Treatments (T)	14.63	13.86		15.34	14.65	
L x T	32.15	34.56		33.24	34.76	
CV (%)		3.67			4.58	

Fig 1 : Germination of sponge gourd scarified seeds with KNO_3 treatment and control

Fig. 2 : Germination of snake gourd scarified seeds with KNO_3 treatment and control

seeds compared to non-scarified seeds with KNO_3 and GA_3 treatment. Therefore, these results obviously indicated manual scarification has helped to break the physical dormancy of the seeds and increase 15 to 20 per cent of germination in gourd seeds. Loyma *et al*. (2009) have also stated that scarifying the seed coat by manual method scratched only the outer seed coat, but had no effect on the inner seed coat however, the seed coat of scarified seeds was the thinnest. Application of growth regulators in addition to scarification would further assist in enhancing germination by way of removing dormancy.

Mean Germination Time (MGT)

The MGT of sponge and snake gourd seeds by different methods of breaking dormancy is shown in Table 5. The seeds scarified and treated with KNO_3 @ 0.5 per cent registered shortest MGT of 4.78, 4.63 days in Sponge gourd and 3.16, 3.09 days in Snake gourd of different lots, respectively. This was the fastest and had the highest seed germination of up to 80 per cent (Table 1) and it was followed by seeds scarified and treated with GA_3 @ 100 ppm. However, the non-scarified seeds showed longer MGT of 8.52, 8.27 days

TABLE 5

Effect of different dormancy breaking methods on mean germination time without removing the seed coat in sponge gourd and snake gourds

Treatments	Seedling vigour index-I					
	Sponge gourd			Snake gourd		
	L_1	L_2	Mean	L_1	L_2	Mean
T0	7.49	7.39	7.44	4.93	4.81	4.87
T1	5.28	5.42	5.35	4.17	4.26	4.21
T2	5.16	5.29	5.22	3.49	3.24	3.36
T3	4.78	4.63	4.70	3.16	3.09	3.12
T4	5.63	5.72	5.67	4.86	4.75	4.80
T5	6.09	6.41	6.25	5.78	5.46	5.62
T6	7.48	7.56	7.52	5.13	5.03	5.08
T7	7.96	7.64	7.80	4.42	4.56	4.49
T8	8.52	8.27	8.39	4.98	5.21	5.09
Mean	6.49	6.48	6.48	4.55	4.49	4.52
	SEm±	CD (0.05P)		SEm±	CD (0.05P)	
Lots (L)	0.014	0.041		0.015	0.042	
Treatments (T)	0.029	0.081		0.029	0.083	
L x T	0.040	0.115		0.041	0.117	
CV (%)		1.29				1.86

T0 : Control
T1 : Scarification (Mechanical)
T2 : Scarification + GA3 @100ppm for 18 h
T3 : Scarification + KNO3@ 0.5% for 18 h
T4 : Scarification + Water soaking for 18 h
T5 : Scarification + Dry heat @ 700C for 3 h
T6 : GA3 @ 100 ppm for 18 h without scarification
T7 : KNO3@ 0.5% for 18 hrs without scarification
T8 : Water soaking for 18 hrs without scarification

in Sponge gourd and 4.98, 5.21 days in Snake gourd as against scarified seeds in both seed lots.

Radicle emergence was tested by placing the seeds in petri plates lined with three layers of moist filter paper after removing the seed coats. It was observed that MGT was shortened by two days when the seed coats were removed (Table 6). The scarified seeds treated with KNO_3@0.5 per cent recorded the shortest MGT of 2.17, 2.26 days in Sponge gourd and 1.26, 1.37 days in Snake gourd in both seed lots, respectively followed by seed scarified and treated with GA_3@100ppm and water soaking. Similarly, Pinmanee *et al.* (2001) reported that cutting the bottom of the bitter gourd seed, but not removing the seed coat completely, increased germination from 40.5 to 70 per cent, while germination was increased to 90 per cent by removing the entire seed coat. The germination of watermelon seed has also been increased by removing the seed coat (Nerson, 2002).

Understanding germination requirements of gourd species is one of the most important steps in the survival of these species besides improving germination and seedling vigour in terms of speed of radical emergence and subsequent growth of seedlings. These species generally encounter germination problem due to hard seed coat and accumulation of inhibitors.

TABLE 6

Effect of different dormancy breaking methods on mean germination time after removing the seed coat in sponge gourd and snake gourds

Treatments	Seedling vigour index-I					
	Sponge gourd			Snake gourd		
	L_1	L_2	Mean	L_1	L_2	Mean
T0	5.67	5.43	5.55	3.16	3.28	3.22
T1	3.85	3.76	3.80	3.24	3.49	3.36
T2	2.56	2.73	2.64	1.75	1.85	1.80
T3	2.17	2.26	2.21	1.26	1.37	1.31
T4	3.46	3.59	3.52	2.34	2.42	2.38
T5	4.18	4.09	4.13	3.46	3.54	3.50
T6	5.34	5.27	5.30	3.69	3.72	3.70
T7	5.93	5.69	5.81	2.34	2.38	2.36
T8	6.47	6.38	6.42	2.73	2.76	2.74
Mean	4.40	4.36	4.38	2.66	2.76	2.71
	SEm±	CD (0.05P)		SEm±	CD (0.05P)	
Lots (L)	0.014	0.040		0.014	0.041	
Treatments (T)	0.028	0.080		0.029	0.082	
L x T	0.040	0.113		0.041	0.116	
CV (%)		1.93				3.02

T0 : Control
T1 : Scarification (Mechanical)
T2 : Scarification + GA3 @100ppm for 18 h
T3 : Scarification + KNO3@ 0.5% for 18 h
T4 : Scarification + Water soaking for 18 h
T5 : Scarification + Dry heat @ 700C for 3 h
T6 : GA3 @ 100 ppm for 18 h without scarification
T7 : KNO3@ 0.5% for 18 hrs without scarification
T8 : Water soaking for 18 hrs without scarification

Findings of our study revealed that seed dormancy of sponge and snake gourd, is caused by hard seed coat that is water impermeability which results in blocking of germination process. A high level of germination was observed by scarification of seed coat and making it permeable to water and oxygen through various methods adopted. It was found that breaking dormancy by manual scarification with growth regulators treatments like KNO_3(0.5 %) and GA_3 (100ppm) had increased the germination to the extent of 15 to 20 per cent when compared to control in both sponge and snake gourd seeds. Minimum Seed Certification Standards for germination of both the gourds is 60 per cent and through scarification and chemical treatments it can be enhanced up to 80 per cent germination. Further, it is always better to remove ill-filled, immature and deteriorated seeds by floating techniques. Therefore, it is suggested that cucurbit seed growers can adopt these techniques before sowing in order to obtain better plant establishment in the field and achieve adequate and uniform plant population to get higher seed yield.

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Authentication and DNA Bar-Coding of *Curcuma caesia* Roxb. Genotypes and other *Zingiberaceae* Species Using ITS-2 Gene

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Abstract

Curcuma caesia Roxb. is widely distributed in Indian subcontinent, presently the species has been categorized as critically endangered. As a conservation strategy DNA bar-coding with ITS-2 marker (ITS2-F: ATGCGATACTTGGTGTGAAT, ITS2-R: ACGCTTCTCCAGACTACAAT) was done. The present study aims to identify species with at most precision and to avoid mismatch. All 20 samples taken for study yielded PCR product of ITS-2 gene of around 700 base pairs. The MOLE-BLAST results clearly showed that the percent identity of the all the species ranges from 79.14 to 99.9 per cent, where 75 to 98 per cent BLAST sequence identity is suggested. The percentage of individual sequence of the genotypes aligned to a sequence in gene bank is ranged from 62 to 92 per cent. Highest query coverage was observed for GKJ-5 (92 %) and GMV-6 (92 %) and least was for GNF-27 (62 %). The E value of the sequence blast ranges from $1e^{-83}$ to $9e^{-115}$, this clearly shows high quality match of the sequence with database. Genotype GKK-30 had least E value (e^{1-83}) followed by GGR-10 (e^{1-100}), GMF-21 (e^{1-114}), GAP-20 (e^{1-130}) and GMR-31 (e^{1-132}). BG-1 and BG-2 species were identified as *Kaempferia parviflora* (Black ginger), The unknown species (UNK-7) was identified as *Curcuma kwangsiensis* with an accession number KF694813.1 in the NCBI library record. These results helped us to identify the species in precision, the mole-blast sequences of each genotype of black turmeric and other species can be used as an identity marker.

Keywords : *Curcuma caesia* Roxb., DNA bar-coding, Nuclear marker, ITS-2, Mole-blast, Query coverage, E value, Phylogeny

Curcuma caesia Roxb. is commonly known as black turmeric, is an important, lesser known, non-conventional medicinal plant of Zingiberaceae family. Species is widely distributed in India, Bangladesh, China, Nepal, Malaysia and Thailand also reported from Java and Myanmar as cultivated species (Liu *et al.,* 2013). In India black turmeric is found in West Bengal, Madhya Pradesh, Orissa, Chhattisgarh and Uttar Pradesh States. The species is native to northeast and central India also sparsely found in papi hills of Godavari, foot hills of the Himalaya and Northern hill forests of Sikkim (Anonymous, 2001).

Presently black turmeric has been categorized as critically endangered by the Central forest department of India. National medicinal plant board (NMPB) of India has listed this plant as vulnerable species. Ministry of Environment imposes restrictions on export without permission of the legal competent authorities. Research work so far carried out to exploit the medicinal value of the herb is limited.

By looking in to the present status of the herb and broad spectrum activity on several ailments, conservation measures need to be taken for this economically important plant. Thus efforts should be made to conserve and work for the betterment of this plant species.

There are 40 curcuma species present in the Indian subcontinent. Some times because of collection of false taxonomic identification of the specimen, confusion may arise with the morphological characters like, emergence of the flower, colour and position of the coma bract, rhizome characters, including essential oil biochemical constituents. To avoid this and precise

identification of the species and accessions of *C. caesia* DNA barcoding with ITS-2 marker has taken.

DNA barcoding is a route for taxonomic identification using a short, standard DNA region that is universally present in the target lineages and has enough sequence variation to identify species and assign unidentified individuals to their correct species (Hebert *et al.,* 2003 and Kress & Erickson, 2007).

Initially *rbcL* and *matK* genes were proposed as plant core barcodes but recently other regions such as ITS-2 (Chen *et al.,* 2010) and ITS (Anonymous, 2011) were added. DNA barcoding has been proved and has provided a potential effectiveness in the identification and evaluation of quality for medicinal plants; stands advantageous over phylogenetic analysis. (Newmaster *et al.,* 2006; Chen *et al.,* 2007; Taberlet *et al.,* 2007; Valentini *et al.,* 2009 and Chen *et al.,* 2010). Earlier studies had tested the ability of DNA barcoding to identify *Curcuma* species through sequence data stored in gene bank so that others can use it as reference library (Shi *et al.,* 2011; Záveská *et al.,* 2012; Vinitha *et al.,*2014 and Chen *et al.,* 2015).

The species selected for the study were rare medicinal plants and having high medicinal values. In this direction 17 promising black turmeric genotypes, two black ginger and one unknown species of *Zingiberaceae* family were subjected for DNA barcoding using ITS2 marker (Table 1), mainly to confirm the black turmeric genotypes precisely, and to identify the unknown species accurately.

TABLE 1

Details of black turmeric genotypes and other Zingiberaceae sps. used in the study

Species	Code	Place of collection Latitude	Longitude	Longitude	Altitude (m)	State
Black turmeric	GKM-2	Mangalore	12°55'2.03"N	74°51'21.71"E	22	Karnataka
Black turmeric	GKJ-5	Joida	15.1688° N	74.4848° E	532	Karnataka
Black turmeric	GMV-6	Vidarbha-Gadchirolli	21.1286° N	79.0964° E	1000	Maharashtra
Unknown species	UNK-7	Nagpur	21.1458^{0}N	79.0882^{0}E	310	Maharashtra
Black turmeric	GBH-9	Hajipur	25.6858392N	85.2145907E	56	Bihar
Black turmeric	GGR-10	Rajkote	22° 17' 30N	70° 47' 36E	252	Gujarat
Black turmeric	GAB-13	Bokoliya	26.0564°N	93.1955°E	600	Assam
Black turmeric	GMA-17	Aizwal	23.727106°N	92.717636°E	1132	Mizoram
Black turmeric	GOK-19	Koraput	18.82°N	82.72°E	870	Odisha
Black turmeric	GAP-20	Pasighat Area	28.0619° N	95.3260° E	153	Arunachal Pradesh
Black turmeric	GMI-21	Manipur – Forest	24° 48' 50.2812" N	93° 57' 1.0044" E	900	Manipur
Black turmeric	GMT-22	Imphal	24.8170° N	93.9368° E	786	Manipur
Black ginger	BG-1	Thoubal	24.63^{0}N	94.02^{0}E	765	Manipur
Black turmeric	GMS-24	Sagar	23.8388° N	78.7378° E	427	Madhya Pradesh
Black turmeric	GNF-27	Nepal – Forest	27° 42' 2.7684" N	85° 18' 0.5040" E	330	Nepal
Black ginger	BG-2	Mandalay	21.98^{0}N	96.08^{0}E	80	Burma
Black turmeric	GKK-30	IISR Kozhikode	11.2588° N	75.7804° E	1	Kerala
Black turmeric	GMR-31	Ri-Bhoi	25.8432° N	91.9856° E	485	Meghalaya
Black turmeric	GJG-35	Godda	24.8255° N	87.2135° E	87	Jharkhand
Black turmeric	GNP-36	Phek	25.6634° N	94.4703° E	1524	Nagaland

Material and Methods

Isolation of DNA

Isolation of total genomic DNA of black turmeric genotypes was carried out according to Porebski *et al.* (l997) using CTAB with some modifications, the standardized protocol is as follows;

- Genomic DNA was extracted from fresh young leaves using a modified CTAB method (Saiki *et al.,* 1988).
- Two hundred mg of young leaves were ground into fine powder in liquid nitrogen with the help of pestleand mortar, while crushing extraction buffer (consisting of 100 mM Tris HCl of 8 pH, 2M NaCl, 25 mM EDTA, 2% C-TAB, 2% PVP and 0.2% b- Mercapto ethanol) is used. Homogenate was transferred to 2 ml eppendorf tube
- The tubes were incubated at 60 °C for one hour with occasional shaking. After incubation, the tubes were cooled to the room temperature
- Equal volume of (100 ml) chloroform: Iso-amyl alcohol (24:1) was added and the tubes were inverted gently for minimum twenty times for mixing two phases and centrifuged @ 11000 rpm for 10 minutes at 10 ºC for separation of DNA from rest of the materials (proteins). The upper aqueous phase (supernatant) was taken without disturbing the lower solid portion to another tube then this step is repeated once again.
- The supernatant was transferred without disturbing the lower solid portion to fresh labeled 1.5 ml tubes then 750 ml isopropanol (IPA) was added and the tubes were inverted gently for mixing two phases and then kept in deep freezer for 30 min. and later centrifuged @ 10000 rpm for 10 min at 4 °C.
- The pellet formed after centrifugation was washed with 70 per cent (v/v) ethanol for 30 min. Then alcohol was decanted and pellets were dried at least for 30 min till there was no alcohol smell. After drying the pellet was later dissolved in (150 ml) T10E1 buffer and stored at -20 °C until use.
- RNase treatment: Required quantity (3 ml) of RNAse was mixed to the DNA sample and tubes were incubated on water bath at 37 °C for one hour and 50 °C for five minutes to remove the RNA present in the DNA.

The quantity and purity of DNA was confirmed by electrophoresis, using agarose (0.8 %) gel. DNA concentration was calculated based on standard ladder which was 1Kb. Column purification was done using spin column-based tube (cat. No. 69702) with a solid phase of silica layer (0.45 µm pore size) to get rid of salt contamination (Table 2 and Plate 1).

Table 2

DNA quantification of promising black turmeric genotypes and other Zingiberaceae species for sequencing studies

Species	Code	Nucleic acidconcen tration (ng/µl)	A260/A280 ratio
Black turmeric	GKM-2	35.4	1.61
Black turmeric	GKJ-5	123.0	1.86
Black turmeric	GMV-6	125.5	1.62
Un Identified species	UNK-7	68.3	1.80
Black turmeric	GBH-9	73.3	1.74
Black turmeric	GGR-10	49.0	1.81
Black turmeric	GAB-13	53.5	1.55
Black turmeric	GMA-17	47.6	1.75
Black turmeric	GOK-19	101.3	1.82
Black turmeric	GAP-20	61.7	1.76
Black turmeric	GMF-21	134.3	1.80
Black turmeric	GMI-22	224.8	1.82
Black Ginger	BG-1	124.4	2.40
Black turmeric	GMS-24	38.8	1.80
Black turmeric	GNF-27	215.4	1.92
Black Ginger	BG-2	122.3	1.81
Black turmeric	GKK-30	397.2	1.83
Black turmeric	GMR-31	82.2	1.64
Black turmeric	GJG-35	98.7	1.80
Black turmeric	GNP-36	84.9	1.84

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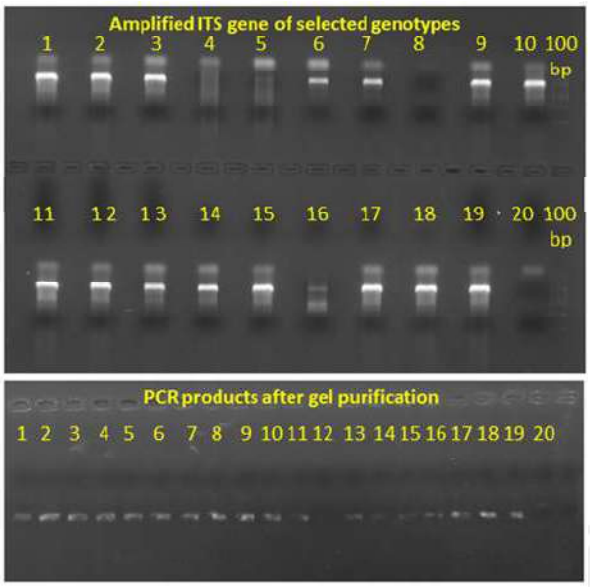

Plate 1 : A: Amplification of ITS2 gene of selected genotypes and species; B: Purified PCR products ready for Sanger sequencing.

Amplification of Nuclear Gene

The target genes were amplified using ITS-2 forward and reverse primers (ITS2-F: ATGCGATACTTGGTGTGAAT, ITS2-R: ACGCTTCTCCAGACTACAAT). The reaction mixture for PCR amplification of the isolated DNA was set after gel electrophoresis. Reaction mixture contained 25ng of genomic DNA, 10pM of forward and reverse primers, 10pM dNTP's, 0.5U of Taq polymerase and 10x reaction buffer was prepared and PCR plate was kept inside the thermo cycler which was programmed to target the respective gene; initial denaturation 95 °C for 2 minutes, final denaturation 95 °C for 30 seconds, annealing 55 °C for 30 seconds, elongation 72 °C for 1 minute for 30 cycles followed by final elongation 72 °C for 10 minutes. After PCR amplification, entire reaction volume was run on gel to observe the amplified product. The PCR bands were cut precisely, dissolving in buffer and was eluted to obtain purified DNA for Sanger sequencing.

Sanger Sequencing

After gel purification, the samples were sequenced bidirectional by performing sequencing PCR using ITS2 primers which is followed by post sequencing PCR purification. The program used is as follows: initial denaturation 95 °C for 2 minutes, final denaturation 95 °C for 30 seconds, annealing 55 °C for 30 seconds followed by termination 60 °C for 4 minutes for 30 cycles. The purified plate was linked in a 16 capillary genetic analyser (3130XL, Applied Biosystems). The obtained sequences were queried against NCBI's sequence databases using on-line BLAST search (Madden *et al.,* 1996). The hit having maximum coverage and more similarity percentage will be considered as relevant species.

Phylogeny

The DNA sequences obtained were minimally edited and manually aligned and partition homogeneity of sequences were implemented to get a total molecular evidence analysis. Further, all the sequences obtained from BLAST were aligned using the clustal omega computer program to understand the relationship between the species (Compson *et al*., 1997).

Results and Discussion

The nuclear ITS-2 is regarded as an appropriate DNA barcode region because of its high variability and has capacity to distinguish even closely related species. All the sequences obtained from Sanger sequencing were extracted to fasta sequences, and were subjected for multiple sequence alignment using Clustal Ω.

All 20 samples taken for study yielded PCR product of ITS2 gene of around 700 base pairs (Plate 1A, 1B). The sequences obtained were subjected to NCBI BLAST data base to check its similarity with nearest hits (Plate 2).

MOLE-BLAST is an experimental tool that helps taxonomists to find the closest database neighbors of submitted query sequences. It computes a multiple sequence alignment (MSA) between the query sequences along with their top BLAST database hits, and generates a phylogenetic tree. Query sequences in the tree are denoted with highlighted node yellow labels.

The present study aims to identify species with atmost precision and to avoid mismatch. The MOLE-BLAST

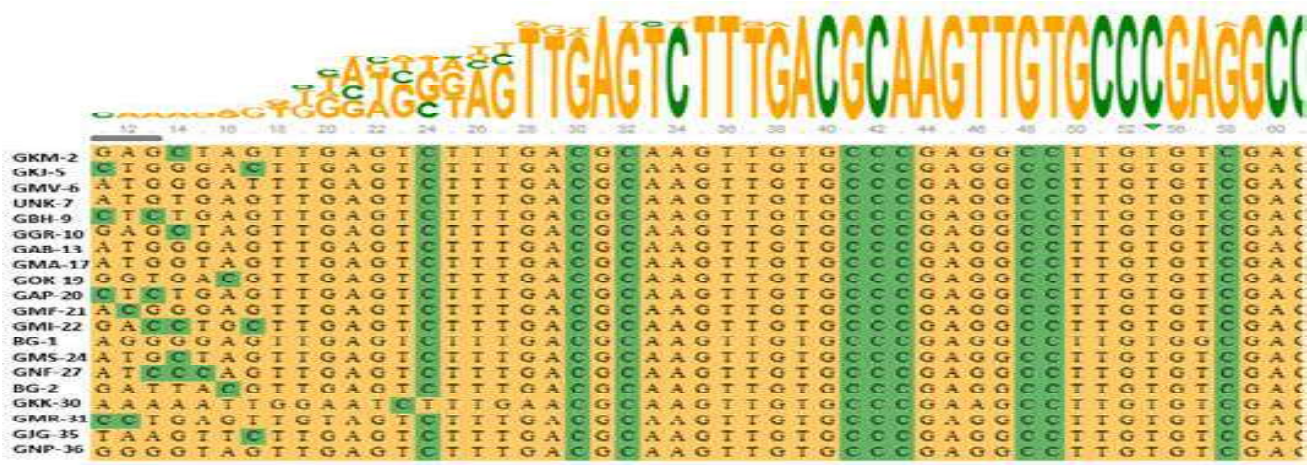

Plate 2: All the sequences of *Curcuma caesia* and other *Zingiberaceae* species aligned using Clustal Ω

results clearly shows that the percent identity of the all the species ranges from 79.14 to 99.9 per cent, where 75 to 98 per cent BLAST sequence identity is suggested. The genotypes GMS-24 and GJG-35 had exhibited highest percentage of sequence identity with the database. Followed by GAB-13 (98.50 %), GNF-27 (95.86 %), GMA-17 (92.88 %), GOK-19 (92.88 %), GMF-21 (92.13 %) and GKM-2 (90.03 %), clearly denotes that all the species are identified precisely and accurately (Table 3).

MOL-BLAST results of 17 promising *Curcuma caesia* Roxb genotypes are; genotype GKM-2, GKJ-5, GBH-9, GAB-13, GMA-17, GOK-19, GAP-20, GMF-21, GMI-22, GNF-27, GKK-30, GMR-31, GJG-35 and GNP-36 had equal Max score and Total score, which denotes highest alignment of the sequence for the matched nucleotide.

The percentage of individual sequence of the genotypes aligned to a sequence in gene bank is ranged

TABLE 3

NCBI BLAST results of *Curcuma caesia* and other Zingiberaceae species

Code	Description	Max score	Total score	Query coverage	E value	Identity(%)	Accession number
GKM-2	*Curcuma caesia* isolate Zn_58.6 clone 2 18S ribosomal RNA gene	379	379	69%	8e-101	90.03	KF304492.1
GKJ-5	*Curcuma caesia* isolate cgbottu36 5.8S ribosomal RNA gene and internal transcribed spacer 2,	536	536	92%	4e-148	88.81	MF076980.1
GMV-6	*Curcuma caesia* isolate cgbottu36 5.8S ribosomal RNA gene and internal transcribed spacer 2	436	672	92%	5e-118	85.16	MF076980.1
UNK-7	*Curcuma wenyujin* voucher DQY32 5.8S ribosomal RNA gene, partial sequence	588	588	96%	1e-163	89.70	KF694813.1
GBH-9	*Curcuma caesia* isolate Zn_58.6 clone 7 18S ribosomal RNA gene,	488	488	68%	2e-133	96.01	KF304497.1
GGR-10	*Curcuma caesia* isolate Zn_58.6 clone 2 18S ribosomal RNA gene,	379	578	78%	1e-100	90.03	KF304492.1

Code	Description	Max score	Total score	Query coverage	E value	Identity(%)	Accession number
GAB-13	*Curcuma caesia* isolate Zn_58.6 clone 9 18S ribosomal RNA gene	468	468	65%	$2e^{-127}$	98.5	KF304499.1
GMA-17	*Curcuma caesia* isolate Zn_58.6 clone 7 18S ribosomal RNA gene	425	425	66%	$9e^{-115}$	92.88	KF304497.1
GOK-19	*Curcuma caesia* isolate Zn_58.3 clone 10 18S ribosomal RNA gene	425	425	66%	$9e^{-115}$	92.88	KF304479.1
GAP-20	*Curcuma caesia* isolate cgbottu 36 5.8S ribosomal RNA gene and internal transcribed spacer 2,	479	479	71	$1e^{-130}$	85.71	MF076980.1
GMF-21	*Curcuma caesia* isolate Zn_58.6 clone 1 9 18S ribosomal RNA gene, partial sequence; internal transcribed spacer	425	425	64%	$1e^{-114}$	92.13	KF304499.1
GMI-22	*Curcuma caesia* isolate cgbottu 36 5.8S ribosomal RNA gene and internal transcribed spacer 2,	307	307	68%	$5e^{-79}$	79.44	MF076980.1
BG-1	*Kaempferia parviflora* isolate K96_5667 18S ribosomal RNA gene, partial sequence; internal transcribed spacer	496	799	86%	$1e^{-135}$	99.9%	1 KY701332.1
GMS-24	*Curcuma caesia* voucher BSI/WRC/IDEN.CER./2017/H3-28 5.8S ribosomal RNA gene	333	647	68%	$6e^{-87}$	99.9	MG725946.1
GNF-27	*Curcuma caesia* isolate Zn_58.6 clone 7 18S ribosomal RNA gene, partial sequence; internal transcribed spacer	507	507	62%	$4e^{-139}$	95.86	KF304497.1
BG-2	*Kaempferia parviflora* voucher BKF:J. Mood 3087 18S ribosomal RNA gene, partial sequence	435	435	68%	$2e^{-117}$	98.78%	KU159396.1
GKK-30	Curcuma caesia 18S ribosomal 1 RNA gene, partial sequence; internal transcribed spacer	322	322	80%	1e-83	82.01	KX148596.1
GMR-31	Curcuma caesia 18S ribosomal RNA gene, partial sequence; internal transcribed spacer 1, 5.8S ribosomal RNA gene	484	484	81%	1e-132	89.56	KX148596.1
GJG-35	Curcuma caesia voucher BSI/WRC / IDEN.CER./2017/H3-28 5.8S ribosomal RNA gene and internal transcribed spacer 2	366	366	60%	8e-97	99.9	MG725946.1
GNP-36	Curcuma caesia isolate cgbottu36 5.8S ribosomal RNA gene and internal transcribed spacer 2, partial sequence	448	448	70%	3e-121	85.14	MF076980.1

from 62 to 92 per cent. Higest query coverage was observed for GKJ-5 (92 %) and GMV-6 (92 %) and least was for GNF-27 (62 %).

The E value of the sequence blast ranges from $1e^{-83}$ to $9e^{-115}$, E value (expect value) is a parameter that describes the number of hits one can expect to see by chance when searching a database of a particular size. Blast results are sorted by E-value by default (best hit in 1st line), the smaller the E value better the match. Genotype GKK-30 had least E value e^{1-83}, followed by GGR-10 (e^{1-100}), GMF-21 (e^{1-114}), GAP-20 (e^{1-130}) and GMR-31 (e^{1-132}). This clearly shows high quality match of the sequence with database. All the genotypes were precisely identified and confirmed that the genus belongs to *Curcuma caesia* Roxb.

BG-1 and BG-2 species were identified as *Kaempferia parviflora* (Black ginger) with an accession number KY701332.1 and KU159396.1 in the NCBI library records, respectively. NCBI blast resulted 86 and 68 per cent query coverage, 99.9 and 98.78 per cent identity along with 496 and 435 max score out of 799 and 435 Total score and $1e^{-135}$ and $2e^{-117}$ E value for BG-1 and BG-2 species respectively. This result clearly shows the precision of the MOL-BLAST and both the species belongs to *Kaempferia parviflora* (black ginger) species.

The unknown species (UNK-7) was identified as *Curcuma kwangsiensis* with an accession number KF694813.1 in the NCBI library record. The per cent identity of the specimen is 89.70 per cent, having 96 per cent query coverage. The blast had scored 588 Max score out of 588 Total score with $1e^{-163}$ E values. These results are clearly helps to identify the unknown species (Table 3).

These results are helpful in identifying the species in precision (Fig.1-5), the sequence obtained from the

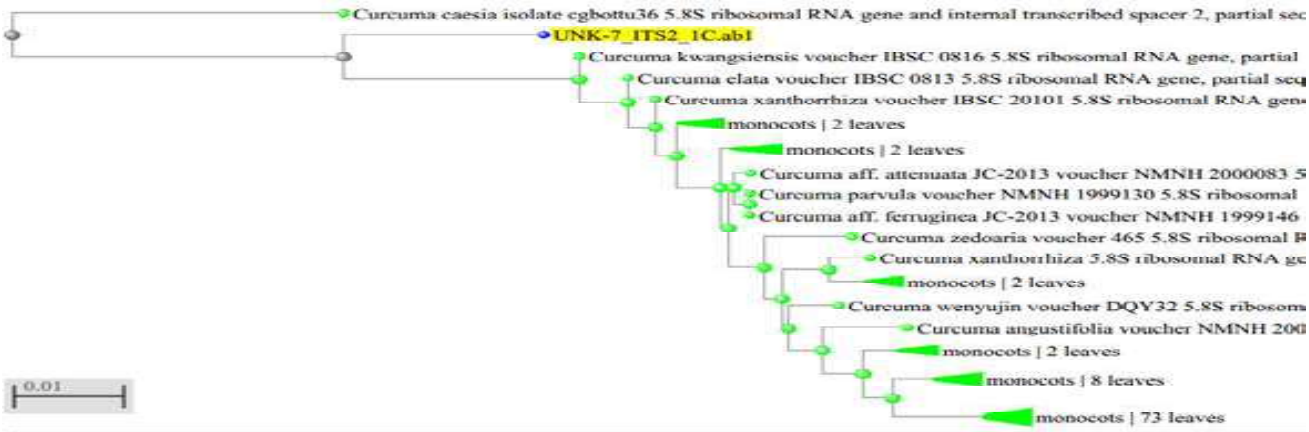

Fig. 1: Phylogenetic tree created through MOLE-BLAST for UNK-7

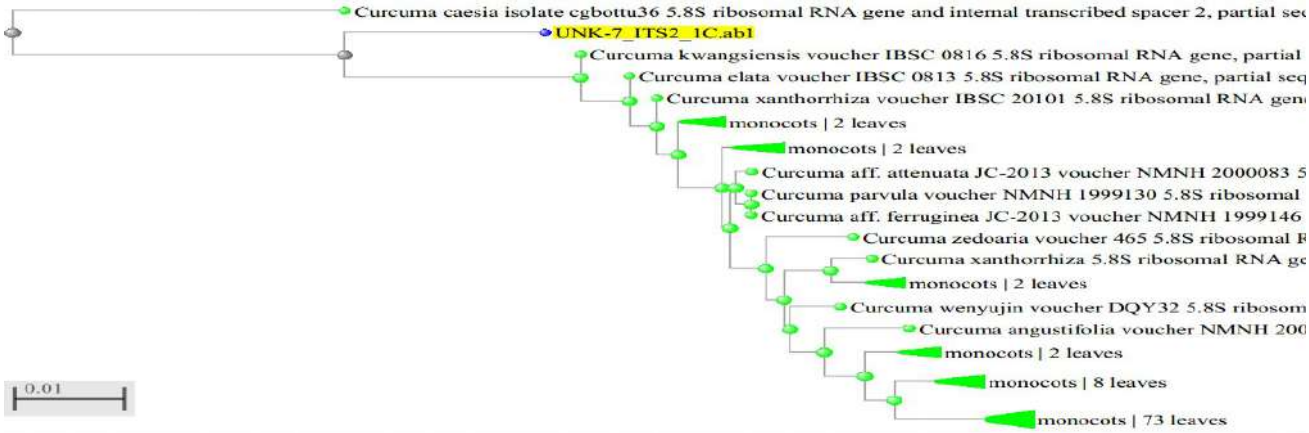

Fig. 2 : Phylogenetic tree created through MOLE-BLAST for BG-1

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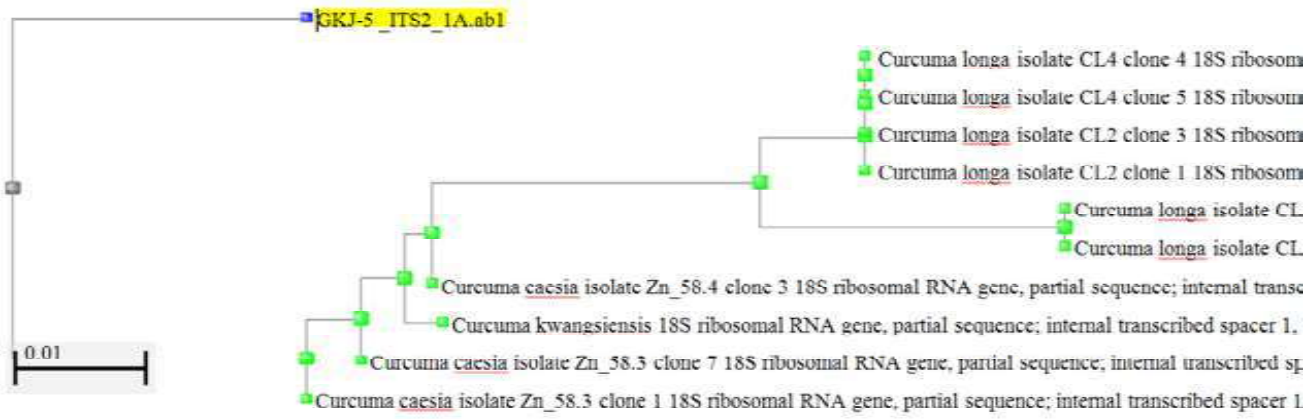

Fig. 3: Phylogenetic tree created through MOLE-BLAST for GKJ-05

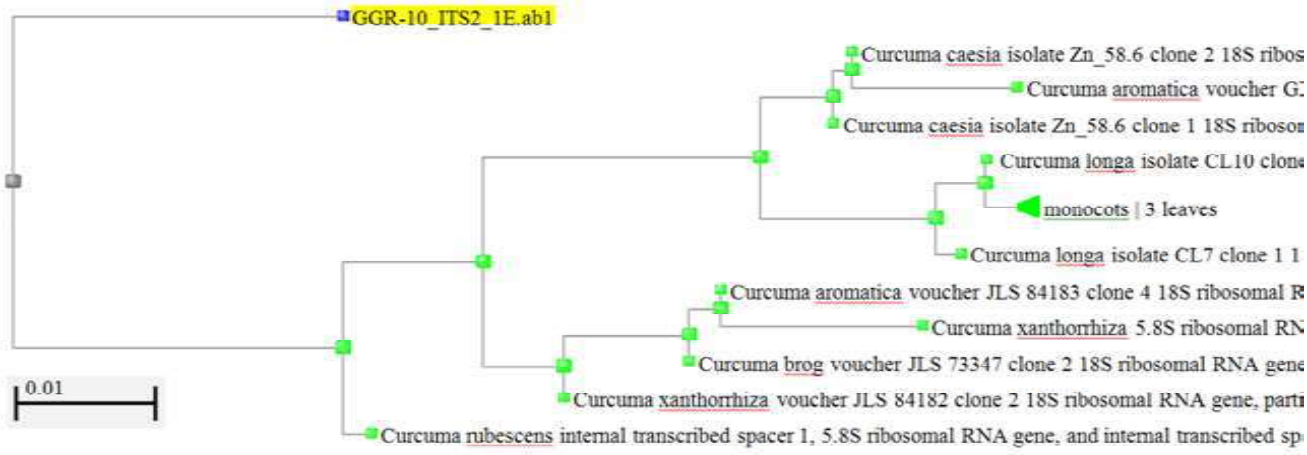

Fig.e 4: Phylogenetic tree created through MOLE-BLAST for GGR-10.

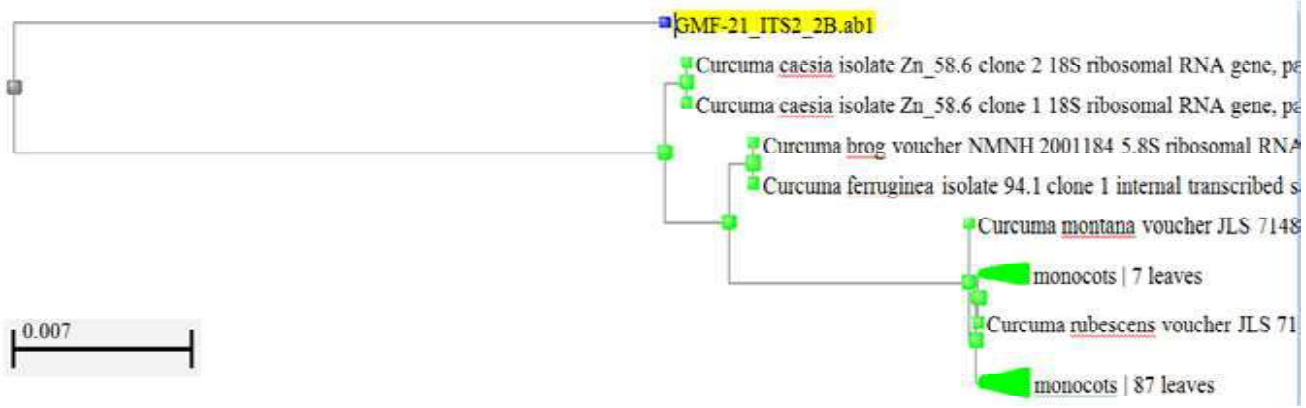

Fig. 5: Phylogenetic tree created through MOLE-BLAST for GMF-21

mole-blast sequencing of each genotypes of black turmeric and other species can be used as an identity marker for the respective genotypes or species (Plate 2). Hence, there is an urgent need to submit the sequences to NCBI and get accession numbers for *Curcuma caesia* genotypes, *Kaempferia parviflora* (BG-1 and BG-2*)* and *Curcuma kwangsiensis* (UNK-7) species.

The results are confirmatory with the findings of Sharma and Lamichhane (2020) who reported 100

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per cent sequence similarity with NCBI blast by using ITS barcode candidate gene for black turmeric accessions collected from different locations of Nepal.

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Attitude of Farmers Towards Rose Cultivation

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Abstract

The present study was conducted in Anekal taluk of Bengaluru Rural district of Karnataka during 2020-21 to analyze the attitude of farmers towards rose cultivation and to identify the production problems of farmers. Sixty rose growers were personally interviewed using a pre-tested interview schedule. Attitude of rose growers was analyzed using the scale developed by Mangal Singh (2014). The scale consisted of 14 attitude statements and the response for each attitude statement of rose growers was measured on 'Likert (1932) format' using five response continuum of strongly agree, agree, undecided, disagree and strongly disagree with a score of 5, 4, 3, 2 and 1, respectively. Ex-post facto research design was adopted for the present study. The results revealed that a majority of the farmers (51.67 %) were possessing more favourable attitude towards rose cultivation, whereas 31.67 and less than one-fifth (16.66 %) of the respondents were possessing favourable and less favourable attitude, respectively. Chi square test revealed that education, land holding, annual income, cosmopoliteness, mass media participation, extension agency contact and extension participation of rose growers had significant to highly significant association with their attitude towards rose cultivation. The results of the multiple regression analysis revealed that ten independent variables together contributed to the tune of nearly 72.18 per cent out of the variation in the development of favourable attitude towards rose cultivation among the respondents. High investment for cultivating rose and incidence of pests and disease were the major production problems faced by the farmers in rose cultivation.

Keywords : Attitude, Rose cultivation, Seed money, Chi square test, Extension participation

Rose is often referred to as the 'Queen of flowers' and it is the symbol of elegant beauty, purity, love, friendship and sympathy. It belongs to the genus Rosa and family Rosaceae. It is the woody perennial plant with hundreds of species and thousands of cultivars and most species are native to Asia. Flowers vary in their size, shape and fascinating, mainly grown for their beauty and fragrance. Rose have acquired cultural significance and has become an integral part of almost all the religious or spiritual ceremonies in India. Roses are best known ornamental plants grown for their flowers both garden and indoors. They are widely used in commercial perfumery, pharmaceuticals and also as commercial cut flower crops. Scented flowers valued for worship, making garlands and preparation of rose oil, rose water, gulkhand, rose attar and rose otto. Rose oil is the valuable perfumery raw materials which imparts characteristic fragrant to perfumes. Rose hips (fruits of rose) are occasionally made into jam, jelly, marmalade, and soup or are brewed for tea, primarily for their high vitamin C content. Rose water, herbal tea, rose syrup, ice cream, kulfi, etc., are also prepared using rose flowers.

Rose is one of the leading cut flowers in the global floriculture trade which is used at almost every event in both local and international markets. The major rose producing countries of the world include :The Netherlands, Colombia, Kenya, Israel, Italy, United States and Japan. The production of rose flowers in India is almost negligible when compared to the developed countries of the world. Rose flowers in the country are mostly grown under cover in Nasik, Pune, Hosur, Kodaikanal, Kalimpong, Ooty, Darjeeling, Bangalore, Solan, Palampur, Shimla, Srinagar, Delhi, Ludhiana and Calcutta.

Attitude is the degree of positive or negative disposition / association towards an innovation, object, programme,

enterprise etc. (Likert, 1932). Whereas, Thurstone (1946) has defined attitude as the degree of positive or negative effect associated with some psychological object. There is no limit to the topics which people may have attitudes. Attitude is nothing but the way of thinking or feeling about diversification. It is found that some characteristic feeling or emotion is experienced as we expect accordingly some definite action. It is also influenced by many factors of farmers like social factors, family, prejudices, personal experience, media exposure, educational and religious institutions and physical factors. The family is the most powerful source for the formation of attitudes. The parents, elder brother or sister provide information about various things. Attitudes developed by an individual, whether positive or negative are the result of family influence and are very powerful and difficult to change. Hence, it can be persuasively argued that everything in life depends on attitude. The success and failure of any enterprise mainly depends upon the people's mindset or attitude towards a particular enterprise, hence attitude of a farmer plays an important role in accepting or rejecting the enterprise. In view of this, the present was carried out with the following specific objectives;

1. To know the profile characteristics of farmers practicing rose cultivation
2. To analyze the attitude of farmers towards rose cultivation
3. To find out the association and extent of contribution of profile characteristics of farmers with their attitude towards rose cultivation
4. To identify the production problems of farmers practicing rose cultivation

Methodology

The study was carried out in Bangalore urban district of Karnataka state during 2020-21. Bangalore urban district is purposively selected for the study, since it is the largest producer of roses in the Southern districts of Karnataka and more over Bangalore Urban district is the hub of floriculture industry, wherein 70 per cent of the rose exports from India are from this district. Rose was cultivated in an area of 1082 ha in Bangalore urban district during the year 1082 ha. Out of the five taluks in Bangalore urban district, Anekal taluk was purposively selected for the study since rose was cultivated in more area (656 ha) as compared to Bangalore East (257 ha), Yelhanka (132 ha), Bangalore South (26 ha) and Bangalore North (11 ha) taluks of Bangalore urban district during the year 2019-20 (Anonymous, 2020). Twelve villages were randomly selected in Anekal taluk for the study. Five rose growers were again randomly selected from each of the 12 sampled villages. Thus, the total sample constituted 60 rose growers from twelve villages. Ex-post facto research design was adopted for the present study.

Attitude towards rose cultivation (dependent variable) in the present study refers to *'the degree of positive or negative effect or feelings of farmers towards rose cultivation'*. The scale developed by Mangal Singh (2014) was used to analyze the attitude of rose growers towards rose cultivation. The scale consisted of 14 attitude statements and the response for each attitude statement of rose growers was measured on 'Likert (1932) format' using five response continuum of strongly agree, agree, undecided, disagree and strongly disagree with a score of 5, 4, 3, 2 and 1, respectively. The summed score thus obtained was considered as attitude score of individual respondent. The maximum score an individual could get was 70 and minimum score was 14. The respondents were categorized based on mean (50.00) and half standard deviation (3.00).

Category	Score
Less favourable	<47.0-0
Favourable	47.00 to 53.00
More favourable	<53.00

Information regarding ten profile characteristics (independent variables) of farmers practicing rose cultivation was collected using a structured schedule with standardized scale and suitable scales. The collected data was analyzed using frequency, mean, standard deviation, chi square test and multiple regression analysis. Chi-square test was employed to

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find out the association between the profile characteristics of rose growers (independent variables) with their attitude towards rose cultivation, while the extent of contribution of the profile characteristics of rose growers to the attitude towards rose cultivation was found out by using multiple regression analysis.

Results and Discussion

Profile Characteristics of Farmers Practicing Rose Cultivation

The research data in Table 1 presents the profile characteristics of farmers practicing rose cultivation. It is seen from the results in Table 1 that a larger proportion of respondents were of middle aged (45.00 %), while 35.00 per cent of the respondents were of young age and the remaining 20.00 per cent of the respondents were of old age. Half of the respondents were having to medium level of education (50.00 %), where as an equal percentage of respondents (25.00 % each) were belonging to low and high category of education. As high as 48.34 per cent of the respondents had medium size family, while 31.66 and 20.00 per cent of the respondents had large and small sized family, respectively. About 43.33 per cent of the respondents interviewed were small farmers, whereas 38.33 and 18.34 per cent of the respondents interviewed were small and big farmers, respectively.

Table 1 also indicates that a majority of respondents were belonging to medium level of annual income (60.00 %), while 25.00 and 15.00 per cent of the respondents were belonging to low and high annual income groups, respectively. A greater proportion of the respondents (46.67 %) were belonging to high level of cosmopoliteness, 28.33 per cent and one-fourth (25.00 %) of the respondents were belonging to medium and high cosmopoliteness groups, respectively. A perusal of Table 1 reveals that 45.01 per cent of the respondents were falling under high level of social participation, whereas 28.33 and 26.66 per cent of them were belonging to medium and low level of social participation, respectively. As high as 43.34 per cent of the respondents were belonging to high mass media participation group, whereas 30.00 and 26.66 per cent of the respondents were belonging to medium and

Table 1

Profile characteristics of farmers practicing rose cultivation

(n = 60)

Characteristics	Category	Farmer's	
		Number	Per cent
Age			
	Young (<35 years)	21	35.00
	Middle (36 - 50 years)	27	45.00
	Old (>50 years)	12	20.00
Education			
	Low (< 3.52 score)	15	25.00
	Medium (3.52 to 4.52 score)	30	50.00
	High (> 4.52 score)	15	25.00
Family size (members per family)			
	Small (< 4)	12	20.00
	Medium (4 to 6)	29	48.34
	Large (> 6)	19	31.66
Land holding			
	Marginal farmers (<2.5 acres)	23	38.33
	Small farmers (2.5 to 5.0 acres)	26	43.33
	Big farmers (> 5.0 acres)	11	18.34
Annual income (Rs)			
	Low (< 3 lakh)	15	25.00
	Medium (3 to 6 lakh)	36	60.00
	High (> 6 lakh)	11	15.00
Cosmopoliteness			
	Low (<5.71 score)	15	25.00
	Medium (5.71 to 6.71 score)	17	28.33
	High (>6.71 score)	28	46.67
Social participation			
	Low (<12.02 score)	16	26.66
	Medium (12.02 to 13.98 score)	17	28.33
	High (>13.98 score)	27	45.01
Mass media participation			
	Low (<10.94 score)	16	26.66
	Medium (10.94 to 12.44 score)	18	30.00
	High (>12.44 score)	26	43.34
Extension agency contact			
	Low (<10.46 score)	14	23.33
	Medium (10.46 to 11.46 score)	18	30.00
	High (>11.46 score)	28	46.67
Extension participation			
	Low (<10.77 score)	15	25.00
	Medium (10.77 to 11.89 score)	16	26.67
	High (>11.89 score)	29	48.33

low mass media participation groups, respectively. Table 1 also reveals that 46.67 per cent of the respondents were belonging to high extension agency contact group followed by 30.00 and 23.33 per cent of the respondents were belonging to medium and low extension agency contact groups, respectively. Less than half of the respondents (48.33 %) exhibited high level of extension participation followed by medium (26.67 %) and low (25.00 %) level of extension participation .

The above findings reveals that more number of farmers practicing rose cultivation were of middle age (45.00 %), having land size of 2.50 to 5.00 acres (43.33 %), medium size family (48.34 %) with medium level of education (50.00 %) and annual income (60.00 %). A greater proportion of the rose growers were belonging to high category of cosmopoliteness (46.67 %), social participation (45.01%), mass media participation (43.34 %), extension agency contact (46.67 %) and extension participation (48.33 %).

Attitude of Farmers towards Rose Cultivation

Table 2 presents the data on the attitude of farmers towards rose cultivation. A majority of the respondents

TABLE 2

Attitude of farmers towards rose cultivation

(n = 60)

Statements	Farmer's				
	Strongly agree	Agree	Undecided	Disagree	Strongly disagree
Adoption of rose cultivation is quite difficult for small and marginal farmers	01 (1.66)	02 (3.33)	03 (5.00)	11 (18.33)	43 (71.69)
The most successful rose grower is one who gets maximum return with minimum cost	41 (68.35)	41 (18.33	04 (6.66)	01 (1.66)	03 (5.00)
It is better to grow other traditional crops than to go for rose cultivation.	01 (1.66)	01 (1.66)	06 (10.00)	19 (31.66)	33 (55.02)
I think that resource poor people can also grow rose	43 (71.68)	11 (18.33)	03 (5.00)	02 (3.31)	01 (1.66)
I consider that rose cultivation is possible for rich farmers only	01 (1.66)	02 (3.31)	03 (5.00)	11 (18.33)	43 (71.68)
In my view adoption of rose cultivation means inviting risks	03 (5.00)	03 (5.00)	07 (11.66)	16 (26.66)	31 (51.68)
Rose cultivation can improve the living standard of growers	45 (75.03)	09 (15.00)	03 (5.00)	01 (1.66)	02 (3.31)
I think that the cost of rose cultivation is very high	31 (51.68)	13 (21.66)	06 (10.00)	05 (8.33)	05 (8.33)
Investment on rose cultivation is wastage of money	02 (3.31)	04 (6.66)	01 (1.66)	10 (16.69)	43 (71.68)
Rose cultivation ensures assured income for a farmer	46 (76.70)	08 (13.33)	03 (5.00)	01 (1.66)	02 (3.31)
Rose cultivation is the effective way to utilize family members	48 (79.99)	10 (16.69)	0 (0.00)	01 (1.66)	01 (1.66)
I think that rose cultivation is suitable only for those farmers who have irrigation facility	45 (75.03)	12 (19.99)	01 (1.66)	01 (1.66)	01 (1.66)
Rose cultivation could obtain good price by following effective post-harvest management practices	46 (76.70)	10 (16.67)	01 (1.66)	02 (3.31)	01 (1.66)
I feel that rose cultivation is like gambling	05 (8.33)	07 (11.66)	06 (10.00)	11 (18.33)	31 (51.68)

Figures is parenthesis indicates percentage

had strongly agreed for the positive attitude statements such as: rose cultivation helps for effective utilization of family members (79.99 %), rose cultivation assures guarantee income for a farmer (76.70 %), rose growers could obtain good price by following effective post-harvest management practices (76.70 %), rose cultivation improves the standard of living of rose growers (75.03 %), rose cultivation is suitable only for the farmers who are having irrigation facility (75.03 %), resource poor farmers could also cultivate rose (71.68 %), the successful rose farmer will get maximum return with minimum cost (68.35 %) and the cost of cultivation of rose is very high (51.68 %).

The results in Table 2 also reveals that over half of the rose growers have strongly disagreed for the following negative attitude statements: adoption of rose cultivation is difficult for small and marginal farmers (71.69 %), rose cultivation is for rich farmers only (71.68 %), investment on rose cultivation is mere waste of money (71.68 %), it is better to grow other traditional / conventional crops than to go for rose cultivation (55.02 %), adoption of rose cultivation means taking risks (51.68 %) and rose cultivation is like gambling (51.68 %). Parmar *et al.* (2015) have reported similar findings such as: adoption of rose cultivation practices is difficult for marginal farmers (70.00 %), rose cultivation is for elite and rich farmers (68.00 %), investment on rose cultivation is waste of money (65.00 %), it is easier and better to grow conventional crops than rose (56.00 %), rose cultivation is a risky venture (55.00 %) and rose cultivation is mere gambling (51.00 %).

The results of the research study revealed that a majority of respondents had strongly agreed for the positive attitude statements, on the other hand more than half of the respondents had strongly disagreed for the negative attitude statements. It is very clear from the research results that majority of the farmers practicing rose cultivation possessed favorable attitude towards rose cultivation. The cultivation of rose could be taken up by all the categories of farmers (including the resources poor farmers), provides employment to the family members, gives maximum returns with minimum cost, assures good income and thereby improves the living standard of the farmers, hence majority of the respondents possessed favourable attitude towards rose cultivation.

Overall Attitude of Farmers towards Rose Cultivation

A majority of the farmers (51.67 %) were possessing more favourable attitude towards rose cultivation, whereas 31.67 and less than one-fifth (16.66 %) of the respondents were possessing favourable and less favourable attitude, respectively (Table 3). The cultivation of rose ensures maximum return with minimum costs and improves the standard of living of the farmers, hence a majority of farmers were possessing more favourable attitude towards rose cultivation.

TABLE 3

Overall attitude of farmers towards rose cultivation (n = 60)

Attitude category	Farmer's	
	No.	Per cent
Less favorable (<47 score)	10	16.66
Favorable (47 to 53 score)	19	31.67
More favorable (>53 score)	31	51.67
Total	60	100.00

Association and Extent of Contribution of Profile Characteristics on the Attitude of Farmers towards Rose Cultivation

Chi square test was employed to find out the association between the profile characteristics of farmers with their attitude towards rose cultivation (Table 4). The results of chi square test reveals that age, family size and social participation of the farmers had no association with their attitude towards rose cultivation.Whereas, education, land holding, annual income, cosmopoliteness and mass media participation of farmers had significant association with their attitude towards rose cultivation at five per cent level of probability. The extension agency contact and extension participation of farmers had highly significant association with their attitude towards rose cultivation at one per cent level of probability. Favorable attitude

TABLE 4

Association and extent of contribution of profile characteristics on the attitude of farmers towards rose cultivation

(n = 60)

Characteristics	Degrees of freedom (df)	Chi-square value	Regression co-efficient (b)	Standard error	't' value
Age	4	2.599 NS	0.176	0.199	0 .884 NS
Education	4	10.199 *	0.671	0.317	2.116 *
Family size	4	1.922 NS	0.259	0.280	0.925 NS
Land holding	4	11.961 *	0.861	0.358	2.402 *
Annual income	4	11.011 *	0.911	0.414	2.211 *
Cosmopoliteness	4	12.101 *	0.440	0.219	2.111 *
Social participation	4	3.961 NS	0.479	0.482	0.993 NS
Mass media participation	4	10.001 *	0.260	0.123	2.118 *
Extension agency contact	4	11.111 **	0.912	0.251	3.633 **
Extension participation	4	13.999 **	0.916	0.308	2.970 **

NS= Non-significant; * = Significant at 5% level; ** = Significant at 1% level; R^2 = -0.7218; F=18.33**

may be developed towards rose cultivation when there is higher level of education, land holding, annual income, cosmopoliteness, mass media participation, extension agency contact and extension participation among rose growers.

The results in Table 4 also reveals that variables such as education, land holding, annual income, cosmopoliteness, mass media participation, extension agency contact and extension participation were significantly contributing in explaining the variation in the development of favourable attitude towards rose cultivation, whereas variables like age, family size and social participation were not significantly contributing to the variation in the development of favourable attitude towards rose cultivation. Ten independent variables together contributed to the tune of nearly 72.18 per cent out of the variation in the development of favourable attitude towards rose cultivation among the farmers practicing rose cultivation. The 'f' value (18.33) was found to be significant at one per cent level. It can be inferred that variables such as education, land holding, annual income, cosmopoliteness, mass media participation, extension agency contact and extension participation of farmers were significantly contributing in developing favourable attitude towards rose cultivation.

Production Problems Encountered by Farmers Practicing Rose Cultivation

Table 5 presents the data on the production problems encountered by farmers in rose cultivation. Requirement of high investment for cultivating rose

TABLE 5

Production problems faced by farmers in rose cultivation

(n = 60)

Problems*	Farmer's		
	No.	%	Rank
High investment requirement	60	100.00	I
Incidence of more pests and disease	60	100.00	I
Water scarcity	55	91.66	III
Scarcity of skilled labours	52	86.66	IV
Non-availability of timely credit	49	81.66	V
Lack of knowledge on pruning	45	75.00	VI
Expensive agricultural inputs (fertilizers, plant protection chemicals etc.)	43	71.66	VII
High labour cost	35	58.33	VIII
Non availability of quality planting materials	18	30.00	IX

*Multiple response

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and incidence of pests and disease were accorded the first ranks by the respondents. Water scarcity, scarcity of skilled labour, non- availability of timely credit, lack of knowledge on pruning and expensiveness of agricultural inputs were accorded III, IV, V, VI and VII rank, respectively by the respondents. High labour cost (Rank VIII) and non-availability of quality planting materials (Rank IX) was accorded the last two ranks by the respondents. The Karnataka State Department of Horticulture should address the above production problems of farmers for the development of favourable attitude towards rose cultivation.

It can be concluded from the study results that a majority of the farmers (51.67 %) were possessing more favourable attitude towards rose cultivation, whereas 31.67 and less than one-fifth (16.66 %) of the rose growers were possessing favourable and less favourable attitude, respectively. It was also found that mass media participation extension agency contact and extension participation of farmers had significant to highly significant association with their attitude towards rose cultivation. Seed money to farmers who are willing to take up rose cultivating, timely credit facilities, subsidy for agro-chemicals, availability of adequate quantity of planning materials and training on recommended rose cultivation practices would help the farmers in developing favourable attitude towards rose cultivation leading to adoption of more recommended rose cultivation practices for getting higher yield and income.

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Effect of Organic Nutrient Management on Soil Chemical Properties, Microbial Population and Nutrient Uptake by Plants

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ABSTRACT

A field experiment was conducted at University of Agricultural Sciences, Bangalore, during *kharif,* 2016 to study the effect of organic sources of nutrients on soil chemical properties, microbial population and nutrient uptake by plants. The experiment was laid out in a RCBD with seven treatments replicated thrice. A significant increase in the available NPK status of soil after harvest as compared to initial status was observed. The available nitrogen, phosphorous and potassium were significantly higher with FYM at 50 kg N eq. ha^{-1} + vermicompost at 50 kg N eq. ha^{-1} + EBDLM at 50 kg N eq. ha^{-1} + panchagavya spray (3 %) at 15 and 45 DAS + vermiwash spray at 30 DAS (381.93, 37.67 and 275.73 kg ha^{-1}, respectively) as compared to other treatments. The same treatment also recorded significantly higher population of bacteria, fungi and actinomycetes (85.37, 13.57 and 14.07 × 10^3 CFU g^{-1} soil, respectively). The nutrient uptake was also higher in the same treatment.

Keywords : Organic, Baby corn, EBDLM, Panchagavya, Vermiwash

MAIZE is the third most important cereal crop globally. A recent trend is growing maize for vegetable purpose, commonly known as 'baby corn'. It is a small young cob or ear or the female inflorescence before pollination or fertilization. The important attributes relevant to baby corn are early maturity, synchronized ear emergence and small palatable yellow kernels. Organic farming is gaining popularity as organic food is being perceived as healthier and of late there is an uptick in demand for organically grown foods. It is also a key to improve the soil health (both physical and biological) and sustainable maintenance of environment.

The greatest challenge facing by the nation in the coming years is to provide safe food for the growing population. In this regard, organic farming is a holistic production management system for promoting and enhancing health of agro-ecosystem. It avoids largely use of synthetic fertilizers, pesticides, growth regulators and livestock feed additives and relies on green manures, crop rotations, crop residues, animals manure, biofertilizers, bio/botanical pesticides, different kinds of cow based liquid organic manure (Ali *et al.*, 2011).

MATERIAL AND METHODS

The field experiment was conducted to study the 'effect of organic nutrient management on soil chemical properties, microbial population and nutrient uptake by plants' during *kharif* 2016 at Zonal Agricultural Research Station, University of Agricultural Sciences, Gandhi KrishiVigyana Kendra, Bengaluru, Karnataka.

Treatments

T_1: Vermicompost at 75 kg N eq. ha^{-1} + EBDLM at 75 kg N eq. ha^{-1}

T_2: FYM at 75 kg N eq. ha^{-1} + Vermicompost at 75 kg N eq. ha^{-1}

T_3: FYM at 50 kg N eq. ha^{-1} + Vermicompost at 50 kg N eq. ha^{-1} + EBDLM at 50 kg N eq. ha^{-1}

T_4: Vermicompost at 75 kg N eq. ha^{-1} + EBDLM at 75 kg N eq. ha^{-1} + Panchagavya (3 %) at 15 and 45 DAS + Vermiwash (3 %) at 30 DAS

T_5: FYM at 75 kg N eq. ha^{-1} + Vermicompost at 75 kg N eq. ha^{-1} + Panchagavya (3 %) at 15 and 45 DAS + Vermiwash (3 %) at 30 DAS

T_6: FYM at 50 kg N eq. ha^{-1} + Vermicompost at 50 kg N eq. ha^{-1} + EBDLM at 50 kg N eq. ha^{-1} + Panchagavya (3 %) at 15 and 45 DAS + Vermiwash (3 %) at 30 DAS

T_7: FYM at 10t ha^{-1} + 150:75:40 kg NPK ha^{-1}

Note: FYM : Farmyard Manure, EBDLM : Enriched Bio-digested Liquid Manure, DAS: Days After Sowing, eq: Equivalent

The experiment was laid out in a randomized complete block design (RCBD) with seven treatments replicated thrice.

The soil of the experimental site was sandy clay loam. Before start of the experiment, composite soil samples were collected from 0 to 15 cm depth and were analyzed for mechanical and chemical properties. The soil is moderately acidic in nature, low in organic carbon and medium in available nitrogen, phosphorus and potassium. The results of soil analysis and the methods followed for their estimation are presented in Table 1.

Analysis of Microbial Population in Soil

Soil samples were collected from the rhizosphere of the plants from each treatment at harvest. They were placed in a polyethylene bag and stored at 5 ^{0}C in refrigerator and then analyzed.

Enumeration of Soil Microbial Population

Microbial population were enumerated from the soil samples collected at 0-15 cm depth. The samples were mixed thoroughly and were subjected to serial dilution using 1 g of soil in 100 ml of sterile water. The enumeration of micro-organisms was done after culturing these organisms using different media by standard dilution plate technique. The media used were soil extract agar for bacteria, Martins Rose Bengal Agar with streptomycin sulphate for fungi and Kusters agar for actinomycetes. The number of colonies appeared on agar medium in plate were counted and multiplied by the representative dilution factor for each group of micro-organisms and expressed as number of colonies per gram of oven dry soil.

Plant Analysis

Plant samples collected for dry matter estimation at harvest from the respective treatments were oven dried and grinded into fine powder in and used for estimating nitrogen, phosphorus and potassium (Table 2).

Results and Discussion

Soil Chemical Properties

Organic carbon of the soil after the harvest of baby corn did not differ significantly among organic sources of nutrients and with recommended dose of fertilizers (150:75:40 kg NPK ha^{-1}) + FYM at 10 t ha^{-1}. However, the organic carbon ranged from 0.46 to 0.54 per cent. Application of organic sources of nutrients did not significantly influence the pH of the soil. It ranged from 5.64 in T_7 (150:75:40 N:P_2O_5:K_2O per ha^{-1}+10 t FYM ha^{-1}) to 6.11 in T_6 (FYM at 50 kg N eq. ha^{-1} + vermicompost at 50 kg N eq. ha^{-1} + EBDLM at 50 kg N eq. ha^{-1} + panchagavya spray (3 %) at 15 and 45 DAS + vermiwash spray (3 %) at 30 DAS. The electrical conductivity of soil ranged from 0.176 to 0.215 d Sm^{-1} (Table 3).

Table 1

Chemical properties of soil of the experimental site at ZARS, UAS, GKVK, Bengaluru

Particulars	Methods followed	Values
pH	Glass electrode pH meter (Piper, 1966)	5.95
EC (dSm^{-1})	Conductometry (Jackson, 1967)	0.14
Organic carbon (%)	Walkey and Black wet oxidation method (Subbiah and Asija, 1956)	0.49
Available N (kg ha^{-1})	Alkaline permanganate method (Subbiah and Asija, 1956)	298.5
Available P_2O_5 (kg ha^{-1})	Olsen's method (Jackson, 1967)	27.9
Available K_2O (kg ha^{-1})	Neutral normal ammonium acetate method (Jackson, 1967)	180.8

TABLE 2

Analytical methods employed for plant analysis

Particulars	Methodology
Nitrogen	Micro Kjeldahl's method (Humphries 1956)
Phosphorus	Tri acid digestion and Vanado - molybdate yellow colour method (Jackson, 1967)
Potassium	Tri acid digestion and flame photometric method (Jackson, 1967)

A significant increase in the available NPK status of soil after harvest as compared to initial status was observed. The available nitrogen, phosphorous and potassium were significantly higher with FYM at 50 kg N eq. ha^{-1} + vermicompost at 50 kg N eq. ha^{-1} + EBDLM at 50 kg N eq. ha^{-1} + panchagavya spray (3 %) at 15 and 45 DAS + vermiwash spray (3 %) at 30 DAS (381.93, 37.67 and 275.73 kg ha^{-1}, respectively) as compared to other treatments.

The soil nutrient status after the harvest of baby corn under different treatments is dependent on the sources of nutrient supply and the crop uptake, besides the losses or transformation into unavailable forms. Addition of organic manures tended to increase the available nitrogen, available phosphorus and potassium status in the soil, as compared to initial soil status. Soil available nutrients increased significantly upon application of different sources of organic manures, indicating their build up in the treated soil. The treatment which comprised of FYM at 50 kg N eq. ha^{-1} + vermicompost at 50 kg N eq. ha^{-1} + EBDLM at 50 kg N eq. ha^{-1} + panchagavya spray (3 %) at 15 and 45 DAS + vermiwash spray (3 %) at 30 DAS recorded higher available N, P_2O_5 and K_2O (381.93, 37.67 and 275.73 kg ha^{-1}, respectively). The results were in conformity with Manjunatha (2010) in maize crop, Choudharya and Suresh Kumar (2013) in baby corn and Kanu Murmu *et al*. (2013) in case of sweet corn.

The increase in available nutrients may be due to the effect of enrichment of bio-digested liquid manure with neem cake that was more pronounced in increasing the post harvest soil available nutrients. Inhibition of nitrification process by neem cake which slows down the release of nitrogen from organic manures might have reduced the loss of nitrogen from soil since organic carbon in the soil was higher than that from inorganic fertilizer application. Increased solubility of native phosphorus by means of organic acids produced during the course of decomposition of organic sources of nutrients may have lead to increase the available soil phosphorus. The increase in available potassium might be related to release of K from EBDLM and also due to the solubilization of mineral bound K or

TABLE 3

Chemical properties of soil after harvest of baby corn as influenced by the organic nutrient management

Treatments	OC (%)	pH	EC (dSm^{-1})	N (kg ha^{-1})	P_2O_5 (kg ha^{-1})	K_2O (kg ha^{-1})
T_1	0.51	5.67	0.18	322.13	31.10	241.83
T_2	0.52	5.77	0.19	352.87	32.37	251.13
T_3	0.53	5.83	0.20	360.17	34.10	260.00
T_4	0.53	5.91	0.20	367.47	34.10	267.17
T_5	0.52	5.96	0.21	373.83	36.17	268.87
T_6	0.54	6.11	0.21	381.93	37.67	275.73
T_7	0.46	5.64	0.17	285.43	28.40	186.23
Initial	0.49	5.95	0.14	298.5	27.9	180.8
S.Em.±	0.01	0.01	0.001	10.65	1.13	7.41
C.D. ($p = 0.05$)	NS	NS	NS	32.83	3.47	22.85

OC – Organic carbon, EC – Electrical conductivity

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native K. Further, it may also due to prevention of leaching losses owing to retention of more K by organic colloids as they possess higher cation exchange capacity (CEC) than mineral colloids (Reddy *et al.,* 2011).

Soil Microbial Population

The data (Table 4) indicates significantly higher population of bacteria,fungal colonies and actinomycetes (86.13, 13.57 and 14.07 × 10^3 CFU g^{-1} of soil, respectively) with FYM at 50 kg N eq. ha^{-1} + vermicompost at 50 kg N eq. ha^{-1} + EBDLM at 50 kg N eq. ha^{-1} + panchagavya spray (3 %) at 15 and 45 DAS + vermiwash spray (3 %) at 30 DAS as compared to other treatments. It was highly beneficial in improving bacteria, fungi and actinomycetes. Similarly, Pradeep Gopakkali *et al*. (2011) also found increase in soil microflora with the application of FYM and cattle urine in rice. Enriched bio-digested liquid manure might have improved the activity of beneficial micro-organisms due to increase in the fast decomposing organic matter fraction as a consequence there was higher availability of NPK in soil. While, the lower microbial activity with inorganic fertilizer use was attributed to the lower availability of organic matter and unfavourable conditions in the soil.

TABLE 4

Bacteria, fungi and actinomycetes population after harvest of baby corn as influenced by the organic nutrient management

Treatments	Bacteria (10^3 CFU g^{-1} soil)	Fungi (10^3 g^{-1} soil)	Actinomycetes (10^3 g^{-1} soil)
T_1	70.40	5.27	9.83
T_2	71.10	6.93	10.77
T_3	74.07	8.23	10.73
T_4	77.10	10.70	11.53
T_5	86.13	12.97	13.63
T_6	85.37	13.57	14.07
T_7	64.60	3.70	7.77
S.Em.±	3.17	0.44	0.64
C.D. (p = 0.05)	9.77	1.37	1.98

CFU – colony forming units

Influence of Organic Nutrient Management on Nutrient uptake by Baby Corn

Total nitrogen uptake (dehusked baby corn + stover), total phosphorous and total potassiumuptake (Table 5) was significantly higher with recommended dose of fertilizers (150:75:40 kg N: P_2O_5: K ha^{-1}) + 10 t FYM ha^{-1} (190.85 kg N ha-^{1}, 34.60 kg P ha^{-1} and 232.35 kg K ha^{-1} respectively) and was on par with the application of FYM at 50 kg N eq. ha^{-1} + vermicompost at 50 kg N eq. ha^{-1} + EBDLM at 50 kg N eq. ha^{-1} + panchagavya spray (3 %) at 15 and 45 DAS + vermiwash spray (3 %) at 30 DAS(183.17 kg N ha^{-1}, 32.85 kg P ha^{-1} and 223.39 kg K ha^{-1}, respectively).

TABLE 5

Total nitrogen uptake (baby corn and stover) as influenced by the organic nutrient management

Treatments	Uptake of nitrogen		
	Total N uptake (kg N ha-1)	Total P uptake (kg P ha-1)	Total K uptake (kg K ha-1)
T1	133.90	15.57	161.48
T2	143.52	17.75	175.14
T3	152.93	21.53	187.82
T4	165.25	25.46	204.26
T5	176.61	28.52	215.53
T6	183.17	32.85	223.39
T7	190.85	34.60	232.35
S.Em.±	5.78	1.21	9.23
C.D. (p = 0.05)	17.82	3.73	28.44

Significant increase in total N, P and K uptake was due to increased baby corn and stover yield (Thavaprakash *et al.,* 2007 and Hossain *et al*., 2012). As a result of enhanced nutrient availability and increased microbial activity which is in turn responsible for quick release of nutrients resulting in more uptake of nutrients.

Foliar application of panchagavya and vermiwash was found to colonize ammonia and nitrite oxidizers in the leaves and increased the uptake of total N and the indole acetic acid (IAA) and gibberelic acid (GA) present in panchagavya could have created stimuli in

the plant system and increased the production of growth regulator in cell system and the action of growth regulators in plant system stimulated the necessary growth and development. These results are in agreement with the findings of Somasundaram *et al.* (2007) and Lourduraj (2005). Indole acetic acid stimulated the growth of adventitious roots and activated the functioning of root tips which may be the possible reason for higher uptake of nutrients available in the soil. These results are in agreement with the findings of Beaulah (2002) in drumstick. Higher phosphorus uptake could be attributed to higher concentration of phosphorus in vermicompost and conversion of fixed phosphorus into readily available form by the organic acids released during the decomposition of compost and EBDLM and consequent improvement in the available P in the soil. These results are in accordance with the findings of Praveen Kumar (2010). Highest potassium uptake due to application of EBDLM along with panchagavya and vermiwash sprays was attributed to the increase in the concentration of potassium.

It can be concluded that the use of organic nutrient sources may have a positive influence on the productivity and soil health. Application of FYM at 50 kg N eq. ha^{-1} + vermicompost at 50 kg N eq. ha^{-1} + EBDLM at 50 kg N eq. ha^{-1} + panchagavya spray (3 %) at 15 and 45 DAS + vermiwash spray (3 %) at 30 DAS can result in higher as well as sustainable productivity of crops without deteriorating the soil.

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Studies on Seed Transmission of Urdbean Leaf Crinkle Virus (ULCV) in Blackgram

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Abstract

Blackgram is an important pulse crop in India. Among the viral diseases, it is more susceptible to yellow mosaic and leaf crinkle. ULCV (Urdbean Leaf Crinkle Virus) is more severe in blackgram than other pulses and causes yield loss ranging from 35 to 81 per cent. Seed transmission studies were carried out in blackgram infected by ULCV to characterize the pathogen. In grow-out test, it was revealed that ULCV was seed transmitted both under natural and controlled conditions.The per cent seed transmission was in the range of 59.20 to 95.45 under field conditions, while it was 56.00 to 72.91 in glass house plants. Further, the symptoms were recorded at trifoliate leaves under field conditions and at the two-leaf stage under glasshouse conditions. Sprout seed abrasion studies showed the maximum disease incidence in sap inoculated soaked seeds kept for germination for two days.

Keywords : Blackgram, ULCV, Seed transmission, Sprout seed abrasion

Pulses are a rich source of proteins among the cultivated crops in India. They are second most important crops in human diet after cereals. They fix atmospheric nitrogen and add organicmatter to the soil. They are used in crop rotation with cereals and increase the fertility of the soil. They have good fibre content with a low glycemic index and thus are beneficial todiabetic people. India is the largest producer and consumer of pulses. The important pulses grown in India are bengalgram, redgram, blackgram and greengram (Mudryj *et al*., 2014).

Blackgram [*Vigna mungo* (L.) Hepper], with chromosome number 2n=22, belongs to the family Fabaceae (Jayamani and Satya, 2013 and Thamodharan *et al*., 2016). Commonly known as Urdbean, it has a good protein content of 25 per cent. It is mainly a *kharif* crop in most of the states of India (Vishalakshi *et al*., 2017). The crop is susceptible to many fungal, bacterial and viral diseases. The important viral diseases include Mungbean Yellow Mosaic Virus (MYMV) and Urdbean Leaf CrinkleVirus(ULCV).

Among pulses, blackgram is more susceptible to ULCV than other pulses (Saha *et al*., 2017)). Urdbean leaf crinkle is the most devastating disease in blackgram resulting in 35-81 per cent of yield loss depending on the time of infection and genotype (Bhavani *et al*., 2018 and Sharma *et al*., 2015). It results in symptoms like mild to severe crinkle, puckering, stunting, rugosity, floral malformation resulting in significant damage and yield loss (Gautam *et al*., 2016). In India, it was first reported from Punjab by Chohan and Kalia (1967). It was named as Urdbean Leaf Crinkle by Kolte and Nene (1972). There are conflicting reports on the etiology and transmission studies of ULCV. Hence, seed transmission studies of ULCV were carried out in blackgram.

Seed transmission studies play an important role in crop viral diseases epidemiology. They serve as a primary source of inoculum of viruses, facilitating the introduction of viruses tonew areas and resulting in secondary transmission of the viruses. Seed transmitted viruses affect the germination of the crops, affecting the crop stand (Aishwarya *et al*., 2020). Seed transmission studies help in roguing of plants at the early stages of the crop, thus preventing the spread of the virus to other plants and other crops (Aishwarya, 2018 and Reddy, 2018). Hence, present seed transmission studies of ULCV were carried out in blackgram.

Material and Methods

Identification of ULCV Infected Blackgram Plants

Blackgram plants showing typical symptoms of crinkling, puckering, stunting and floral malformation were identified in the field. Fifteen plants showing ULCV were tagged.

Maintenance of ULCV Inoculum in the Glasshouse

Fresh leaves were harvested from symptomatic plants and sap inoculated to healthy blackgram plants grown in the glasshouse at the two-leaf stage. Plants that showed the ULCV symptoms upon sapinoculation were maintained.

Collection and Sowing of Seeds from ULCV Symptomatic Plants

Seeds were harvested from 15 symptomatic tagged plants separately. Each of the harvested seeds of 10 plants was sown individually in the plant to row progeny in the field and five plants in a glasshouse under controlled conditions. The plants were later observed for the symptom expression and percent disease incidence was worked out

$$\text{Per cent disease incidence} = \frac{\text{No. of plants with symptoms}}{\text{Total no of germinated plants}} 100$$

Sprout Seed Abrasion Studies

ULCV sap was prepared using ULCVsymptomatic fresh leaves with phosphate buffer of 0.1 M. β mercapta ethanol (2 µl/ml of buffer) was added to sap to remove the host impurities. A small pinch of ceilite/ carborundum was added to sap to create abrasions. Healthy black gramseeds of different treatments (Table 1 and Fig. 1) were inoculated with ULCV sap for three hours (Fig. 2) to artificially detect the seed transmission.

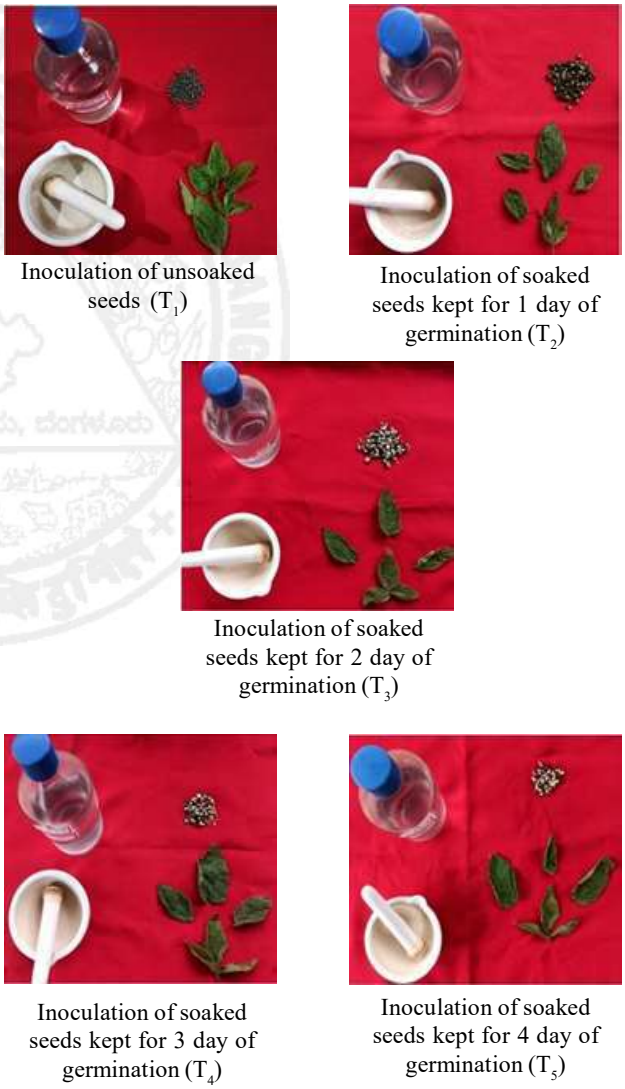
Results and Discussion

Upon sap inoculation at two-leaf stage, the plants started to show symptoms 25-33 days after sowing. Symptoms included crinkling, puckering, rugosity, twisting of leaves and floral malformation. Fig.3

Table 1

Different treatments used for sprout abrasion studies of ULCV in blackgram

T_1	Unsoaked seeds
T_2	Water-soaked seeds and kept for germination for one day
T_3	Water-soaked seeds and kept for germination for two days
T_4	Water-soaked seeds and kept for germination for three days
T_5	Water-soaked seeds and kept for germination for four days



Inoculation of unsoaked seeds (T_1)

Inoculation of soaked seeds kept for 1 day of germination (T_2)

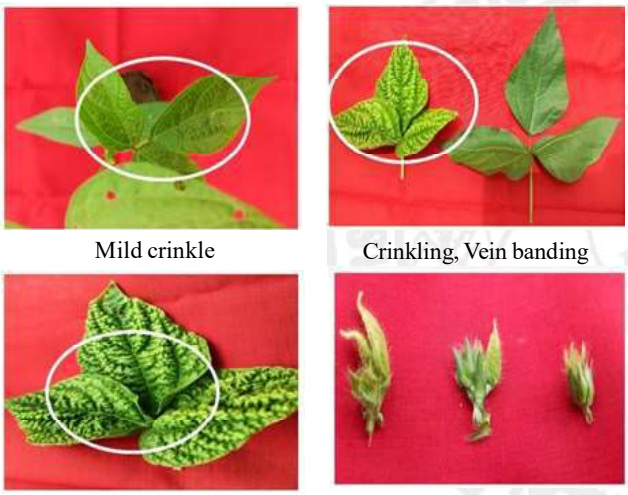
Inoculation of soaked seeds kept for 2 day of germination (T_3)

Inoculation of soaked seeds kept for 3 day of germination (T_4)

Inoculation of soaked seeds kept for 4 day of germination (T_5)

Fig.1 : Different treatments used in sprout seed abrasion studies

Fig 2 : Inoculation of blackgram seeds with ULCV sap for three hours



Mild crinkle | Crinkling, Vein banding

Rugosity and twisting of leaves | Floral malformation

Fig 3: Different types of symptoms recorded in the glasshouse upon sap inoculation

represents the ULCV symptoms recorded in the glasshouse.

Symptoms were observed in the field and glasshouse in the plants sown from the seeds of 15 symptomatic plants. In the field, mild crinkle symptoms were recorded on first trifoliate leaves, while the symptoms were recorded in cotyledonary leaves in the glasshouse (Fig. 4). The incubation period was 8-10 days for symptom expression in the glasshouse, while in the field it was for 15-20 days.This showed that the incubation period for symptom expression is more

Seed transmission in glass house | Seed transmission in field

Fig 4 : Mild crinkle symptoms in the plants raised from seeds of symptomatic plants in the glass house and field

under field conditions compared to controlled conditions.

The per cent disease incidence (PDI) differed among the plants raised (plants sown from the seeds of 15 symptomatic plants) in the field and glasshouse. PDI was in the range between 59.20 to 95.45 in the field while it was 56.00 to 72.91 in glass house plants (Table 2 and Table 3). It was further observed that there was a cent per cent disease incidence in field plants after five to ten days of symptom expression. Sprout seed abrasion studies showed that the symptoms started to express 26 days after sowing the sprouted inoculated seeds. The per cent seed transmission was 71.40 for unsoaked sap treated seeds (T_1) at 26 and 31 DAS (Days After Sowing), while it was 55.50 per cent at 25 DAS and 66.60 per cent at 30 DAS for one day germinated sap treated seeds (T_2). The two days germinated sap treated seeds (T_3) showed 83.30 per cent at 28 DAS and 33 DAS, whilethree days germinated sap treated seeds (T_4) showed 60 per cent transmission at 26 DAS and40 per cent at 31 DAS. The per cent seed transmission for four days of germinated sap treated seeds (T_5) was 50 per cent at 26 DAS and 70 per cent at 31 DAS (Fig. 5).

The maximum per cent seed transmission was recorded in the treatment T_3 (Seeds soaked and kept for germination for two days) (Table 4).This indicated that seed transmission efficiency was seen when seeds were soaked and kept for germination for two days compared to other treatments.

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TABLE 2

Per cent seed transmission from seeds of symptomatic plants under field conditions

Plants raised from the seeds of symptomatic plants (Plant to row progeny)	The total number of plants germinated	Number of plants with symptoms	Number of plants without symptoms	Per cent seed transmission
Plant 1	69	48	21	69.56 %
Plant 2	198	137	61	69.10 %
Plant 3	41	33	8	80.40 %
Plant 4	22	21	1	95.45 %
Plant 5	34	24	10	70.50 %
Plant 6	66	42	24	63.60 %
Plant 7	45	32	13	71.10 %
Plant 8	40	27	13	67.50 %
Plant 9	51	34	17	66.60 %
Plant 10	54	32	22	59.20 %

Average percent seed transmission under field conditions : 71.30

TABLE 3

Percent seed transmission from seeds of symptomatic plants under controlled conditions

Plants raised from the seeds of symptomatic plants (Plant to row progeny)	The total number of plants germinated	Number of plants with symptoms	Number of plants without symptoms	Per cent seed transmission
Plant 11	50	28	22	56.00 %
Plant 12	49	32	17	65.30 %
Plant 13	66	49	17	74.20 %
Plant 14	44	34	10	77.20 %
Plant 15	48	35	13	72.91 %

Average percent seed transmission under field conditions : 69.12

TABLE 4

Effect of sprout seed abrasion on seed transmission of ULCV

Number of days soaked seeds left for germination	Number of plants with symptoms		Number of plants without symptoms		Total number of plants	Per cent seed transmission (%)	
	1st reading	2nd reading (5days after 1st reading)	1st reading	2nd reading (5days after 1st reading)		1st reading	2nd reading (5days after 1st reading)
Zeroday (Unsoaked seeds)	5	5	2	2	7	71.40	71.40
Firstday	5	6	4	3	9	55.50	66.60
Second day	5	5	1	1	6	83.30	83.30
Third day	3	3	2	3	5	60.00	40.00
Fourth day	5	7	5	3	10	50.00	70.00

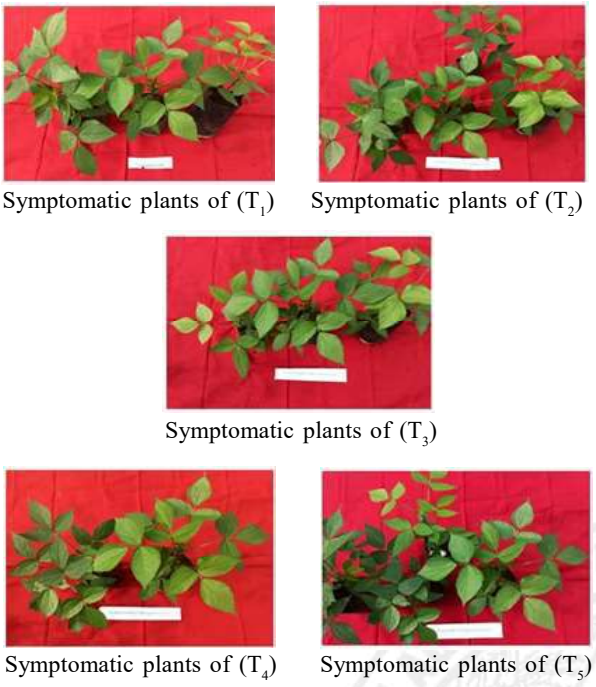

Fig 5 : Plants showing symptoms of ULCV of different treatments subjected to sprout seed abrasion studies

Seed transmission studies help biologically to characterise the pathogen, determine host-pathogen interaction and helps to devise better disease management strategies. The grow-outtest confirmed the seed transmission nature of ULCV both in the field (natural conditions) and in the glasshouse (controlled conditions). On an average, the per cent seed transmission of ULCV was 71.30 under field conditions and 69.12 under controlled conditions. It took more number of days for symptom expression under field conditions (symptoms seen at trifoliate leaves) than in glass house (symptoms seen at a two-leaf stage). Sprout seed abrasion studies revealed that sap inoculated sprouted seeds kept for two days of germination (T_3) showed maximum seed transmission compared to other treatments.

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Comparative Performance of Dryland Cropping Systems under Reduced Runoff Farming in Alfisols of Karnataka

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ABSTRACT

Cropping systems are important tool to tackle runoff, erosion and soil loss. The kind and sequence of crops will decide the kind and amount of vegetative cover, the nature of tillage operations performed on the physical and chemical properties of the soil. The field experiment was conducted during *kharif* 2019-20 and 2020-21 at AICRP for Dryland Agriculture, GKVK, UAS, Bangalore to study 'Comparative performance of dryland cropping systems under reduced runoff farming in alfisols of Karnataka'. Significantly better growth parameters *viz.*, plant height, number of leaves, number of branches, leaf area, leaf area index, leaf area duration and SPAD, yield parameters *viz.*, grain/pod yield, straw/stover yield and economics were recorded in cropping systems with one sensor based micro irrigation of 25 mm during dry spell from farm pond as compared to their respective checks. Significantly higher finger millet equivalent yield was recorded in french bean with one protective irrigation (9627 kg ha^{-1}) when compared to non-irrigated (7732 kg ha^{-1}) and other cropping systems. It was followed by pigeonpea + field bean (1:1) (5624 kg ha^{-1}). Similarly, french bean sole with one sensor based micro irrigation resulted in higher gross return (Rs.303706 ha^{-1}), net return (Rs.24556 ha^{-1}) and B:C ratio (5.22) as compared to non-irrigated and other cropping systems. However, the runoff, soil loss and nutrient losses were higher with french bean sole as compared to other cropping systems.

Keywords : Cropping systems, Dry spells, Economics, Finger millet equivalent yield, Runoff farming

In India, rainfed agriculture accounts for two-thirds of the total cropped area (66 %) and contributes 40 per cent to the national food basket. The importance of rainfed agriculture is obvious in the country considering its contribution in the production of coarse cereals (91 %), pulses (90 %), oilseeds (85 %), cotton (65 %) and rice (55 %). The mean annual rainfall in rainfed region ranging from 400 mm to 1000 mm, which is uncertain, erratic and unevenly distributed. In India, ensuring the sustainability of rainfed agriculture is more critical for population living in these areas (Anonymous, 2010). Karnataka is a rainfed agrarian state having nearly 66 per cent of the cultivated area under rainfed agriculture. Since Karnataka is an upper riparian state, the possibility of the increasing area under irrigation is limited. 55 per cent of food grain and 75 per cent of oilseed production comes from rainfed areas in the state (Ramachandrappa *et al.,* 2016). According to rainfall pattern analysis in the state, three to four years out of ten years face severe drought, sometimes even in alternate years also. Among 18 years during 2001 to 2018, 14 years were declared as drought in the state of Karnataka (Thimmegowda *et al.,* 2018).

Among 400 M ha-m of rainfall received, 150 M ha-m flows as surface runoff, subsurface runoff and will not available to any type of production in India (Mathur *et al.,* 1997). To mitigate the runoff caused by uneven, erratic and heavy rains, *in-situ* and *ex-situ* water harvesting techniques can be used efficiently. During the rainy season when water is not required for irrigation, the excess water can be stored in a ancillary reservoir or farm ponds and used effectively during crucial periods of crop growth (Ramachandrappa *et al.,* 2017). The *in-situ* water harvesting can be attained through selection of proper cropping systems. Cropping systems are commonly recognized to affect

runoff, erosion and crop yields. The kind and sequence of crops will decide the kind and amount of vegetative cover, the nature of tillage operations performed and the physical and chemical properties of the soil.

Harnessing small water sources and integrating with affordable technologies, information and access to markets makes a significant improvement in rural livelihoods. Reduced runoff farming could be an option in improving the livelihood security of the rainfed farmers. With these objectives the field experiment was carried out in *kharif* 2019-20 and 2020-21 to assess the comparative performance of different cropping system to reduce runoff, soil loss and obtain higher productivity in Eastern Dry Zone of Karnataka.

Material and Methods

Experiment Location

Experiment was carried out to study 'Comparative performance of dryland cropping systems under reduced runoff farming in alfisols of Karnataka' at the All India Co-ordinated Research Project on Dry Land Agriculture, University of Agricultural Sciences, Gandhi Krishi Vignan Kendra, Bengaluru in the Eastern Dry Zone of Karnataka at 12^0 58' N latitude and 75^0 35' E longitude at an altitude of 930 meter above mean sea level during 2019-20 and 2020-21. The soil of experimental site was slightly acidic in reaction (5.60), medium in average available nitrogen (253.87 kg ha^{-1}), medium in average available phosphorous (32.00 kg ha^{-1}) and medium in average available potassium (155.83 kg ha^{-1}).

Treatment Details

The experiment was conducted using RCRD design with factorial concept with two factors consisting of cropping systems for harvesting of runoff water from the micro watershed in the farm ponds and water productivity enhancement strategies through sensor based protective irrigation having three replications. The factor one titled 'Cropping system for harvesting of runoff water from the micro watershed in farm ponds' consist of cropping system *viz.,* T_1: french bean sole T_2: Finger millet sole, T_3: Pigeonpea + field bean (1:1), T_4: Finger millet + Pigeonpea (8:2), Perennial mixed fruit (Pomelo + Guava) orchard and Kitchen garden (Ladies finger, capsicum, tomato, french bean, brinjal, leafy vegetables, green chilli, knol khol, cluster bean, ridge guard, cabbage) and factor two titled 'Water productivity enhancement strategies' consist of I_1: Protective advanced irrigation (sensor based micro irrigation during dry spell) and I_2: Control. The respective recommended dose of fertilizers of crops were given along with 7.5 t ha^{-1} FYM during experiment.

Collection of Hydrological Data

The water harvested from five different micro water shed during runoff events are facilitated to store in respective farm ponds constructed at the end of plots. The weekly soil moisture during crop growth period from the depth of 0-15 cm and 15-30 cm were taken with Moisture probe meter (MPM-160-B), manufactured by ICT international limited, Australia. Based on soil moisture percentage and dry spell during the crop growth period the protective irrigation was given at vegetative stage in both years. The protective irrigation was given through sprinkler using diesel pump. The quantity of irrigation for different crops is indicated below.

Methods/ Seasons	*Kharif* 2019 (mm)	Date	*Kharif* 2020 (mm)	Date
Pigeonpea+ field bean (1:1)	25	05-07-2019	25	21-06-2020
Finger millet sole	25	11-09-2019	25	28-08-2020
Finger millet+ pigeonpea (8:2)	25	11-09-2019	25	28-08-2020
French bean	25	14-09-2019	25	01-11-2020
Pumelo	25	04-11-2019	25	01-11-2020

Biometric Observations

The plant height of five randomly selected plants were measured from base of plant to tip of the panicle in finger millet, perpendicular distance from ground level to the tip of main stem in pigeonpea, ground to tip of plants in field bean and french bean were taken, averaged and expressed in centimeters. Number of leaves was recorded from the randomly selected five

hills of finger millet and fully opened trifoliate leaves in pigeonpea, field bean and french bean was counted and averaged to get leaves per hill/plant. Total numbers of tillers produced by five random tagged hills in finger millet and number of branches emerging directly from main stem was counted and the average of the five plants was expressed as number of branches per plant in pigeonpea, field bean and french bean. The SPAD observation was taken by using SPAD meter at at 90 DAS in finger millet, 60 DAS in field bean and french bean, 150 DAS in pigeon pea.

The fresh green leaves from five hills/plant were collected and passed through a leaf area meter INC/ LI-COR Ltd., Nebraska, USA to measure the leaf area. Then it is expressed in square centimeter. Leaf area index was worked out by dividing the leaf area $hill^{-1}$ / plant from land area covered by the plants as per the formulae given by Watson (1952). Leaf area duration was calculated between 60 - 90 DAS in field bean & french bean, 90 DAS - harvest in finger millet and 150-180 DAS in pigeonpea by using the formula given by Power *et al.* (1967).

$$LAD = \frac{LAI_1 + LAI_2}{2} \times (t_2 - t_1)$$

Where, LAD = Leaf area duration, expressed in days

LAI_1= Leaf area index of hill at time t_1

LAI_2 = Leaf area index of hill at time t_2

During each picking, pods in field bean and french bean were harvested from net plots according to treatments, weighed and expressed as kg ha^{-1}. The grain yield of finger millet and pigeon pea obtained from each net plot area was harvested, threshed, sun dried to 10-12 per cent moisture and later yield was converted to kg ha^{-1}. The straw and stalk from net plot area was cut close to the ground level and was left for air drying in the for one week. Later it was weighed and computed as straw yield in kg ha^{-1}. The respective grain and pod yield of different crops were converted into finger millet equivalent yield (kg ha^{-1}). The formula to calculate FMYE is given below.

$$\text{Finger millet equivalent yield (FMEY)} = \frac{\text{Yield of crop (kg ha}^{-1}\text{)} \times \text{Price of crop (Rs. kg}^{-1}\text{)}}{\text{Price of finger millet (Rs. kg}^{-1}\text{)}}$$

Statistical Analysis

The experimental data collected on various growth components of plant were subjected to student's 't' test. Whenever table 't' test value is more than calculated 't' test value of two means, significant difference exists between the treatments means. Otherwise values abbreviation 'NS' (Non-Significant) was indicated. Finger millet equivalent yield were subjected to Fisher's method of 'Analysis of variance' (ANOVA). Whenever F-test was significant for comparison amongst the treatments means, an appropriate value of critical differences (CD) was worked out. Otherwise against CD values abbreviation 'NS' (Non-Significant) was indicated. All the data were analyzed and the results are presented and discussed at a probability level of 5 per cent (Gomez and Gomez, 1984).

Results and Discussion

Experiment 'Comparative performance of dryland cropping system under reduced runoff farming in alfisols of Karnataka' was conducted during *kharif* 2019-20 and 2020-21. The data pertaining to different growth and yield parameters of both years and pooled are given in respective tables. The pooled data of the both years is presented and discussed below.

Effect of Water Productivity Enhancement Strategies on Plant Height, Number of Leaves and Number of Branches

Plant growth is a function of several physiological and biological processes which is measured in terms of rate of dry matter production and their partitioning into various plant parts which finally reflected on economic yield. With regarded to this vegetative plant parts serve as a source for dry matter production and the grains as sink for dry matter accumulation. The plant height was significantly higher with application of one protective sensor based micro irrigation during dry spell from runoff water stored in farm ponds of micro catchment area in french bean (57.9 cm), finger millet (120.6 cm), pigeonpea (231.5 cm) and field bean (71.7 cm) in pigeonpea + field bean (1:1) cropping system, finger millet (119.2 cm) and pigeonpea (165.3 cm) in

finger millet + pigeonpea (8:2) cropping system when compared to their respective control (54.3, 111.7 , 214.6 & 62.9 and 110.9 & 156 cm, respectively) (Table 1). The increase in plant height was due to the amount of rainfall and irrigation applied to meet the water required by the crop for its metabolism. When the water extracted from the soil is less, causes a negative effect on the development of tissues and the parts of the crop such as stem. The plant heights recorded under protectively irrigated cropping systems are higher as compared to non-irrigated crops. Eric Manzi (2013) also observed higher plant height in mustard and chickpea with supplemental irrigation in rainfed condition as compared to non-irrigated.

Significantly higher number of leaves were recorded with one protective irrigation during dry spell in french bean (23.2), finger millet (83.1), pigeonpea (381.8) & field bean (26.6) in pigeonpea + field bean (1:1) cropping system, finger millet (81.6) & pigeonpea (159.6) in finger millet+ pigeonpea (8:2) cropping system as compared to their respective control (20,

TABLE 1

Growth parameters as influenced by water productivity enhancement strategies in different cropping systems under open field reduced runoff farming

Treatments	Plant height (cm)			No. of leaves***			Number of branches / tillers		
	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled
T_1: French bean sole *									
T_1I_1: French bean	59.5	56.3	57.9	23.8	22.6	23.2	8.5	8.1	8.3
T_1I_2: French bean	55.4	53.1	54.3	20.5	19.4	20.0	7.7	7.4	7.6
't' test	S	S	S	S	S	S	S	S	S
T_2: Finger millet sole **									
T_2I_1: Finger millet	123.3	118.0	120.6	84.1	82.1	83.1	11.2	10.5	10.9
T_2I_2: Finger millet	114.3	109.0	111.7	74.8	69.9	72.3	9.9	9.5	9.7
't' test	S	S	S	S	S	S	S	S	S
T_3: Pigeonpea * + Field bean * (1:1)									
T_3I_1: Pigeonpea	233.5	229.5	231.5	390.4	373.1	381.8	23.5	22.8	23.1
T_3I_2: Pigeonpea	217.9	211.2	214.6	360.6	350.4	355.5	21.7	19.3	20.5
't' test	S	S	S	S	S	S	S	S	S
T_3I_1: Field bean	70.5	72.9	71.7	26.2	26.9	26.6	6.0	6.8	6.4
T_3I_2: Field bean	59.3	66.4	62.9	19.7	23.1	21.4	4.9	6.2	5.5
't' test	S	S	S	S	S	S	S	S	S
T_4: Finger millet ** + Pigeonpea* (8:2)									
T_4I_1: Finger millet	120.7	117.7	119.2	83.0	80.3	81.6	11.4	10.9	11.2
T_4I_2: Finger millet	109.9	111.9	110.9	73.6	73.4	73.5	10.9	10.0	10.4
't' test	S	S	S	S	S	S	S	S	S
T_4I_1: Pigeonpea	167.7	162.9	165.3	161.4	157.7	159.6	12.7	12.4	12.5
T_4I_2: Pigeonpea	159.2	152.9	156.0	153.1	139.5	146.3	11.3	10.7	11.0
't' test	S	S	S	S	S	S	S	S	S

Water productivity enhancement strategies

I_1: Sensor based micro irrigation during dry spell I_2: Control

Note : * Trifoliate leaves per plant; ** Leaves per hill

*** No. of leaves were taken at 90 DAS in finger millet, 60 DAS in field bean and french bean, 150 DAS in pigeon pea

72.3, 355.5 & 21.4 and 73.5 & 146.3, respectively). Similarly, higher number of branches/tillers were recorded in french bean (8.3), finger millet (10.9), pigeonpea (23.1) & field bean (6.4) in pigeonpea + field bean (1:1) cropping system, finger millet (11.2) & pigeonpea (12.5) in finger millet+ pigeonpea (8:2) cropping system as compared to their respective control (7.6, 9.7, 20.5 & 5.5 and 10.4 & 11, respectively). The moisture played a major role in physiology of the plant. Hence, availability of moisture around optimum level during the period of growth due to life saving irrigation lead to higher number of leaves and branches in all crops as compared to without irrigation.

Effect of Water Productivity Enhancement Strategies on Leaf Area, Leaf Area Index, Leaf Area Duration and SPAD

Application of one protective irrigation during dry spell has significantly increased the leaf area of french bean (726 cm^2), finger millet (2143 cm^2), pigeonpea (6769 cm^2) & field bean (2032 cm^2) in pigeonpea + field bean (1:1) cropping system, finger millet (2227 cm^2) & pigeonpea (2808 cm^2) in finger millet+ pigeonpea (8:2) cropping system as compared to their respective control (653, 2048, 5367 & 1890 and 2090 & 2560 cm^2, respectively) (Table 1). The higher leaf area was a result of higher number of leaves and tiller/branch production (Table 1). Due to higher leaf area, there was marked increase in the leaf area index with one supplemental irrigation was observed in french bean (1.08), finger millet (7.14), pigeonpea (1.88) & field bean (2.26) in pigeonpea + field bean (1:1) cropping system, finger millet (7.42) & pigeonpea (1.56) in finger millet+ pigeonpea (8:2) cropping system (Table 2). The leaf area index showed a curvilinear trend of increase up to grain formation stage in finger millet & pigeon pea and pod formation in french bean & field bean and later declined marginally due to senescence. Application of irrigation during dry spell might increase metabolic activities like increase in turgidity, cell division and elongation of leaves resulting in higher biomass. Further, this has been resulted in increased leaf area and LAI which is an indicative of higher mobilizable protein pools available at the beginning of the reproductive phase and later on greater plant bearing capacity. Similar findings were also reported by Eric Manzi (2013) in mustard and chickpea.

Significantly higher leaf area duration was recorded in french bean (26.6), finger millet (165.2), pigeonpea (52.7) & field bean (52.3) in pigeonpea + field bean (1:1) cropping system, finger millet (173.5) & pigeonpea (44.4) in finger millet+ pigeonpea (8:2) cropping system as compared to their respective control (23.8, 153.6, 42.5 & 47 and 158.2 & 40.2, respectively). This higher LAD improved the crop growth parameters and resulted in higher grain and straw yield. The yield of any crop is directly proportional to its duration. As the duration increases, there will be more availability of opportunity time for photosynthesis and resulting in more dry matter production and its distribution to economic parts. Similar findings were also reported by Eric Manzi (2013).

Application of one irrigation at dry spell to different cropping system has lead to increased uptake of nutrients and resulted in significantly higher SPAD readings, which is the index of chlorophyll content in french bean (47.6), finger millet (38.9), pigeonpea (48) & field bean (47.9) in pigeonpea + field bean (1:1) cropping system, finger millet (41.2) & pigeonpea (46) in finger millet+ pigeonpea (8:2) cropping system as compared to their respective control (44.4, 36.9, 44.7 & 44.4 and 38.5 & 43.3, respectively).

Influence of Water Productivity Enhancement Strategies on Grain or Pod Yield, Stover or Straw Yield and Finger Millet Equivalent Yield in Different Crops

Yield is the resultant of different metabolic activities taking place in different stages of the growth of the plants. A sound source in terms of plant height and number of tillers to support and hold the leaves are logically able to increase the total dry matter and later lead to higher grain yield. Significantly higher grain/pod yield was recorded with application of one sensor based micro irrigation during dry spell in french bean (10097 kg ha^{-1}), finger millet (4126 kg ha^{-1}), pigeonpea (887 kg ha^{-1}) & field bean (3258 kg ha^{-1}) in pigeonpea + field bean (1:1) cropping system, finger millet

TABLE 2

Leaf area (cm^2), Leaf area index Leaf area duration and SPAD as influenced by water productivity enhancement strategies in different cropping systems under open field reduced runoff farming

Treatments	Leaf area (cm 2) ***			Leaf area index ***			Leaf area duration (Days)			SPAD***		
	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled
T_1: French bean sole *												
T_1I_1: French bean	753	700	726	1.12	1.04	1.08	27.7	25.5	26.6	49.0	46.3	47.6
T_1I_2: French bean	686	620	653	1.02	0.92	0.97	24.6	23.0	23.8	45.1	43.7	44.4
't' test	S	S	S	S	S	S	S	S	S	S	S	S
T_2: Finger millet sole **												
T_2I_1: Finger millet	2273	2014	2143	7.58	6.71	7.14	176.2	154.3	165.2	39.0	38.7	38.9
T_2I_2: Finger millet	2146	1949	2048	7.15	6.50	6.83	162.0	145.1	153.6	37.1	36.8	36.9
't' test	S	S	S	S	S	S	S	S	S	S	S	S
T_3: Pigeonpea* + Field bean* (1:1)												
T_3I_1: Pigeonpea	6980	6557	6769	1.94	1.82	1.88	54.6	50.7	52.7	48.8	47.3	48.0
T_3I_2: Pigeonpea	5503	5230	5367	1.53	1.45	1.49	44.2	40.8	42.5	45.2	44.2	44.7
't' test	S	S	S	S	S	S	S	S	S	S	S	S
T_3I_1: Field bean	1824	2240	2032	2.03	2.49	2.26	47.8	56.7	52.3	49.7	46.0	47.9
T_3I_2: Field bean	1684	2097	1890	1.87	2.33	2.10	43.8	50.1	47.0	45.9	42.8	44.4
't' test	S	S	S	S	S	S	S	S	S	S	S	S
T_4: Finger millet+ Pigeonpea* (8:2)**												
T_4I_1: Finger millet	2293	2161	2227	7.64	7.20	7.42	181.2	165.8	173.5	41.7	40.8	41.2
T_4I_2: Finger millet	2163	2017	2090	7.21	6.72	6.97	165.0	151.4	158.2	39.2	37.7	38.5
't' test	S	S	S	S	S	S	S	S	S	S	S	S
T_4I_1: Pigeonpea	2834	2782	2808	1.57	1.55	1.56	44.8	43.9	44.4	47.0	45.1	46.0
T_4I_2: Pigeonpea	2593	2528	2560	1.44	1.40	1.42	40.8	39.6	40.2	44.3	42.3	43.3
't' test	S	S	S	S	S	S	S	S	S	S	S	S

Water productivity enhancement strategies

I_1: Sensor based micro irrigation during dry spell I_2: Control

Note : * Leaf area per plant; ** Leaf area per hill

* Leaf area, leaf area index and SPAD were taken at 90 DAS in finger millet, 60 DAS in field bean and french bean, 150 DAS in pigeon pea

TABLE 3

Grain or pod yield (kg ha^{-1}), stover or straw yield (kg ha^{-1}) and finger millet equivalent yield as influenced by water productivity enhancement strategies in different cropping systems under open field of reduced runoff farming

Treatments	2019-20					2020-21					Pooled				
	Grain yield (kg ha^{-1})			Straw yield (kg ha^{-1})		Grain yield (kg ha^{-1})			Straw yield (kg ha^{-1})		Grain yield (kg ha^{-1})			Straw yield (kg ha^{-1})	
	MC	IC	FMEY	MC	IC	MC	IC	FMEY	MC	IC	MC	IC	FMEY	MC	IC
T_1I_1: French bean	10623		10280	3808		9572		8973	4126		10097		9627	3967	
T_1I_2: French bean	8416		8144	3208		7808		7320	3553		8112		7732	3380	
T_2I_1: Finger millet	4502		4502	5221		3751		3751	5144		4126		4126	5182	
T_2I_2: Finger millet	3695		3695	4493		3114		3114	4465		3405		3405	4479	
T_3I_1: Pigeonpea + Field bean (1:1)	954	2826	5277	3896	3301	820	3690	5970	3147	4553	887	3258	5624	3521	3927
T_3I_2: Pigeonpea + Field bean (1:1)	803	2018	3976	3369	3129	612	2722	4416	2549	3718	707	2370	4196	2959	3423
T_4I_1: Finger millet + Pigeonpea (8:2)	4119	172	4413	4941	694	3416	161	3682	4553	596	3768	166	4048	4747	645
T_4I_2: Finger millet + Pigeonpea (8:2)	3277	126	3493	3129	623	2734	118	2929	3971	539	3005	122	3211	3550	581
T_5I_1: Pumelo	16252		2621			14606		2282			15429		2452		
T_5I_2: Pumelo	13732		2215			11691		1827			12712		2021		
T_6: Kitchen Garden	10491		8850			9473		8209			9982		8529		

Statistical analysis of FMEY (2019)

	T_1	T_2	T_3	T_4	T_5	Mean	T_6		T	I	T X I
I_1	10280	4502	5277	4413	2621	5419	8850	S.Em±	116.48	73.67	167.25
I_2	8144	3695	3976	3493	2215	4305		CD @ 5%	346.09	218.89	493.40

Statistical analysis of FMEY (2020)

T_1	T_2	T_3	T_4	T_5	Mean	T_6		T	I	T X I
I_1	8973	3751	5970	3682	2282	4932	8209	S.Em±	102.85	65.05	149.15
I_2	7320	3114	4416	2929	1827	3921		CD @ 5%	305.59	193.27	439.99

Statistical analysis of FMEY (Pooled)

T_1	T_2	T_3	T_4	T_5	Mean	T_6		T	I	T X I
I_1	9627	4126	5624	4048	2452	5175	8529	S.Em±	109.60	69.31	158.10
I_2	7732	3405	4196	3211	2021	4113		CD @ 5%	325.62	205.94	466.39

Note: MC : Main crop, IC: Inter crop, FMEY: Finger millet equivalent yield

TABLE 4

Economics as influenced by water productivity enhancement strategies in different cropping systems under open field of reduced runoff farming

Treatments	Gross return (Rs. ha^{-1})			Net return (Rs. ha^{-1})			B:C ratio		
	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled
T_1I_1: French bean sole	319437	287975	303706	261227	229886	245556	5.49	4.96	5.22
T_1I_2: French bean sole	253117	234936	244026	197547	179086	188317	4.55	4.21	4.38
T_2I_1: Finger millet sole	133878	127743	130810	105625	98880	102252	4.74	4.43	4.58
T_2I_2: Finger millet sole	110200	106350	108275	84187	79727	81957	4.24	3.99	4.12
T_3I_1: Pigeonpea + Field bean (1:1)	163598	191049	177323	128470	150881	139675	4.66	4.76	4.71
T_3I_2: Pigeonpea + Field bean (1:1)	123268	141315	132292	90380	103387	96883	3.75	3.73	3.74
T_4I_1: Finger millet + Pigeonpea (8:2)	136815	125558	131186	107076	95534	101305	4.60	4.18	4.39
$T_4I_,$: Finger millet +Pigeonpea (8:2)	108273	100495	104384	80774	72711	76742	3.94	3.62	3.78
T_5I_1: Pumelo	81260	73030	77145	51971	44021	47996	2.77	2.52	2.65
T_5I_2: Pumelo	68660	58455	63558	41891	31686	36788	2.56	2.18	2.37
T_6: Kitchen Garden	314727	284190	299459	215539	186008	200774	3.17	2.89	3.03

Water productivity enhancement strategies

I_1: Sensor based micro irrigation during dry spell I_2: Control

French bean pods – Rs. 30 kg^{-1} ; Pigeonpea- Rs. 5300 qt^{-1} ; Finger millet- Rs. 3100 qt^{-1} ; Field bean pods- Rs. 40 kg^{-1} Pumelo- Rs. 5 kg^{-1}

(3768 kg ha^{-1}) & pigeonpea (166 kg ha^{-1}) in finger millet+ pigeonpea (8:2) cropping system, pumelo fruit yield (15429 kg ha^{-1}) as compared to their respective control (8112, 3405, 707 & 2370, 3005 & 112 and 12712 kg ha^{-1} respectively) (Table 3).

The crops *viz.,* ladies finger, capsicum, tomato, french bean, brinjal, leafy vegetables, green chilli, knol khol, cluster bean, ridge guard, cabbage were grown using water harvested through runoff in farm ponds in kitchen garden, which is one of sustainable component of dryland ecosystem to meet house hold requirement of the farm family. Hence, it recorded a total of 9982 kg ha^{-1} yield from various crops grown during the study in kitchen garden. The results are in line with Bhandarkar and Reddy (2010), where they noticed twofold increase in yield of soybean, chickpea, rice and wheat with application of irrigation from farm pond. Samindre and More (2012), reported 100.64 per cent higher grain yield of safflowers with one protective irrigation as compared to no protective irrigation. Ramachandrappa *et al.* (2017) reported higher yield with protective irrigation from farm pond in field bean, aerobic rice and finger millet.

Similarly, application of one irrigation during dry spell also increased stover/straw yield in french bean (3967 kg ha^{-1}), finger millet (5182 kg ha^{-1}), pigeonpea (3521

kg ha^{-1}) & field bean (3927 kg ha^{-1}) in pigeonpea + field bean (1:1) cropping system and finger millet (4747 kg ha^{-1}) & pigeonpea (645 kg ha^{-1}) in finger millet+ pigeonpea (8:2) cropping system as compared to their respective control (3380, 4479, 2959 & 3423 and 645 & 581 kg ha^{-1}, respectively).

The grain yield and pod yield of different crops in different cropping systems are converted into finger millet equivalent yield to analyze and compare the productivity. Significantly higher finger millet equivalent yield was noticed with one sensor based micro irrigation during dry spell from farm pond water in french bean sole (9627 kg ha^{-1}), finger millet sole (4126 kg ha^{-1}), pigeonpea + field bean (1:1) cropping system (5624 kg ha^{-1}), finger millet+ pigeonpea (8:2) cropping system (4048 kg ha^{-1}) and pumelo (2452 kg ha^{-1}) as compared to their respective control (7732, 3405, 4196, 3211 and 2021, respectively) (Table 3). Finger millet equivalent of crops grown in kitchen garden was 8529 kg ha^{-1}. Among different cropping systems french bean with one protective irrigation has recorded higher finger millet equivalent yield (9627 kg ha^{-1}) as compared to other cropping systems.

Economics

French bean with one protective irrigation during dry spell recorded higher gross returns (Rs.303706 ha^{-1}), net returns (Rs.24556 ha^{-1}) and B:C ratio (5.22) as compared to finger millet sole (Rs.130810 ha^{-1}, Rs.102252 ha^{-1} and 4.58, respectively), pigeonpea + field bean (1:1) (Rs.177323 ha^{-1}, Rs.139675 ha^{-1} and 4.71, respectively), finger millet+ pigeonpea (8:2) (Rs.131186 ha^{-1}, Rs.101305 ha^{-1} and 4.39, respectively) and pumelo (Rs.77145 ha^{-1}, Rs.47996 ha^{-1} and 3.78, respectively) (Table 4 and Fig. 1). Among water productivity enhancement strategies irrespective of cropping systems, sensor based micro irrigation during dry spell has recorded higher gross returns, net returns and B:C ratio as compared to treatments without irrigation. Pandey *et al.* (2005) also recorded higher economics in rice with protective irrigation from lined reservoir under rainfed conditions. Anonymous (2018) also reported higher returns with supplemental irrigation with rain gun in cotton and sorghum.

It can be concluded from two years of experiment that application of sensor based micro irrigation during dry spell by using runoff water stored in the farm pond has resulted in higher yield in french bean (24.46 %), finger millet (21.17 %), pigeonpea (25.45 %) & field bean (37.4 %) in pigeonpea + field bean (1:1) cropping system, finger millet (25.39 %) & pigeonpea (36.06 %) in finger millet + pigeonpea (8:2) cropping system, pumelo fruit yield (21.37 %) as compared to treatments without irrigation during dry spells.

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Enhancing Small Holders Income through Income Diversification : An Evidence from Tamil Nadu

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Abstract

Agriculture is a dynamic source of income. More than one-third of economically active population depends on agriculture directly or indirectly for their livelihood. Tamil Nadu by tradition is an agricultural state which is inseparably reinforced by small and fragmented land holdings, having average size of holding about 0.80 hectares. Due to various reasons like changing climatic condition, rising input cost, unremunerative market prices, lack of labour, degrading natural resources and pest & diseases caused serious disaster in agriculture sector. Thereby, these factors have turned farming to be a non-viable proposition and often not profitable. Out of all the States in India, farmers in Tamil Nadu received an income below Rs.5,502 (GOI, 2016). Due to this, a greater number of farmers are moving out of farming which would cause serious crisis. Consequently, enhancing the livelihood status of farmers stands out to be fore most important factor. Hence, the research work was carried out with the main objective to examine the viability of small and marginal farmer's income. The non-farm and off-farm income sources have been found to contribute towards reduction in income inequality. Socio economic variables such as Education, Farming experience, Family size, credit and extension activity certainly influenced farmers to take up income diversification activity. Educating famers, enhancing their skill through various training programs, creating more productive assets are key to enhancement of farmer's participation in more income generating off-farm and non-farm activities.

Keywords: Income diversification, On-farm sector, Off-farm sector, Gini-coffecient, Logit model

Increase in production and productivity can in no way be a solution to farmers realizing low income. A number of studies from developing countries suggested that diversification of rural economy towards non-farm activities has considerable potential to augment farmers' income and reduce rural poverty (Chand *et al*., 2015; Singh, 2013 and Gecho, 2017). Income diversification is simply a process in which farming households create multiple income sources (Minot *et al.,* 2006; Chand, 2011 and Minithra, 2021). This paper evaluates the nature of income diversification, its effects and factors affecting income diversification.

Methodology

Study Area and Data Collection

Based on Human Development Index,(HDI), which is the composite measure of attainment in three core dimensions of well-being: education, health and income, from Tamil Nadu state human development report 2017, It is evident that the bottom two positions of Human Development Index is obtained by Ariyalur (0.282) and Perambalur districts (0.447) respectively (State Planning Commission, Chennai, 2017) and also from analysis of district wise estimates of sectoral income revealed that among the thirty one districts, the primary sector income contribution was the lowest in Perambalur district at Rs.30572.29 followed by Ariyalur district at Rs.47211.39 during 2010-11, where the role of agricultural sector is predominant (Department of Economics and Statistics, Chennai 2015-16).With such supporting evidence, Ariyalur district was selected for the study**.** The multi-stage sampling method was adopted in the selection of the district as universe, blocks as a stratum, village Panchayats as a primary unit and the number of sample respondents as an ultimate unit. Ariyalur district consists of six development blocks, of which two blocks were selected which consisted of more number of village Panchayats. Primary data was collected from

115 farm households in Ariyalur district through pre tested interview schedule.

Analytical Procedure

The extent of income diversification is measured by employing Herfindahl index. It is constructed as the sum of squares of the shares of different income portfolios in the household.

$HI = \sum_{i=1}^{N} Pi^2$; Herfindal Income Diversification Index HIDI = $1 - \sum_{i=1}^{N} Pi^2$

HI - Measure of concentration of diversification

Pi -The proportion of the i^{th} (=3 in this case) sources of income. The value of Herfindahl Income Diversification Index (HIDI) increases with the number of different income sources and approaches one if the number of income sources becomes very large (Minot, 2006)

For the purpose of determining HI, in the present study, different three specific income sources: On Farm Income-Income from crop cultivation and livestock income (dairy, sheet, goat and poultry). Off-Farm Income-Income from Agricultural labour, Rent from leased out land, Rent by hiring out bullock and machine labour. Non-Farm Income-Income from business, manufacturing teaching and others together were considered.

The determinants of households' participation in a particular income-generating source were identified using logit analysis. According to Gujarati (1995), the functional form of the logit model is presented as follows:

$$P_i = E(Y_i / X_i) = \frac{1}{1 + e^{-(\beta_0 + \beta_1 x_1)}} \text{----------(1)}$$

$$1 - Pi = \frac{1}{1 + e^{z_i}} \text{----------(2)}$$

Dividing equation (1) by equation (2) and simplifying gives

$$\frac{P_i}{1 - P_i} = \frac{1 + e^{zi}}{1 + e^{-zi}} = e^{zi} \text{----------(3)}$$

Equation (3) represents the odds ratio in favor of farmer participating in income diversification. The logit model is obtained by taking the natural logarithm of equation (4) as follows:

$$Li = \ln\left(\frac{Pi}{1 - Pi}\right) = \beta_0 + \beta_i X_i \text{--------(4)}$$

Where;

P_i = the probability that Y=1 (that farmer is participating in income diversification);

$1-P_i$ = the probability that Y=0 (that a farmer does not participate in income diversification);

L_i = the natural log of the odds ratio or logit;

β_i = the slope, measures the change in L (logit) for a unit change in explanatory variables;

β_0 = the intercept.

Thus, if the stochastic disturbance term (U_i) is taken into consideration the logit model becomes

$$L_i = \beta_0 + \beta_i X_i + U_i \text{----------(5)}$$

The empirical model used in the study was

$$FID = \beta_0 + \beta_1 AGE + \beta_2 EDU + \beta_3 EXP + \beta_4 FSIZE + \beta_5 LH + \beta_6 LSTOCK + \beta_7 CREDIT + \beta_8 EXTEN$$

Variable label	Description and measurement	Expected sign
FID	Farmers Income Diversification , Dependent variable	
AGEEDU	Educational level of the head of the household in years	+
EXP	Experience of the farmer in years	+
FSIZE	Number of member in the family as agricultural labour	+
LH	Land Holding, Farm size in hectares	+/-
LSTOCK	Livestock with famers(in numbers)	+
CREDIT	Credit Availability	+
EXTEN	Contact with the extension personnel, (dummy, 1 if contact with extension personnel; 0, otherwise)	+

RESULTS AND DISCUSSION

General Characteristics of Sample Farmers in Study Area

The general characteristics of the sample farm households were analyzed and presented in the Table.1.

TABLE 1

General characteristics of the farm households

Particulars	Marginal farmers	Small farmers
Number of farm households(numbers)	68	47
Number of workers in farm households (numbers)	3.91	4.23
Age of the farmer(years)	51.52	50.76
Educational status (years)	6.13	7.09
Farming Experience (years)	27.29	26.83
Assets position (Rs. Lakh/household)	16.32	21.66
Gross cropped area (hectares)	1.75	2.02

Source: Primary household survey (2018-2019)

In the study area, nearly 50 per cent of farms house holds had the average family size of 4-5 members,the age group of 36 to 55 years which implied that medium aged people were involved in agricultural activities and also indicated that sample farmers were educated only up to primary and secondary level of education. Majority of sample farmers had more than 25 years of farming experience.

Households' Sources of Income

Agricultural sector alone cannot be relied upon as the core activity by sample respondents as a means of improving their livelihood. Off farm and Non-farm activities is gaining prominence in off-setting the diverse forms of risks and uncertainties (relating to climate, finance, markets, etc.) associated with agriculture and create a way of smoothing income of farmers sustainably.The income details of farmers is presented in Table 2.

It is evident from Table 2 that the average annual income of marginal and small farmers varied from Rs.1.20 lakhs to 1.46 lakhs per annum across different

TABLE 2

Income details of the farmers

Particulars	Marginal farmers		Small farmers	
Farm income	52955.35	(43.86)	66388.00	(45.40)
Off-Farm Income	26435	(21.89)	35215.96	(24.08)
Non-Fram Income	41354.00	(34.25)	44617.02	(30.51)
Total	120744.40	(100.00)	146221.00	(100.00)

(year / household)

Source: Primary household survey (2018-2019)

categories of farmers. The contribution from crops was about 43.86 per cent and 45.40 per cent, off farm contributed about 21.89 per cent and 24.08 per cent; non-farm contributed 34.25 per cent to 30.51 per cent respectively this confirms that the crop production forms important income sources and assumes critical.

The distribution of farmers based on their different income sources is presented in the Table 3. It is evident from the Table 3, that in Ariyalur district 42.65 per cent of marginal farmers had access to only one source of income *i.e.,* they rely mainly on farm income (Crop Production and Livestock) alone followed by 35.29 per cent of marginal farms have access to two sources of income (farm and off-farm or farm and Non-Farm)

TABLE 3

Distribution of farmers based on their different income sources

Particulars	Marginal farmers		Small farmers	
One source				
On farm	29	(42.65)	16	(34.04)
Two source				
On farm + Off - farm	13		9	
On farm + Non - farm	11		10	
Sub total	24	(35.29)	19	(40.43)
Three source				
On farm + Off - farm + Non - farm	15	(22.06)	12	(25.53)
Total farmers	68	(100.00)	47	(100.00)
Average number of income sources	1.80		1.91	

Source: Primary household survey (2018-2019)

and 22.06 per cent of farmers have access to three sources of income. Correspondingly 34.04 per cent of small farmers in Ariyalur district had access only to one source of income followed by 40.43 per cent with access to two source of income and 25.53 per cent of farmers with three sources of income.

Diversification index for income sources of sample respondents is given in Table 4. Respondents with the most diversified income sources had the largest index and those with the least sources hadthe smallest index. For marginal farmers as well as small farmers share of farm incomes accounted for about 43.86 per cent to 45.40 per cent of the total income followed by non-farm share of 34.25 per cent to 30.51 and on the other hand off-farm share accounted for 21.89 per cent to 24.08 per cent in the study area.

TABLE 4

Diversification index for income sources of sample respondents

Particulars	Marginal farmers	Small farmers
On Farm	43.86	45.40
Off-farm income	21.89	24.08
Non-farm income	34.25	30.51
HI measure of concentration	0.35	0.36
Herfindal Income Diversification Index (HIDI) measure of diversification	0.65	0.64

The estimates of Herfindahl Income Diversification Index (HIDI)of rural households also confirmed the extent of income spread across various income sources

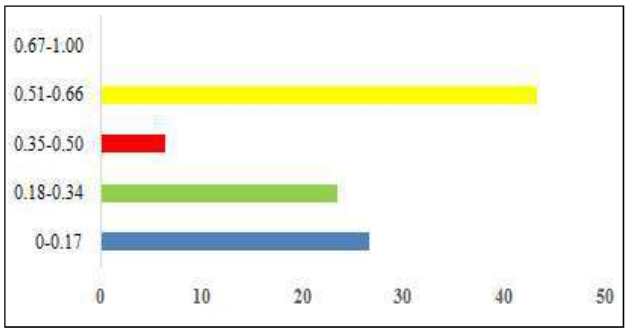

Fig. 1 : Income Diversification Range

among the different household categories. Marginal and small farmers had income diversification range of 0.65 to 0.64 which comes under medium diversification category. These results were similar with survey conducted by Saha and Bahal (2010) and Kumar and Umesh, (2020). By adopting income diversification as important strategy difference in income among sample farmers is shown in Table 5.

Marginal farmers in the Ariyalur district who rely upon On-farm source alone obtained an annual income of Rs.50955.35, farmers having access to two source of income *i.e.,* on farm plus off-farm earned Rs.89216.96 per annum which was Rs.38261.6 higher than the farmers obtaining income from on-farm alone. Similarly, farmers having access to two sources of income *i.e.,* On farm plus non-farm earned Rs.89207.65 per annum which was Rs.38252.30 higher than the income of the farmers with on-farm alone. Likewise, farmers having access to three source of income *i.e.,* on-farm plus off-farm plus Non-farm earned Rs.92887.13 per annum which was Rs.41931.80 higher than the income of the farmers with On-farm alone.

TABLE 5

Income difference among farmers adopting income diversification

(in Rs./annum)

Particulars	Marginal farmers	Difference	Small farmers	Difference
On farm	50955.35	0	66388.98	
On farm + Off-farm	89216.96	38261.6 **	112714.95	46326.0 *
On farm + Non-farm	89207.65	38252.3 *	114921.76	48532.8 **
On farm + Off-farm + Non-farm	92887.13	41931.8 *	115921.67	49532.7 **

Source: Primary household survey (2018); *,**,***- significant difference at 1%,5% and 10% based on t-test.

Small farmers in the Ariyalur district who rely upon On farm source alone obtained an annual income of Rs.66388.98, farmers having access to two sources of income *i.e.,* on farm plus off-farm earned Rs.112714.95 per annum which was Rs.46326 higher than the income of the farmers with on-farm alone. Similarly farmers having access to two sources of income *i.e.,* on farm plus Non-farm earned Rs.114921.76 per annum which was Rs.48532.80 higher than the income of the farmers with on farm alone, likewise farmers having access to three sources of income *i.e.,* on farm plus off-farm plus Non-farm earned Rs.115921.67 per annum which was Rs.49532.70 higher than the income of the farmers with on farm alone. From Table 5, we can articulate that off-farm and non-farm sectors can serve as budding entry points for farm households to enhance their income level.

Factors Affecting Income Diversification

The dependent variable in this study was participation of households in income diversification. Household income diversification is a dichotomous variable representing the status of household income diversification taking value of 1 if a household is diversified and 0 otherwise. Households who had generated their income from only agriculture were considered as non-diversified, while farmers who derived additional income from non-farm or off-farm activities were considered as participating in income diversification. It could be seen from Table 6 that the chi-square value was found to be highly significant (75.12) thereby indicating that the logit model was good fit for the observed data.

'Age' can be considered as a proxy for the working capacity of a person. The age of sample respondents had a negative affiliation with diversification, which intended that as heads of farm households progresses in age, the less they diversify their income sources. The odds ratio indicated that as the age of farmer's increases, the logs of odds ratio in favor of income diversification decreases by 0.83 in Ariyalur district. The coefficient obtained for education was positive and significant at one percent level of probability. The log odd ratio implies that each additional year of schooling increases income diversification by 1.25.

TABLE 6

Logit model estimates for factors affecting farmers' participation in income diversification

Source of income	Coefficients		S.E	Odds ratio
CONSTANT	6.79		4.36	
AGE	-0.175	***	0.08	0.839
EDU	0.225	***	0.08	1.252
EXP	0.09	NS	0.07	1.101
F.SIZE	0.633	*	0.261	1.88
LH	-0.944	***	0.35	0.389
LIVESTOCK	0.10	NS	0.59	1.110
CREDIT	2.41	***	0.83	11.08
EXTENSION	0.50	NS	0.81	1.662
MEAN	0.669			
STDEV	0.121			
Log-likelihood	-35.40			
Chi square	75.12	***		

Source : Primary household survey (2018-19)

The coefficient obtained for family size was found to be positively significant at ten per cent. By log odds ratio it is evident that each additional member in the family increases the probability of income diversification by 1.88. Land proved to be a perfect determinant of farm income. However, size of landholding had a negative impact on the household's participation in income diversification. Odds ratio indicated that as land holding size increases, income diversification decreases by 0.38. Furthermore, amount of credit received was positive and significant at one per cent level of probability. Having credit as the proxy of household financial capital,the odds ratio indicated in the model with regard to credit keeping others constant infers that when credit is available with farmers, income diversification increases with a factor of about 11.08. Participation in agricultural extension program was found to influence the level of income diversification positively but it is non-significant. The non-significance of the participation in agricultural extension program could be due to the fact that only small number of households participated in agricultural extension program.

Therefore the results from logit model estimation revealed that Age, Land holding and Livestock Possession negatively influenced the farmers to participate in income diversification whereas Education, Farm experience, Family size and Credit positively influenced the farmers to participate in income diversification.

Conclusions and Policy Implications

Empirically, income diversification in the study area was medium. Average number of income sources accessed by all marginal farmers was about 1.80 and all small farmers had an average of 1.91 numbers access to income sources. Age and Land holding negatively influenced the farmers to participate in income diversification whereas Education, Family size and credit availability positively influenced the farmers to participate in income diversification

Income diversification index indicated that farmers in the study area have medium income diversification and the result suggested the local government to take serious steps to create employment avenues for smallholders outside agriculture that provide credit, training and necessary inputs to rural households and also recommend for public investment in rural infrastructure, such as roads and bridges, telecommunications, education, energy and water. Education plays vital role in income diversification. Since low level of education prevails in the study area, steps should be taken to promote education through skill training which enhances the technical competence and risk-taking ability.

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Biological Management of Rice Sheath Blight caused by *Rhizoctonia solani* Kuhn. under *In-vivo* Condition

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Abstract

Sheath blight caused by *Rhizoctonia solani* is one of the most destructive diseases in rice contributing to significant yield loss. Bioagents and bio-fumigants and their combination were evaluated for their effect on disease severity of rice sheath blight during *kharif* and *rabi* seasons of 2017 under *in-vivo* conditions. During *kharif* 2017, foliar application of propiconazole 25 per cent EC @ 0.1 per cent at 30 days after transplanting (DAT) and 60 DAT was found to be most effective (3.70 and 92.6 %) followed by soil application of mustard leaf @ 5 g/100 g soil before transplanting and foliar application of *Pseudomonas fluorescens* @ 5 g/L at 30 DAT (6.48 and 87.04 %) and least effective treatment was foliar application of *Trichoderma viride* @ 5 g/L at 30 DAT (41.66 and 16.68 %) on the basis of mean disease severity and per cent reduction over control. The same trend was noticed during *rabi* 2017. The foliar application of propiconazole 25 per cent EC @ 0.1 per cent at 30 DAT and 60 DAT recorded the lowest per cent of chaffiness and highest per cent decrease over control (7.33 and 80.7 per cent) whereas, the highest per cent of chaffiness and lowest per cent decrease over control was observed in foliar application of *T. viride* @ 5 g/L at 30 DAT (34 and 10.5 per cent). The highest average grain yield per plant and average per cent increase over control was recorded in foliar application of propiconazole 25 per cent EC @ 0.1 per cent at 30 DAT and 60 DAT (13.4g and 94.2%).

Keywords : Bioagents, Bio-fumigants, Disease severity

Rice (*Oryza sativa* L.) is second most important cereal and the staple food for more than half of the world's population. Rice is the most prominent crop of India as it is the staple food for most of the people of the country. In India rice crop is being cultivated in an area of 43.19 m ha with production of 110.5 m tonnes and productivity of 2550 kg ha^{-1}. In Karnataka it occupies an area of 1.01 m ha, production of 2.54 m tonnes and productivity of 2522 kg ha^{-1} (Anonymous, 2017).

Rice is prone to many fungal, bacterial, viral and nematode diseases. Among all pathogenic organisms, fungal pathogens are limiting the rice productivity to great extent. Several out-break of diseases such as blast, sheath blight and bacterial blight have been reported from many rice growing areas of India. Worldwide the annual losses due to rice diseases is estimated to 10-15 per cent, depending upon the age of the plant, time of infection and severity, diseases caused yield loss to the extent of 5.9 to 69 per cent (Venkat Rao *et al.,* 1990 and Naidu, 1992).

Sheath blight is one of the major biotic constraints that affects rice production in India and is considered economically important disease of rice in the world (Lee and Rush 1983 and Webster & Gunnell, 1992). The disease is caused by *Rhizoctonia solani* Kuhn (teleomorph: *Thanatophorus cucumeris* (Frank) Donk). The Sheath blight is becoming most destructive, being second only to rice blast disease among the rice diseases constraining rice productivity (Ou, 1985). The disease is endemic to areas where temperature and relative humidity are high and cultivation is intensive. The pathogen is polyphagous competitive saprophyte and has a wide host range. Continuous rice cropping, high density and heavy canopy associated with high nitrogen management favours disease build up from tillering to panicle initiation (Biswas, 2001).

The incidence of rice sheath blight disease has increased in recent years, because of the unavailability of resistant cultivars or any other suitable economic disease management measures. The yield losses due to this disease is reported to range from 5.2 to 50 per

cent, depending on environmental conditions, crop stages at which the disease appears, cultivation practices and cultivars in India (Rajan, 1987; Sharma and Teng, 1996).

The management of sheath blight through fungicide application is the most common approach among the farmers. Because of the disadvantages of using the fungicides, it has become necessary to adopt eco-friendly approaches for enhancing crop yield and better crop health. The use of biological methods for the management of this disease is scarce. It is necessary to evaluate the biological methods including use of bioagents, bio fumigants, botanicals etc., to manage the disease effectively to avoid resistance development in pathogen and minimize the fungicidal residues for ecological sustainability. In view of the importance of the crop and seriousness of the sheath blight disease an investigation was undertaken under green house condition to evaluate bioagents and bio fumigants for its management.

Material and Methods

The investigations were conducted during 2017 in the Department of Plant Pathology, College of Agriculture, V.C. Farm, Mandya.

In-vivo Evaluation of Bioagents and Bio Fumigants Against Sheath Blight of Rice

The pot experiments were carried out for two seasons *kharif* and *rabi* 2017 with 13 treatments (Table 1). Three replications of each treatment were maintained including control. The inoculum of the pathogen was mixed in the soil @ 20 per cent of the soil weight. In case of T_7 to T_{10} the plant material was added one week after pathogen added to soil. Two weeks after treatment, 25 days old seedlings of variety Jyothi were transplanted in two hills per pot. The assessment of disease severity was made by following Standard Evaluation System (SES) scale (IRRI, 1996) on 45 and 75 DAT. Per cent chaffiness and yield was recorded at harvest and the yield was expressed per plant.

Table 1

Details of the treatment

T_1	Foliar application of *Trichoderma viride* (Tv) @ 5 g/L at 30 DAT
T_2	Foliar application of Tv @ 5 g/L at 30 DAT and 60 DAT
T_3	Foliar application of *Pseudomonas fluorescens* (Pf) @ 5 g/L at 30 DAT
T_4	Foliar application of Pf @ 5 g/L at 30 DAT and 60 DAT
T_5	Soil application of Pf (2 g) at the time of transplanting
T_6	Soil application of Pf (2 g) and foliar application of Pf (5 g/L) at 30 DAT
T_7	Soil application of mustard leaf @ 5 g/100 g soil before transplanting
T_8	Soil application of radish leaf @ 5 g/100 g soil before transplanting
T_9	Soil application of mustard leaf @ 5 g/100 g soil before transplanting and foliar application of Tv @ 5 g/L at 30 DAT
T_{10}	Soil application of mustard leaf @ 5 g/100 g soil before transplanting and foliar application of Pf @ 5 g/L at 30 DAT
T_{11}	Foliar application of propiconazole 25 % EC @ 0.1 % at 30 DAT
T_{12}	Foliar application of propiconazole 25 % EC @ 0.1 % at 30 DAT and 60 DAT
T_{13}	Untreated control

DAT = Days after transplanting

Statistical analysis

The data obtained in different experiments were statistically analysed by following Complete Randomized Design (CRD) as per the procedures suggested by Snedecor and Cochran (1967) and Panse and Sukhatme (1978). The data pertaining to percentage were transformed into arc sin transformation, as it is required before statistical analysis.

Results and Discussion

In-vivo Evaluation of Bioagents and Bio Fumigants Against Sheath Blight of Rice

The bioagents and the bio fumigants found to be most effective during *in-vitro* studies were validated for

their effect against sheath blight of rice by conducting pot studies. The experiments were carried during *kharif* and *rabi* 2017 with 13 treatments.

Effect of Different Treatments on Disease Severity

The bioagents and bio fumigants and their combination were evaluated for their effect on disease severity of rice sheath blight during *kharif* and *rabi* 2017. The effect of different treatments on disease severity is shown in Table 2 (Fig. 1) and Table 3 (Fig. 2)**.** On the basis of mean disease severity and per cent reduction over control, foliar application of propiconazole 25 EC @ 0.1 per cent at 30 DAT and 60 DAT (T_{12}) was most effective (3.70 and 92.6 per cent) followed by (T_{10}) soil application of mustard leaf @5 g/100 g soil before transplanting and foliar application of *P. fluorescens* @ 5 g/L at 30 DAT (6.48 and 87.04 %). The least effective treatment was (T_1) foliar application of *Trichoderma viride* (Tv) @ 5 g/L at 30 DAT (41.66 and 16.68 %) followed by (T_8) soil application of radish leaf @5 g/100 g soil before transplanting (38.89 and 22.22 %) whereas, in T_{13} (control) the mean disease severity was observed to be 50 per cent. The remaining treatments showed the mean disease severity ranging from 7.41 to 32.40 per cent and 35.20 to 85.18 per cent reduction over control. The same trend was also observed during *rabi* 2017 wherein treatment (T_{12}) foliar application of propiconazole 25 EC @ 0.1 per cent at 30 DAT and 60 DAT was the most effective with mean disease severity and percent reduction over control (4.17 and 90.31 %) followed by (T_{10}) soil application of mustard leaf @5 g/100 g soil before transplanting and foliar application of *P. fluorescens* @ 5 g/L at 30 DAT (5.56 and 87.08 %). Among the treatments, (T_1) foliar application of *Trichoderma*

TABLE 2

In-vivo evaluation of bioagents and bio fumigants on disease severity of rice sheath blight during *kharif* 2017

Treatments	Disease Severity (%)			
	45 DAT	75 DAT	Mean	% reduction over control
T_1	24.07 (29.15)	59.25 (50.61)	41.66 (40.15)	16.68
T_2	12.96 (21.01)	24.07 (29.15)	18.52 (25.32)	62.96
T_3	20.37 (26.78)	44.44 (41.75)	32.40 (34.61)	35.20
T_4	12.96 (21.01)	20.37 (26.78)	16.66 (24.04)	66.68
T_5	16.66 (24.09)	37.03 (37.44)	26.85 (31.18)	46.30
T_6	11.11 (19.47)	18.51 (25.43)	14.81 (22.61)	70.38
T_7	14.81 (22.55)	29.63 (32.88)	22.22 (28.03)	55.56
T_8	22.22 (28.12)	55.55 (48.24)	38.89 (38.54)	22.22
T_9	5.55 (13.62)	11.11 (19.06)	8.33 (16.62)	83.34
T_{10}	3.70 (9.08)	9.26 (17.52)	6.48 (14.68)	87.04
T_{11}	0.00 (0.00)	14.81 (22.55)	7.41 (15.73)	85.18
T_{12}	0.00 (0.00)	7.40 (15.57)	3.70 (10.94)	92.60
T_{13}	29.63 (32.88)	70.36 (57.30)	50.00 (44.98)	0.00
S. Em±	1.93	3.11	1.90	
C.D. (0.05)	5.63	9.06	5.54	
C.V.%	15.54	16.36	11.93	

DAT = Days After Transplanting; Figures in parenthesis are arcsine transformed values

TABLE 3

In-vivo evaluation of bioagents and bio fumigants on disease severity of rice sheath blight during *rabi* 2017

Treatments	Disease Severity (%)			
	45 DAT	75 DAT	Mean	% reduction over control
T1	25.92 (30.57)	48.14 (43.93)	38.88 (38.56)	9.69
T2	12.96 (21.01)	25.92 (30.50)	16.67 (24.09)	61.28
T3	20.37 (26.78)	40.74 (39.62)	29.16 (32.64)	32.26
T4	11.11 (19.47)	20.37 (26.78)	15.28 (22.99)	64.51
T5	18.51 (25.43)	37.03 (37.44)	29.16 (32.64)	32.26
T6	9.26 (17.52)	18.51 (25.43)	13.89 (21.81)	67.74
T7	14.81 (22.55)	33.33 (35.26)	25.00 (29.99)	41.93
T8	22.22 (28.12)	44.44 (41.80)	33.33 (35.26)	22.58
T9	3.70 (9.08)	14.81 (22.55)	9.72 (18.13)	77.42
T10	0.00 (0.00)	12.96 (21.01)	5.56 (13.63)	87.08
T11	1.85 (4.54)	16.66 (23.89)	6.94 (15.23)	83.88
T12	0.00 (0.00)	9.26 (17.52)	4.17 (11.66)	90.31
T13	31.48 (34.10)	53.70 (47.12)	43.05 (41.00)	0.00
S.Em±	2.11	1.76	0.94	
C.D. (0.05)	6.17	5.15	2.75	
C.V.%	18.25	9.42	6.05	

DAT = Days after After transplanting; Figures in parenthesis are arcsine transformed values

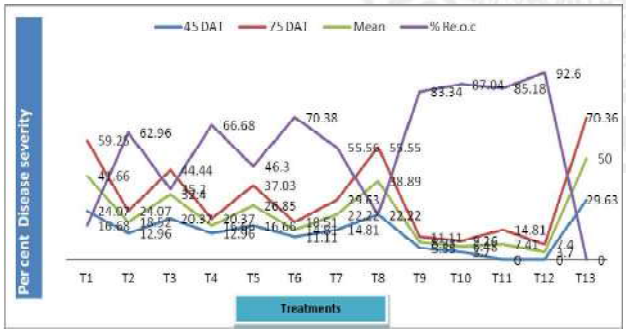

Fig. 1: *In-vivo* evaluation of bio agents and bio fumigants on disease severity of rice sheath blight during *kharif* 2017

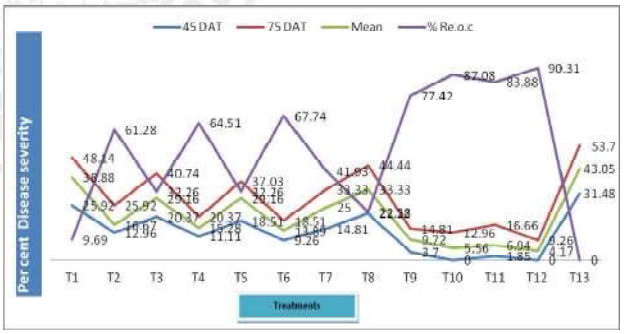

Fig. 2: In vivo evaluation of bio agents and bio fumigants on disease severity of rice sheath blight during *rabi* 2017

viride @ 5 g/L at 30 DAT was least effective with mean disease severity of 38.88 per cent and per cent reduction over control 9.69%.

Effect on Plant Height

The plant height was significantly influenced by the treatments during *kharif* and *rabi* 2017. The mean plant height in different treatments ranged from 52.8 cm to 81.3 cm (Table 4). The treatment foliar application of propiconazole 25 EC @ 0.1 per cent at 30 DAT and 60 DAT (T_{12}) had a significant effect on plant height which recorded highest mean plant height (81.3 cm) and mean percent increase over control (53.9 %) compared to other treatments. It was followed by

TABLE 4

In vivo effect of bioagents and bio-fumigants against sheath blight of rice / plant height

Treatments	*Kharif* 2017		*Rabi* 2017		Mean	
	Plant height (cm)	% increase over control	Plant height (cm)	% increase over control	Plant height (cm)	% increase over control
T_1	53.2	2.3	55.3	3.4	54.3	2.8
T_2	62.7	20.6	66.5	24.3	64.6	22.3
T_3	56.5	8.7	61.3	14.6	58.9	11.6
T_4	64.5	24.0	68.5	28.0	66.5	25.9
T_5	58.5	12.5	63.5	18.7	61.0	15.5
T_6	66.2	27.3	70.2	31.2	68.2	29.2
T_7	59.7	14.8	63.8	19.3	61.8	17.0
T_8	55.8	7.3	58.8	9.9	57.3	8.5
T_9	73.7	41.7	78.2	46.2	75.9	43.8
T_{10}	74.9	44.0	81.8	52.9	78.4	48.7
T_{11}	70.0	34.6	74.2	38.7	72.1	36.6
T_{12}	78.0	50.0	84.7	58.3	81.3	53.9
T_{13}	52.0	0.0	53.5	0.0	52.8	0.0
S.Em±	0.91		0.84		0.70	
C.D. (0.05)	2.66		2.47		2.04	
C.V.%	2.53		2.19		1.87	

(T_{10}) soil application of mustard leaf @ 5 g/100 g soil before transplanting and foliar application of *P. fluorescens* @ 5 g/L at 30 DAT (78.4 cm and 48.7 %), (T_9) soil application of mustard leaf @ 5 g/100 g soil before transplanting and foliar application of *T. viride* @ 5 g/L at 30 DAT (75.9 cm and 43.8 %) and (T_{11}) foliar application of propiconazole 25 EC @ 0.1 per cent at 30 DAT (72.1 and 36.6 %). (T_{10}) soil application of mustard leaf @ 5 g/100 g soil before transplanting and foliar application of *P. fluorescens* @ 5 g/L at 30 DAT was on par with (T_{12}) foliar application of propiconazole 25 per cent EC @ 0.1 per cent at 30 DAT and 60 DAT and the least mean plant height and mean per cent increase over control was observed in (T_1) foliar application of *T. viride* @ 5 g/L at 30 DAT (54.3 cm and 2.8 %) which was followed by (T_8) soil application of radish leaf @ 5 g/ 100 g soil before transplanting (57.3 cm and 8.5 %) and (T_3) foliar application of *P. fluorescens* @ 5 g/L at 30 DAT (58.9 cm and 11.6 %).

Effect on Grain Chaffiness

The per cent of grain chaffiness was significantly influenced by different treatments (Table 5). The mean chaffiness percentage observed in different treatments ranged from 7.33 to 38 per cent. The treatment foliar application of propiconazole 25 EC @ 0.1 per cent at 30 DAT and 60 DAT (T_{12}) was superior to all other treatment which recorded the lowest per cent of chaffiness and highest per cent decrease over control (7.33 and 80.7 %) followed by (T_{10}) soil application of mustard leaf @ 5 g/100 g soil before transplanting and foliar application of *P. fluorescens* @ 5 g/L at 30 DAT (10 and 73.7 %), (T_9) soil application of mustard leaf @ 5 g/100 g soil before transplanting and foliar application of *T. viride* @ 5 g/L at 30 DAT (11 and 71.1 %) and (T_{11}) foliar application of propiconazole 25 EC @ 0.1 per cent at 30 DAT (12.67 and 66.7 %). The highest per cent of chaffiness and lowest per cent decrease over control was observed in (T_1) foliar application of *T. viride* @ 5 g/L at 30 DAT (34 and

TABLE 5

In vivo effect of bioagents and bio-fumigants against sheath blight of rice/chaffiness

Treatments	*Kharif* 2017		*Rabi* 2017		Mean	
	Chaffiness (%)	% decrease over control	Chaffiness (%)	% decrease over control	Chaffiness (%)	% decrease over control
T1	35.67(36.65)	10.1	32.33 (34.65)	11.0	34.00 (35.66)	10.5
T2	24.00 (29.28)	39.5	24.67 (29.77)	32.1	24.33 (29.54)	36.0
T3	31.00 (33.82)	21.9	30.00 (33.20)	17.4	30.50 (33.51)	19.7
T4	21.67 (27.71)	45.4	20.00 (26.54)	44.9	20.83 (27.15)	45.2
T5	29.67 (32.99)	25.2	28.33 (32.13)	22.0	29.00 (32.58)	23.7
T6	19.67 (26.30)	50.4	19.00 (25.83)	47.7	19.33 (26.07)	49.1
T7	26.67 (31.08)	32.8	26.33 (30.86)	27.5	26.50 (30.97)	30.3
T8	34.33 (35.86)	13.5	32.00 (34.44)	11.9	33.17 (35.15)	12.7
T9	10.33 (18.66)	74.0	11.67 (19.90)	67.9	11.00 (19.34)	71.1
T10	9.00 (17.44)	77.3	11.00 (19.27)	69.2	10.00 (18.39)	73.7
T11	12.33 (20.49)	68.9	13.00 (21.01)	64.2	12.67 (20.82)	66.7
T12	7.00 (15.31)	82.4	7.67 (16.02)	78.9	7.33 (15.71)	80.7
T13	39.67 (39.02)	0.0	36.33 (37.04)	0.0	38.00 (38.05)	0.0
S.Em±	0.91		1.08		0.60	
C.D. (0.05)	2.65		3.14		1.74	
C.V.%	5.42		6.51		3.58	

Figures in parenthesis are aresine transformed values

10.5 %), which was followed by (T_8) soil application of radish leaf @ 5 g/100 g soil before transplanting (33.17 and 12.7 %) and (T_3) foliar application of *P. fluorescens* @ 5 g/L at 30 DAT (30.5 and 19.7%).

Effect on Grain Yield Per Plant

The grain yield per plant was significantly influenced by the treatments and the data is presented in the Table 6. The highest mean grain yield per plant and average per cent increase over control was recorded in (T_{12}) foliar application of propiconazole 25 EC @ 0.1 per cent at 30 DAT and 60 DAT (13.4 g and 94.2 %), followed by (T_{10}) soil application of mustard leaf @ 5 g/100 g soil before transplanting and foliar application of *P. fluorescens* @ 5 g/L at 30 DAT (11.7 g and 69.6 %), (T_9) soil application of mustard leaf @5 g/100 g soil before transplanting and foliar application of *T. viride* @ 5 g/L at 30 DAT (11.2 g and 62.3 %) and (T_{11}) foliar application of propiconazole 25 EC @ 0.1 per cent at 30 DAT (10.6 g and 53.6 %). The lowest mean grain yield per plant and average per cent increase over control among the treatments other than T_{13} (control) was observed in (T_1) foliar application of *T. viride* @ 5 g/L at 30 DAT (7.5 g and 8.7 %) which was followed by (T_8) soil application of radish leaf @ 5 g/100 g soil before transplanting (8.1 g and 17.4 %) and (T_3) foliar application of *P. fluorescens* @ 5 g/L at 30 DAT (8.7 g and 26.1 %).

The present study showed significant result in the treatment foliar application of propiconazole 25 EC @ 0.1 per cent at 30 DAT and 60 DAT (T_{12}) followed by soil application of mustard leaf @ 5 g/100 g soil (T_{10}) before transplanting and foliar application of *P. fluorescens* @ 5 g/L at 30 DAT with significant reduction in disease severity and increase in yield. It was in accordance with the results of Das and Hazarika (2000). The seeds treated with *T. viride* and

TABLE 6

In-vivo effect of bioagents and bio-fumigants against sheath blight of rice/grain yield

Treatments	Yield / plant (g)					
	Kharif 2017		*Rabi* 2017		Mean	
	Grain yield (g)	% increase over control	Grain yield (g)	% increase over control	Grain yield (g)	% increase over control
T_1	7.2	5.9	7.9	12.9	7.5	8.7
T_2	9.7	42.6	9.5	35.7	9.6	39.1
T_3	8.7	27.9	8.6	22.9	8.7	26.1
T_4	9.9	45.6	9.6	37.1	9.8	42.0
T_5	9.0	32.4	9.2	31.4	9.1	31.9
T_6	10.2	50.0	10.0	42.9	10.1	46.4
T_7	9.7	42.6	9.4	34.3	9.6	39.1
T_8	7.9	16.2	8.3	18.6	8.1	17.4
T_9	11.2	64.7	11.1	58.6	11.2	62.3
T_{10}	11.9	75.0	11.6	65.7	11.7	69.6
T_{11}	10.6	55.9	10.5	50.0	10.6	53.6
T_{12}	13.6	100.0	13.2	88.6	13.4	94.2
T_{13}	6.8	0.0	7.0	0.0	6.9	0.0
S.Em±	0.25		0.22		0.19	
C.D. (0.05)	0.72		0.65		0.54	
C.V.%	4.48		4.09		3.36	

T. harzianum showed significant reduction in the sheath infection and reduction in yield. Khan and Sinha (2007) used cultured filtrate of *T. harzianum* and *T. virens* and found that *T. harzianum* was most effective showing 38.8 and 24.6 per cent reduction in disease severity with highest grain yield per plant (21%). Ashraf *et al*. (2011) observed that *T. harzianum* (rice leaf sheath isolate) was best in managing sheath blight compared to some commercial formulations of bioagents with 48 per cent reduction in disease severity. Higher rates of *T. harzianum* (4 or 8 g/l) was found highly effective in reducing disease severity (70 %) and increasing grain yield (27.3 %) over control. Under pot culture conditions, the combined application of *P. fluorescens* as seed treatment @ 10 ml/kg of seeds + seedling root dip @ 3 l/ha significantly reduced the incidence of sheath blight in rice and increased the plant growth and yield of rice to maximum.

Manibhusam Rao and Baby (1991) studied the effect of organic manures (glyricidia and neem cake) alone and combined with *T. longibrachiatum* and *Gliocladium virens* against *R. solani* causing rice sheath blight and found the combined treatments to be more effective in suppressing the disease. The current study also revealed that the combined treatment of bio-fumigant plant and bioagent was more effective than the individual treatments and on par with the fungicide treatment in decreasing the disease severity and increasing the yield over control.

Currently, there is no resistance rice cultivars against sheath blight disease, which warrants the use of chemical fungicides for the management of the disease. Development of alternative eco-friendly strategies like identifying suitable strain of bio agent and employing them and using bio fumigants needs to be explored and adopted for sustainable management of the

disease. Hence, the combination of chemical fungicides, plant products and bio control agents identified in the present study can be used for the integrated management of rice sheath blight disease.

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Effect of Organic Manures and Bio-Fertilizers on Plant Growth and Yield of Dragon Fruit (*Hylocereus undatus* (Haworth) Britton & Rose.) and (*Hylocereus polyrhizus* (F.A.C. *Weber*) under Eastern Dry Zone of Karnataka

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ABSTRACT

A study was conducted in the farmer's field at Suradhenupura, Doddaballapur taluk, which is located 20 kms away from University of Agricultural Sciences, Gandhi Krishi Vignana Kendra, Bengaluru during the year 2019-2021 to investigate the 'Effect of organic manures and bio- fertilizers on plant growth and yield of dragon fruit (*Hylocereus undatus* (Haworth) Britton & Rose.) and (*Hylocereus polyrhizus* (F.A.C. *Weber*) under Eastern Dry Zone of Karnataka'. The experiment was planned by adopting randomized complete block design (RCBD) consisting of 13 treatments with three replications. Each pillar consisted of four plants. Maximum plant height of 385.83 cm and 395.67 cm, number of branches per plant of 7.74 and 7.83, circumference of main stem of 14.98 cm and 15.10 cm, number of new sprouts of 6.50 and 6.52, plant spread from North to South of 174.15 cm and 180.59 cm, plant spread from East to West of 167.33 cm and 172.90 cm, stem diameter of 19.55 cm and 19.74 cm and height of new shoot of 65.45 cm and 68.21 cm, maximum yield of 4.5 kg plant^{-1} and 18.33 kg pillar^{-1} and 6 kg plant^{-1} and 24 kg pillar^{-1} was obtained in both white and pink fleshed dragon fruit, respectively. Among different treatments, T_{-13} comprising of 100 per cent N through vermicompost + PSB @ 10 kg ha^{-1} along with VAM @ 10 kg ha^{-1} showed superiority in growth and yield of white fleshed and pink fleshed dragon fruits.

Keywords : Dragon fruit, FYM, Vermicompost, Poultry manure, Bio-fertilizers, *Hylocereus*

DRAGON FRUIT (*Hylocereus* spp.) also known as pitaya is the newly introduced super fruit in India. It is a fast growing perennial vine cactus belongs to Cactaceae family originated from Mexico and South America. Dragon fruit has spread to Tropical and Subtropical America, Asia, Australia and Middle East. Recently, Dragon fruit is being cultivated as fruit crop in 22 tropical countries, such as Australia, Cambodia, China, Columbia, Ecuador, Guatemala, Hawaii, Indonesia, Israel, Japan, Laos, Malaysia, Mexico, New Zealand, Nicaragua, Peru, Philippines, Spain, Sri Lanka, Taiwan, Thailand, South Western USA and Vietnam (Barbeu, 1990, Wu and Chen, 1997).

The fresh fruit contains 83.00 to 88.00 per cent moisture, 0.16 to 0.23 g protein, 0.21 to 0.61g fats and 0.70 to 0.90 per cent fibre. Every 100 g of fresh fruit pulp contains 6.30 to 8.8 mg of calcium, 30.20 to 36.10 mg of phosphorous, 0.50 to 0.65 mg of iron, 8.00 to 9.00 mg of vitamin-C and the pink-fleshed fruit contain a pigment called betacyanin containing up to 150 to 200 mg per 100 g of fruit (Tripathi *et al.*, 2016).

It is gaining more popularity among the growers within short period of time because of its attractive fruit color and melting pulp embedded with edible black seeds and has medicinal properties indicating that playing role in management of asthma, cough, cholesterol, high blood pressure, relieves stomach disorders, good for heart health, helps in preventing cancer, prevents congenital glaucoma, boosts immune power, reduces arthritis pain, good for pregnant women, prevents renal bone disease, good for bone health, repairs body cells, helps in improving appetite, good for eye health, boosts brain health, flowers are used in Aromatherapy (Nurliyana *et al*., 2010, Liaotrakoon *et al*., 2013, Tao *et al.*, 2014 and Choo & Yong., 2011).

Dragon fruits have recently been traded in the international market, and it has become Vietnam's most

popular export crop, fetching attractive price. Over all dragon fruit is promisingly a new crop in India and it has great potential for its cultivation in Arid and semiarid tracts, but the availability of manurial requirement especially through organic sources for its cultivation is a major constraint in this crop. Available reports indicate that, the crop has to be fertilized frequently in early phase of growth. The recommended fertilizer application of nutrients in Bangladesh is 135 g N, 78 g P_2O_5, 63 g K_2O g plan T^1 $year^{-1}$ along with 5 kg decomposed cowdung in four equal instalments (Chakma *et al*., 2014)

Since dragon fruit can be grown organically without the use of pesticides or inorganic fertilizers, it has market appeal as a safe organic fruit. Cattle or poultry manure, as well as well-decomposed compost, may be used as organic manures. Because of the good international demand for organically grown fruits, instead of producing by using chemical fertilisers, several countries are now using organic manures. Majority of European countries prefer organically grown dragon fruit, providing Indian opportunity to export organically produced dragon fruit.

The availability of scientific information on use of organic forms of nutrition for dragon fruit cultivation is very scarce, as it is new crop introduced across the world for cultivation. However the bio-fertilizers and organic manures, including crop residues may improve the soil productivity. Farm yard manures is proven source of nutrients in orchard but its availability is quite inadequate (Singh *et al*., 2011).

Hence, there is a need to understand the importance of organic manures on this crop. Therefore, the current study was undertaken to determine the effect of organic manures and bio-fertilizers on plant growth and yield of dragon fruit.

Material and Methods

During the year 2019-2021, a field study on 'Effect of organic manures and bio-fertilizers on plant growth and yield of dragon fruit under eastern dry zone of Karnataka'. The experiment was conducted in the farmer's field at Suradhenupura, Doddaballapur taluk, located 20 kms away from UAS, GKVK, Bengaluru. The experimental site is situated at 13^0 20' E latitude and 77^0 56' E longitude at an elevation of 908 m above MSL, consisting of red sandy loam with uniform fertility having soil pH range of 6.23 to 6.26. The mean maximum and minimum temperatures during the period of experimentation were 36.50 C and 20.80 ^{0}C, respectively and mean maximum and minimum relative humidity were 79 and 45 per cent, respectively. The major rainfall was received from South-West monsoon between June and September and from North-Eastern monsoon between October and December.

The experiment was laid out in a Randomized Complete Block Design (RCBD) with 13 treatments and three replications consisting of organic manures and bio-fertilizers for both white fleshed and pink fleshed dragon fruit *viz*., T_1- Control (no manure), T_2-100 per cent N through FYM, T_3-100 per cent N through FYM + PSB @ 10 kg ha^{-1}, T_4-100 per cent N through FYM + VAM @ 10 kg ha^{-1}, T_5-100 per cent N through FYM + PSB @ 10 kg ha^{-1} + VAM @ 10 kg ha^{-1}, T_6-100 per cent N through poultry manure, T_7-100 per cent N through poultry manure + PSB @ 10 kg ha^{-1}, T_8- 100 per cent N through poultry manure + VAM @ 10 kg ha^{-1}, T_9-100 per cent N through poultry manure + PSB @ 10 kg ha^{-1} + VAM @ 10 kg ha^{-1}, T_{10}-100 per cent N through vermicompost, T_{11}- 100 per cent N through vermicompost + PSB @ 10 kg ha^{-1}, T_{12}- 100 per cent N through vermicompost + VAM @ 10 kg ha^{-1}, T_{13}- 100 per cent N through vermicompost + PSB @ 10 kg ha^{-1} + VAM @ 10 kg ha^{-1}.

The treatments were imposed to dragon fruit plants with split dose of organic manures at four installments, first imposition was done after one month of pruning, second imposition was done after one month of first treatment imposition, third imposition was done before one month of flowering and the last imposition was done before fruiting of dragon fruit plants. Other cultural operations were attended to keep the plots clean and plant protection measures were carried out for effective management of pest and diseases during the period.

Results and Discussion

Plant Height (cm)

Plant height of dragon fruit, influenced by different treatments consisting of organic manures and bio-fertilizers was recorded and the values for plant height were significantly higher in treatment T_{13} (385.83 cm and 395.67 cm), however it was on par with T_{12} (382.40 cm and 388.03 cm), T_{11} (375.83 cm and 383.43 cm) and T_{10} (375.47 cm and 377.27 cm).

The treatment T_1 recorded significantly lower value (248.53 cm and 280.27 cm) at 120 days after treatment imposition for white fleshed and pink fleshed dragon fruit respectively (Fig. 1). This might be due to the fact that application of vermicompost resulted in release of various nutrients and also growth stimulating substances excreted by earthworms. Thus, increase in growth could be attributed to fixing of the atmospheric nitrogen by nitrogen fixing bacteria, solubilization and mobilization of nutrients by PSB and VAM by Ghosh *et al*. (2014) in orange.

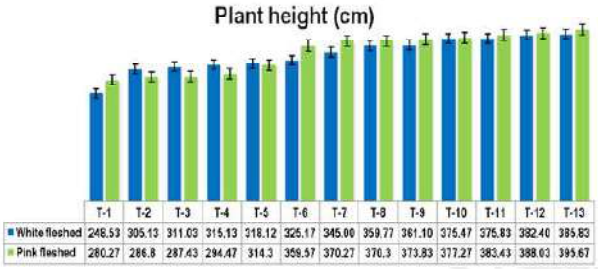

Fig. 1: Effect of organic manures and bio-fertilizers on plant height of white and pink fleshed dragon fruit at120 days after treatment imposition

Number of Branches per Plant

There were significant differences observed with respect to number of branches in white and pink fleshed dragon fruit. At the stage of final harvest, treatment T_{13} recorded significantly higher number of branches (7.74 and 7.83) per plant, followed by T_{12} (7.24 and 7.64), T_{11} (6.68 and 7.42) and T_{10} (6.17 and 7.04), while the lowest value was recorded in T_1 (2.98 and 3.17) at harvest in white and pink fleshed pitaya respectively (Fig. 2). This might be due to the fact that the presence of vermicompost around root zone of plants throughout the period of growth, which is a source of humus, PSB and VAM act as N-fixers and making nutrients available to plants, this might have resulted in the higher values with respect to number of branches per plant. These results are in conformity with the results of Ghosh *et al*. (2014) in orange.

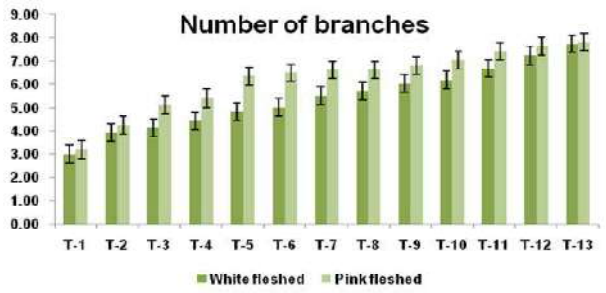

Fig. 2: Effect of organic manures and bio-fertilizers on number of branches per plant in white and pink fleshed dragon fruit at harvest

Circumference of Main Stem (cm)

The data on circumference of main stem of white fleshed and pink fleshed dragon fruit influenced by different treatments consisting of organic manures and bio-fertilizers was found significantly higher in T_{13} (14.98 cm and 15.10 cm) followed by T_{12} (14.51 cm and 14.88 cm), T_{11} (14.03 cm and 13.66 cm) and T_{10} (13.44 cm and 12.84 cm), while it was recorded significantly lower values in treatment T_1 (9.65 cm and 9.40 cm), respectively, at harvest (Fig. 3).

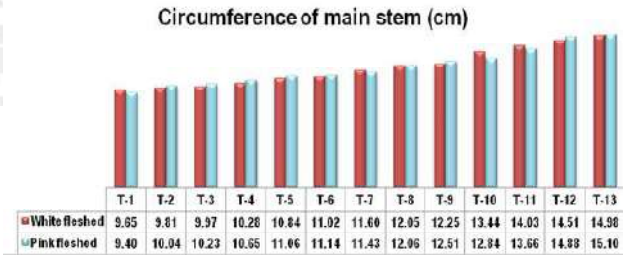

Fig. 3: Effect of organic manures and bio-fertilizers on circumference of main stem in white and pink fleshed dragon fruit at harvest

It might be attributed due to the increased biological nitrogen fixation, better organic nitrogen utilization, better development of root system and the possible synthesis of plant growth regulators like IAA, GA and cytokinins with the combined application of bio-fertilizers and organic manures which was also observed by Ghosh *et al*. (2014) in orange.

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Number of New Sprouts

In white and pink fleshed pitaya, the data pertaining to highest number of new sprouts was found significantly higher in T-$_{13}$ (6.50 and 6.52) followed by T-$_{12}$ (6.22 and 6.31), T-$_{11}$ (6.03 and 6.10) and T-$_{10}$ (5.96 and 6.01), while the significant lowest value was recorded in T-$_{1}$ (3.06 and 3.18), respectively, at harvest (Fig. 4). This might be due to the increased nutrient availability from the organic source of manure and increased availability of atmospheric nitrogen might have influenced to increase various endogenous hormonal levels in the plant tissues. These results are in conformity with the observations made by Ghosh *et al*. (2014) in orange.

Fig. 4: Effect of organic manures and bio-fertilizers on number of new sprouts in white and pink fleshed dragon fruit at harvest

Plant Spread : North to South (cm)

The results showed significant differences in case of plant spread from north-south direction at harvest as influenced by different treatments. The highest plant spread was recorded in treatment T-$_{13}$ (174.15 cm and 180.59 cm) followed by T-$_{12}$ (163.20 cm and 166.52 cm), T-$_{11}$ (156.11 cm and 153.47 cm) and T-$_{10}$ (141.18 cm and 143.51 cm). The lowest plant spread from north-south direction was recorded in treatment T-$_{1}$ (62.74 cm and 69.00 cm) in white and pink fleshed dragon fruit, respectively (Fig. 5 and Fig. 6). This might be due to the fact that FYM enhances the release and uptake of nitrogen. This nitrogen helps in the synthesis of tryptophan which is a precursor for the biosynthesis of auxins which hastened the metabolic activities in the plants resulting in stimulation and increased plant spread. These results are in conformity with the findings of Rani *et al*. (2013) in Litchi.

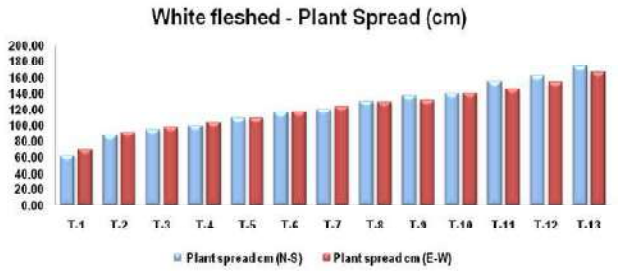

Fig. 5: Effect of organic manures and bio-fertilizers on plant spread (north to south) (east to west) in white fleshed dragon fruit at harvest

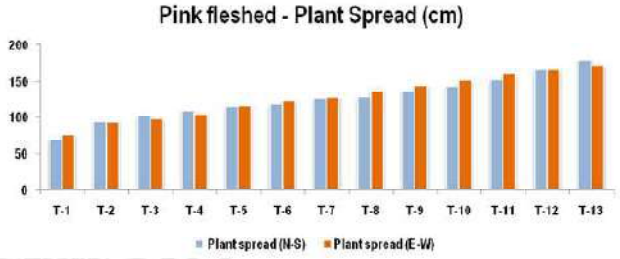

Fig. 6: Effect of organic manures and bio-fertilizers on plant spread (north to south) (east to west) in pink fleshed dragon fruit at harvest

Plant Spread: East to West (cm)

The results revealed that highest plant spread from east to west was found maximum in treatment T-$_{13}$ (167.33 cm and 172.90 cm), followed by T-$_{12}$ (155.13 cm and 167.13 cm), T-$_{11}$ (146.83 cm and 161.00 cm) and T-$_{10}$ (141.43 cm and 152.43 cm). The lowest plant spread from east to west direction was recorded in treatment T-$_{1}$ (70.41 cm and 5.60 cm) in white fleshed and pink fleshed dragon fruit, respectively (Fig. 5 and Fig. 6). According to Khehra and Bal (2014) increase in plant spread might be due to supply of nutrients with increased activity of soil microorganisms. Since nitrogen is an important constituent of nucleoprotein, amino acids and amino-sugars, hence increase in plant spread as a result of nitrogen availability.

Stem Diameter (cm)

The data on stem diameter was found significantly higher in the treatment T-$_{13}$ (19.55 cm and 19.74 cm) and was on par with T-$_{12}$ (19.51 cm and 19.67 cm), T-$_{11}$ (19.40 cm and 19.52 cm) and T-$_{10}$ (19.25 cm and 19.40 cm), while the lowest significant value was recorded in treatment T-$_{1}$ (17.93 cm and 17.96 cm) in

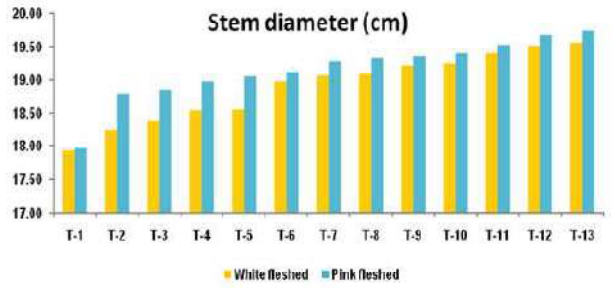

Fig. 7: Effect of organic manures and bio-fertilizers on stem diameter in white and pink fleshed dragon fruit at harvest

white fleshed and pink fleshed pitaya, respectively (Fig. 7). The increase in stem diameter could be attributed to the stimulatory activity of microflora in the rhizosphere leading to increased nutrient availability and hence vigorous plant growth and diameter of stem. These results are in agreement with the findings of Ghosh *et al*. (2014) in orange.

Height of New Shoot (cm)

The height of new shoot significantly differed among the treatments and was recorded highest shoot height in treatment $T-_{13}$ (65.45 cm and 68.21 cm) followed by $T-_{12}$ (57.29 cm and 66.33 cm), $T-_{11}$ (51.81 cm and 62.16 cm) and $T-_{10}$ (47.40 cm and 56.33 cm). The least shoot height was recorded in treatment $T-_{1}$ (22.12 cm and 25.07 cm), respectively in white and pink fleshed dragon fruits (Fig. 8). The results are in conformity with Choudhary (2016) that PSB and VAM altered various enzymatic activities in plants such as peroxidase, catalase etc., which promotes cell elongation, root and shoot growth and carbohydrate metabolism in Ber.

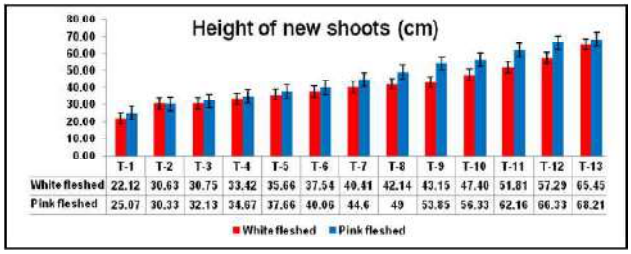

Fig. 8: Effect of organic manures and bio-fertilizers on height of new shoot in white and pink fleshed dragon fruit at harvest

Yield parameters

The results revealed that there was a significant difference among the treatments. The maximum number of fruits per plant and per pillar was observed in $T-_{13}$ (20.83 and 83) and lowest number of fruits per plant and per pillar were observed in $T-_{1}$ (5 and 20), respectively for white fleshed dragon fruit (Table 1). Similarly, maximum number of fruits per plant and per pillar was observed in $T-_{13}$ (25 and 100) and lowest number of fruits per plant and per pillar were observed in $T-_{1}$ (7 and 28), respectively for pink fleshed dragon fruit (Table 1).

The highest fruit yield per plant and fruit yield per pillar was observed in treatment $T-_{13}$ (4.50 and 18.33 kg, respectively). On the other hand, the lowest fruit yield per plant and fruit yield per pillar was found in $T-_{1}$ Control (1.17 and 6.33 kg) for the white fleshed dragon fruit (Table 1). Whereas, pink fleshed dragon fruit also showed significant differences where the highest fruit yield per plant and fruit yield per pillar was observed in treatment T_{13} (6.00 and 24.00 kg, respectively). On the other hand, the lowest fruit yield per plant and fruit yield per pillar was found in $T-_{1}$ Control (2.08 and 8.33 kg) (Table 1).

The most beneficial effect of these treatments might be due to plant growth promoters and improvement in the physical, chemical and biological properties of the soil and it also stimulated soil micro-biological activities, which improved the growth of the plants. These results are in conformity with the findings of Muthu and Ponnuswami (2013) in Noni, Dwivedi (2013) in Guava, Vanilarasu *et al*. (2014) and Selvamani (2014) in Banana.

On the basis of results obtained, in the present investigation it is concluded that 100 per cent N applied through vermicompost + PSB @ 10 kg ha^{-1} + VAM @ 10 kg ha^{-1} was proved significant for improving combination when compared to other treatments with respect to obtaining maximum plant growth (plant height, number of branches per plant, circumference of main stem, number of new sprouts, plant spread, stem diameter and height of new shoots) and yield for both white and pink fleshed dragon fruits. Therefore, data of present study indicated that combined application of organic manures and bio-fertilizer proved to enhance better growth of dragon fruit plants.

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TABLE 1

Effect of organic manures and bio-fertilizers on yield and yield attributes of white and pink fleshed dragon fruit

Treatments	White fleshed dragon fruit				Pink fleshed dragon fruit			
	No. of fruits per plant	No. of fruits per pillar	Yield per plant (kg)	Yield per pillar (kg)	No. of fruits per plant	No. of fruits per pillar	Yield per plant (kg)	Yield per pillar (kg)
T_1	5.0	20	1.17	6.33	7.0	28	2.08	8.33
T_2	10	40	2.50	10.00	10	36	2.62	10.50
T_3	10	40	2.50	10.33	12	48	3.00	12.00
T_4	12	48	3.00	12.00	12	48	3.08	12.33
T_5	12	48	3.00	12.33	12	48	3.17	12.67
T_6	12	48	3.00	12.67	14	56	3.50	14.00
T_7	14	56	3.50	14.00	14	56	3.50	14.00
T_8	14	56	3.50	14.00	14	56	3.58	14.33
T_9	14	56	3.50	14.33	16	64	4.08	16.33
T_{10}	14	56	3.50	14.67	16	64	4.42	17.67
T_{11}	16	64	4.00	16.00	21	84	5.25	21.00
T_{12}	16	64	4.00	16.80	22	88	5.50	22.00
T_{13}	20.83	83	4.50	18.33	25	100	6.00	24.00
Mean	13.06	52.23	3.21	13.22	14.92	59.69	3.83	15.32
F- test	*	*	*	*	*	*	*	*
S. Em±	0.02	0.16	0.05	0.22	0.16	0.16	0.07	0.29
C.D @ 5 %	0.07	0.47	0.13	0.64	0.47	0.47	0.21	0.84
C.V	0.31	0.53	2.50	2.85	1.86	0.46	3.31	3.27

Note : T_1-Control; T_2-100 per cent N through FYM; T_3-100 per cent N through FYM + PSB @ 10 kg ha^{-1}; T_4-100 per cent N through FYM + VAM @ 10 kg ha^{-1}; T_5-100 per cent N through FYM + PSB @ 10 kg ha^{-1}+ VAM @ 10 kg ha^{-1}; T_6-100 per cent N through poultry manure; T_7-100 per cent N through poultry manure + PSB @ 10 kg ha^{-1}; T_8-100 per cent N through poultry manure + VAM @ 10 kg ha^{-1}; T_9-100 per cent N through poultry manure + PSB @ 10 kg ha^{-1} + VAM @ 10 kg ha^{-1}; T_{10}-100 per cent N through vermicompost; T_{11}-100 per cent N through vermicompost + PSB @ 10 kg ha^{-1}; T_{12}-100 per cent N through vermicompost + VAM @ 10 kg ha^{-1}; T_{13}-100 per cent N through vermicompost + PSB @ 10 kg ha^{-1} + VAM @ 10 kg ha^{-1}

Economics

Dragon fruits are sold in the market at Rs.250-300 per kg, but the price at which the farmer is selling the fruits is approximately Rs.160 per kg. Pink fleshed fruits are preferred more in the market than the white fleshed fruits.

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Studies on Methane and Nitrous Oxide Emission from Zero Budget Natural Farming Organic and Conventional Farming in Direct Seeded Aerobic Rice

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Abstract

Rice (*Oryza sativa* L.) is the staple food of more than three billion people is generally cultivated in most part of the country. Its production is facing major challenges including scarcity of irrigation water and ongoing climate change. Cultivation of direct seeded rice with zero budget natural farming (ZBNF) could maintain yield, save water and mitigate greenhouse gas emission. The present study was conducted to compare the methane and nitrous oxide emission and CO_2 equivalent emission in zero budget natural farming, organic farming and conventional farming (Farmer's practice and UAS-B package of practice) in aerobic direct seeded rice variety MAS 26. The results showed that cumulative CH_4 emission found higher in two conventional farming practices *i.e.,* UAS-B package of practices (0.5755 kg ha^{-1}) and farmer's practice (0.5053 kg ha^{-1}), average emission was observed in organic farming (0.4311 kg ha^{-1}) and ZBNF (0.4165 kg ha^{-1}). However, high flux in cumulative N_2O emission was observed in organic farming (0.1230 kg ha^{-1}), average amount of flux is observed in farmer's practice (0.0828 kg ha^{-1}), ZBNF (0.0676 kg ha^{-1}) and UAS-B package of practices (0.0597 kg ha^{-1}). The CO_2 equivalent emission found to be high in organic farming (44.6595 kg CO_2-eq ha^{-1}), average in farmers practice (36.0888 kg CO_2-eq ha^{-1}), UAS-B package of practices (31.9274 kg CO_2-equi.ha^{-1}) and ZBNF (29.5657 kg CO_2-equi.ha^{-1}). This study showed that the ZBNF is effective in reducing CH_4, N_2O and CO_2-equivalent emission than other practices.

Keywords: Zero budget natural farming, CO_2 equivalent, Methane, Nitrous oxide

Global climate change is caused by increasing atmospheric concentrations of greenhouse gases (GHGs) such as carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) etc. As rapidly climate change is affecting food security and other social issues, mitigation strategies for anthropogenic GHG emissions are required worldwide (IPCC, 2014). Methane (CH_4) and Nitrous oxide (N_2O) are significant long-lived greenhouse gases and they together contribute about 20 per cent of the annual increase in radiative forcing (Smith *et al.,* 2007).

Globally, anthropogenic sources of N_2O and CH_4 are dominated by agriculture and further agricultural CH_4 and N_2O emissions have increased by nearly 17 per cent from 1990 to 2005 (Forster *et al.,* 2007). Agricultural N_2O emissions are projected to increase by 35-60 per cent up to 2030 due to increased chemical and manure N inputs (FAO, 2003).

Agriculture in its prevailing form requires farmers to rely heavily on inorganic external inputs such as fertilizers and pesticides. These contaminate ground water and other water-dependent ecosystems that reduce soil fertility over time and contribute to biodiversity loss in farm lands (Aktar *et al.,* 2009). Prevailing agricultural practices such as mono-cropping decrease soil moisture content causing tremendous stress on water resources. Agriculture today accounts for almost 70 per cent of the world's fresh water consumption (Clay, 2004). The use of external inputs by adoption of uniform, hybridized and genetically modified crop varieties erodes genetic diversity of seeds and reduces their capacity to adapt to changing climatic conditions (Jarvis *et al.,* 2010). These practices coupled with wide spread farm land degradation to make agriculture a major contributor to global greenhouse gas (GHG) emissions and climate change.

Alternative low-input farming practices have emerged in pockets across the world promising reduced input costs and higher yields for farmers chemical-free food for consumers and improved soil fertility. Zero Budget Natural Farming (ZBNF) is one such low-input climate-resilient type of farming that encourages farmers to use low-cost locally-sourced inputs, eliminating the use of artificial fertilizers and industrial pesticides (Tripathi *et al.,* 2018).

Rice (*Oryza sativa* L.) the staple food of more than three billion people, is generally cultivated under flooded conditions demanding up to one-third of the World's fresh water resources (Bouman *et al.,* 2007). Rice paddies are considered as one of the most important sources of CH_4 and N_2O emissions, which have attracted considerable attention due to their contribution to global warming (Harris *et al.,* 1985). In India, paddy rice cultivation occupies about 44 million hactare the largest rice producing area in Asia, and accounts for 20 per cent of the total rice production worldwide. India would need to produce up to 130 million tons of milled rice by 2030 to meet the growing demands in contrast with 92 million tonnes in 2005 (Gujja and Thiyagarajan, 2009). Water requirement in aerobic rice systems (with aerobic rice cultivars) were 30-50 per cent less than in flooded systems and the yields were almost 15-20 per cent higher than puddled rice (Prabhudeva and Nagaraju, 2017). Aerobic rice cultivation is a method in which rice is grown in well-drained, non-puddled and non-saturated soils. Under appropriate management practices, the yield obtained under aerobic condition is on par with transplanted puddled rice with an average of 8 to 10 t ha^{-1} (Sylvestre *et al.,* 2018).

Hence, the present study was conducted in aerobic direct seeded Rice to compare the emission of Methane (CH_4) and Nitrous oxide (N_2O) in zero budget natural farming, organic and conventional farming practices with the main objective to estimate the emission of CH_4 and N_2O in ZBNF, organic and conventional farming.

Material and Methods

Study Area

Field experimentwas carried out from October 2020 to March 2021 in the Research Institute on Organic Farming (RIOF), GKVK, Bengaluru, Karnataka, South India. The experiment was laid out in Randomized complete block designwith five replication. The Treatments involved is five farming systems for the direct seeded rice crop *viz.,* T_1: Farmer's practice, T_2: Organic farming, T_3: ZBNF, T_4: Package of practices recommended by UAS-B, T_5: Absolute control.

Particulars	Crop
Name of the Research Station	RIOF, GKVK, Bengaluru
Name of the Crop	Direct seeded rice
Gross plot size	7.2×28=201.6 sq m
Net plot size	6×24=144 sq m
Treatments	5
Replications	5
Design	RCBD
Variety	MAS 26

T_1- Farmers practice (FP): Treatment is based on operations carried out by the farmers in their field, FYM applied at 5 t ha^{-1}, 125 kg ha^{-1} of DAP and two hand weeding.

T_2- Organic farming (OF): Seed treatment with Rhizobium, FYM applied based on N equivalent (25 kg N ha^{-1}), weeding at 30 DAS, straw mulching (4 t ha^{-1}) and need based plant protection using organic materials.

T_3- Zero Budget Natural Farming (ZBNF) : Ghanajeevamrutha application at 1000 kg ha^{-1}, seed treatment with beejamrutha, application of jeevamrutha at 15 days interval at 5000 litres ha^{-1} and straw mulching (4 t ha^{-1}). Need based plant protection measures using preparation like Neemastra, Agniastra, Shuntiastra etc.

T_4- Package of practices recommended by UAS-B (UAS-B PoP): Seed treatment with Rhizobium, FYM

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application at 7.5 t ha^{-1} and NPK (25:50:25 kg ha^{-1}), spraying pre-emergent herbicide (pendimethalin 30 % E.C @1000 ml ha^{-1}) one hand weeding at 30 DAS.

T_5- Absolute control (AC): Only sowing of seeds all other input practices are Nil.

Gas Sample Collection, Analysis and Calculation

The samples were collected using closed chamber method for determination of CH_4 and N_2O concentrations. To avoid the diurnal variation gas samples from the field were collected in definite time span in day throughout the cropping season preferably during morning 9-11 AM and 3-5 PM (Bhatia *et al.,* 2013). Sampling frequency was done once in every 30 days. The gas samples fromall the plots were collected four times during the rice-growing period. Inside the chamber, an electric fan was installed to circulate the air. Gas samples were drawn from the chambers through a three-way stopcock using an airtight 50-mL syringe at 0, 10 and 20 minute after closure. The air inside the chamber was thoroughly mixed by flushing the syringe five times before collection of the gas samples. The gas sample were then transferred to 20-mL vacuum glass vials with rubber stoppers and kept cool and dark until analysis. The concentrations of CH_4 and N_2O were analyzed using a gas chromatograph (PerkinElmer, Arnel Engineered solutions Clarus 590 GC) equipped with a flame ionization detector (FID) and an electron capture detector (ECD), respectively. The CH_4 and N_2O fluxes were calculated by examining the linear increases in CH_4 and N_2O concentrations in the head space of the chambers over time. The total seasonal CH_4 and N_2O emissions from all plots were calculated directly from the fluxes

Calculation of Flux

The flux of methane and nitrous oxide is calculated using the following equations.

Cross-sectional area of the chamber (m^2) = A

Head space (m) = H

Volume of head space (L) = 1000 x AH

CH_4 concentration at 0 time (iL L^{-1}) = C_o

CH_4 concentration after time t (iL L^{-1}) = C_t

Change in concentration in time t (iL L^{-1}) = (C_t -C_o)

Volume of CH_4 evolved in time t (iL) = (C_t -C_o) x 1000 AH

When t is in hours, then flux (mL m^{-2} h^{-1}) = [(C_t-C_o) x AH)/(A x t)

Now 22.4 mL of CH_4 is 16 mg at STP

Hence, CH_4 flux = [(C_t - C_o)/t] x H x 16/22.4 x 10000 x 24 mg ha^{-1} d^{-1}

N_2O flux = [(C_t - C_o)/t] x H x 44/22.4 x 10000 x 24 mg ha^{-1} d^{-1}

CO_2 Equivalent Emission

The equivalent CO_2 (CO_2-equi.) emission for total CH_4 and N_2O emissions were calculated using the equation:

$$CO_2\text{-eq} = (TCH_4 \times 28) + (TN_2O \times 265)$$

Where CO_2-equi. is the total amount of equivalent CO_2 emission (kg CO_2-eq ha^{-1}), TCH_4 is the total amount of CH_4 emission (kg ha^{-1}), TN_2O is the total amount of N_2O emission (kg ha^{-1}), 28 and 265 are the CO_2 Equivalent Emission for CH_4 and N_2O, respectively, to CO_2over a 100-yr time horizon (IPCC, 2014).

Statistical Analysis

The effects of the treatment factors (cropping systems) on CH_4 and N_2O emissions from the direct seeded rice were examined. The experimental data were analyzed by analysis of variance (ANOVA) MS excel 2010.

Results and Discussion

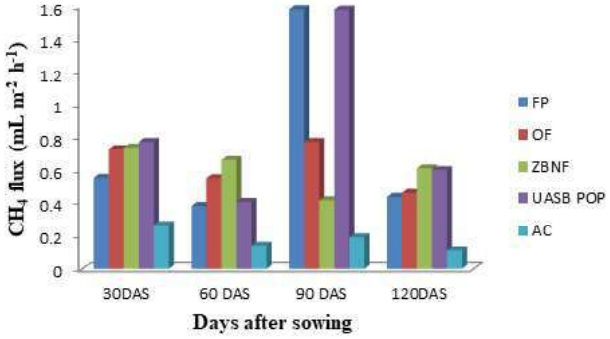
Methods of cropping systems *i.e.,* ZBNF, organic farming and conventional farming in aerobic direct seed rice cultivation recorded significant amount of Methane and Nitrous oxide emission throughout the crop growth stages. During crop growth stages from 30, 60, 90 and 120 DAS, observation were recorded and analyzed under five cropping systems.

Methane fluxes found highest at 90 DAS in UAS-B package of practice and Farmers practice. Fluxes found average at 30 DAS, 60 DAS and 120 DAS.

Plate 1: Collection of methane and nitrous oxide gases placed in the research plots using closed chamber technique and estimation of gases by using GCMS instrument

At 30 DAS, UAS-B Package of Practice (0.1325 kg ha^{-1} d^{-1}) recorded highest flux followed by ZBNF (0.1265 kg ha^{-1} d^{-1}) and organic farming (0.1250 kg ha^{-1} d^{-1}). At 60 DAS highest emission found in ZBNF (0.1139 kg ha^{-1} d^{-1}) followed by organic farming (0.0951 kg ha^{-1} d^{-1}). At 90 DAS fluxes dramatically increased in farmers practice (0.2705 kg ha^{-1} d^{-1}) and UAS-B package of practice (0.2703 kg ha^{-1} d^{-1}), fluxes found high in organic farming (0.1325 kg ha^{-1} d^{-1}). At 120 DAS averaged flux was observed in ZBNF and UAS-B Package of Practice (Table 1 & Fig. 1).

In paddy soils, CH_4 is produced by the process of methanogenesis, where organic matter undergoes decomposition in the absence of oxygen. In the rice-growing season, maximum CH_4 produced in the soil is released by diffusive transport via the aerenchyma system instead of diffusion (Xie and Li, 2002).



FP: Farmers practice; OF: Organic farming; ZBNF: Zero Budget Natural Farming; UASB POP: Package of practices recommended by UASB; AC: Absolute control.

Fig. 1: Average rate of Methane flux (mL m^{-2} h^{-1})

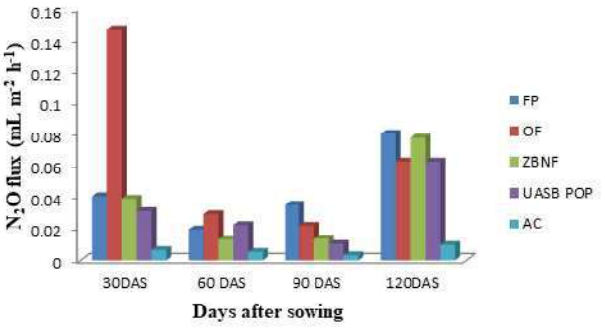
N_2O flux dramatically found highest in organic farming ((0.0693 kg ha^{-1} d^{-1}) at 30 DAS other fluxes averaged in entire crop season. At 60 DAS highest flux found in organic farming (0.0139 kg ha^{-1} d^{-1}) followed by UAS-B package of practice (0.0105 kg ha^{-1} d^{-1}). At 90 DAS highest fluxes was observed in Farmers practice (0.0166 kg ha^{-1} d^{-1}) followed by organic farming (0.0103 kg ha^{-1} d^{-1}). At 120 DAS Farmers practice (0.0378 kg ha^{-1} d^{-1}) was observed high flux followed by ZBNF (0.0366 kg ha^{-1} d^{-1}) and UAS-B package of practice (0.0295 kg ha^{-1} d^{-1}) (Table 2 & Fig. 2).

TABLE 1

Average rate of methane flux (Kg ha^{-1} d^{-1})

	30 DAS	60 DAS	90 DAS	120 DAS
FP	0.0954 ± 0.0551	0.0650 ± 0.0323	0.2705 ± 0.1282	0.0744 ± 0.0526
OF	0.1250 ± 0.0602	0.0951 ± 0.0119	0.1325 ± 0.0799	0.0786 ± 0.0337
ZBNF	0.1265 ± 0.0303	0.1139 ± 0.0289	0.0709 ± 0.0397	0.1052 ± 0.0422
UASB POP	0.1325 ± 0.0540	0.0691 ± 0.0295	0.2703 ± 0.0871	0.1035 ± 0.0405
AC	0.0453 ± 0.0296	0.0240 ± 0.0190	0.0327 ± 0.0213	0.0194 ± 0.0090
CV (%)	34.7372	31.5616	54.9401	55.8835
CD (p=0.05)	0.0489	0.0311	0.1144	0.0571
SEm±	0.0163	0.0104	0.0382	0.0190

FP: Farmers practice; OF: Organic farming; ZBNF: Zero Budget Natural Farming; UAS-B POP: Package of practices recommended by UAS-B; AC: Absolute control.



FP: Farmers practice; of: Organic farming; ZBNF: Zero Budget Natural Farming; UAS-B POP: Package of practices recommended by UASB; AC: Absolute control.

Fig. 2: Average rate of Nitrous oxide flux (mL m^{-2} h^{-1})

N_2O is produced by the microbial transformation of Nitrogen (N) in soils. This transformation of N to N_2O has been related to two biological processes, *i.e.,* the loss of N as N_2O during the nitrification of NH_4^+ under aerobic conditions and the reduction of NO_3^+ to N_2 during denitrification process. Nitrogen fertilization level and water management are the main factors regulating N_2O emission in the paddy soil (Ali *et al.,* 2019). During rice-growing season, N_2O is produced due to alternate wetting / drying period in the underground saturated soil layer as well as rice-winter upland crop rotation and could move upwards with water evaporation and contribute to atmospheric N_2O. Under flooding condition, significant N_2O emission takes place predominately through the rice plants, where rice plants act as a conduit for dissolved gases from the root zone to the atmosphere (Yan *et al.,* 2000). N_2O is a water-soluble molecule and hence can be up taken byplant roots and transported to leaves via the transpiration stream.

The cumulative methane flux was found significantly highest in UAS-B Package of Practice (0.5755 kg ha^{-1}) and farmers practice (0.5053 kg ha^{-1}) followed by organic farming (0.4311 kg ha^{-1}) and ZBNF (0.4165 kg ha^{-1}). The cumulative nitrous oxide flux was found significantly high in organic farming (0.1230 kg ha^{-1}) followed by farmers practice (0.0828 kg ha^{-1}) ZBNF (0.0676 kg ha^{-1}) and UAS-B package of practice (0.0597 kg ha^{-1}). CO_2-equivalent emission was found greater in organic farming than UAS-B package of practice, farmers practice and ZBNF. ZBNF has shown less global warming potential than other three cropping systems (Table 3).

In comparison with ZBNF, organic farming and conventional farming, CH_4 emissions were significantly increased in conventional farming due to application of FYM and irrigation of rice field offered the predominant source of methanogenic substrates and thus promoted CH_4 production over the rice-growing season. N_2O is produced primarily during soil nitrification and denitrification processes, which is highly dependent on aerobic condition in rice which produce more with influence of application of FYM, manures and fertilizers.

TABLE 2

Average rate of nitrous oxide flux(Kg ha^{-1} d^{-1})

	30 DAS	60 DAS	90 DAS	120 DAS
FP	0.0192 ± 0.0217	0.0091 ± 0.0065	0.0166 ± 0.0097	0.0378 ± 0.0242
OF	0.0693 ± 0.0574	0.0139 ± 0.0183	0.0103 ± 0.0084	0.0294 ± 0.0200
ZBNF	0.0185 ± 0.0099	0.0062 ± 0.0025	0.0063 ± 0.0031	0.0366 ± 0.0558
UAS-B POP	0.0148 ± 0.0076	0.0105 ± 0.0037	0.0048 ± 0.0035	0.0295 ± 0.0561
AC	0.030 ± 0.0015	0.0025 ± 0.0013	0.0015 ± 0.0010	0.0124 ± 0.0063
CV (%)	111.2151	106.3394	77.8888	135.3195
CD (p=0.05)	0.0372	0.0120	0.0083	0.0500
SEm±	0.0124	0.0040	0.0028	0.0167

FP: Farmers practice; OF: Organic farming; ZBNF: Zero Budget Natural Farming; UAS-B POP: Package of practices recommended by UAS-B; AC: Absolute control.

TABLE 3

Cumulative CH_4 and N_2O emissions, its calculated CO_2-equivalent emission

	Cumulative CH_4 (Kg ha^{-1})	Cumulative N_2O (Kg ha^{-1})	CO_2-equi.
FP	0.5053 ± 0.2681	0.0828 ± 0.0621	36.0888
OF	0.4311 ± 0.1857	0.1230 ± 0.1041	44.6596
ZBNF	0.4165 ± 0.1412	0.0676 ± 0.0712	29.5657
UAS-B POP	0.5755 ± 0.2111	0.0597 ± 0.0709	31.9274
AC	0.1213 ± 0.0789	0.0115 ± 0.0101	4.6112

FP: Farmers practice; OF: Organic farming; ZBNF: Zero Budget Natural Farming; UASB POP: Package of practices recommended by UASB; AC: Absolute control.

The IPCC CO_2-equivalent factors (mass basis, kg CO_2-equivalent ha^{-1}) for CH_4 and N_2O are 28 and 265 in the time horizon of 100 years, respectively (IPCC, 2014)

In rice paddy, $CH_4$is produced by the Methanogenic archaea and a portion of it is oxidized by the methanotrophic bacteria, whereas the activity of microbial nitrification and denitrification together contribute about 70 per cent of N_2O emission however, denitrification is more often associated with N_2O production (Braker and Conrad, 2011).

Several explanations may be given for the higher CH_4 emissions. First, decomposition of organic matter in rice paddies offered the predominant source of methanogenic substrates, and thus promoted CH_4 production over the rice-growing season. Second, manure application may change soil microbial communities and their activities (Zheng *et al.,* 2007). The DGGE analysis showed that microbial communities, including methanogenic archaea, can change depending on the rice growth and decomposition of organic materials and this explained the difference in CH_4 emissions (Watanabe *et al.,* 2010).

Compared with continuous flooding, midseason drainage and moist irrigation significantly decreased the net GWPs inorganic and conventional rice paddies. In addition, differences in the net GWPs of CH_4 and N_2O emissions between organic and conventional rice paddies depended on irrigation regime. Under continuous flooding CH_4 and N_2O emissions from organic rice paddies were significantly greater and thereby estimated GWP was greater in organic rice paddies than in conventional rice paddies. For rice paddies with midseason drainage CH_4 emissions were significantly higher while N_2O emissions were significantly (Xiong *et al.,* 2010).

Zero budget natural farming practice reduced the CH_4 emissions compared to organic and conventional farming practices under aerobic direct seeded rice. Since the contribution from N_2O emission is higher in organic farming resulted higher CO_2-equivalent emission. The ZBNF is an effective way to mitigate total greenhouse gas emissions from aerobic rice fields. The results suggested that the ZBNF is effective in reducing CO_2-eq emissions. In the context of global warming, the ZBNF is promising way to mitigating greenhouse gas emissions.

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Role of Selected Hormones and Humic Acid on Growth, Fruit Set and Productivity in Mung Bean

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MUNGBEAN being a major pulse crop of India, has been showing lower productivity due to various reasons. Among these, floral abscission due to the inbuilt physiological limitations and competitions assimilates between initial and late formed flowers which is a severe constraint. So, a study was conducted to know the influence of hormone and humic acid spray at flower bud initiation stage to overcome this problem. NAA, GA_3, BA, Brassinosteroids, their combinations and humic acid were applied as foliar spray to mungbean genotypes- two high yielding (C6-11-4, C3-11-6), two low yielding (VC3960-88, EC693363) and a check variety KKM 3 under pot culture and field experiments. It was found that genotypes differed significantly with yield attributing traits. C6-11-4 showed highest flower number, fruiting efficiency and seed yield/plant. Among the different treatments, GA_3 20 ppm followed by Brassinosteroids 0.1 ppm showed reduced flower drop, improved fruiting efficiency, pod number and seed yield/plant. The interaction effect between genotypes and foliar treatments varied significantly. Thus, supplementing phytohormones as foliar spray may boost legume yields. Further attempt was made to understand the influence of manipulating source-sink ratio on fruiting efficiency. Significantly more fruiting efficiency was noted in middle nodes from N3- N7 and low in earlier and late formed nodes. Pod and flower removal showed compensatory mechanism by producing more flowers and pods. When sink capacity was restricted to three pods/plant, it improved grain filling in pods. So, by regulating assimilate partition between source and sink, fruiting efficiency was increased by limiting the competition within growing pods.

Evaluation of Tomato and its Wild Relative Genotypes for Phosphorus Acquisition and Use Efficiency

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TOMATO belonging to family Solanaceae is cultivated across the world. It requires NPK in quite high quantity for growth and development. Phosphorus (P) being important macronutrient is involved in photosynthesis, respiration, energy generation and nucleic acid biosynthesis. Availability of P is one of the major constraints limiting productivity, due to its fixation and binding with other elements in the soil. Plants have adapted through modifications in root morphology, increased organic acids exudation and acid phosphatase activity to utilize bound P. Identification of genotypes having higher P acquisition and use efficiency is highly desirable under P limiting conditions. Hence, twenty-one tomato genotypes and its wild relatives were evaluated under P sufficient and deficient conditions. Based on phosphorus acquisition efficiency (PAE) ten contrasting genotypes were selected for further study and were grown in quartz sand supplemented with modified Hoagland solution to supply two levels of P. The root length, root volume, root P content, root-shoot ratio and activity of acid phosphatase were higher under low P supply and use efficiency was higher in high P supply. The genotypes, Arka Samrat, PKM 1, *Solanum arcanum, Solanum galapagense, Solanum pimpinellifolium* and *Solanum peruvianum* with better root characteristics, plant height, total plant P content were superior. They also had higher photosynthetic rate, stomatal conductance, transpiration rate, PSII yield and chlorophyll content. Thus, exhibited better performance under low P supply condition with higher P use efficiency.

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Physiological and Biochemical Evaluation of Rice Genotypes for Cold Tolerance

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AN experiment was conducted using 30 rice genotypes comprised of test genotypes as well as cold tolerant check varieties (CTH 1 and CTH 3) in 2019-20, to study cold tolerance based on physiological and biochemical parameters like germination percentage, changes in coleoptiles length, seedling length, proline content, electrolyte leakage, relative leaf chlorophyll content etc. at Department of Crop physiology, CoA, V.C. Farm, Mandya of UAS, Bangalore. Under laboratory condition with four temperatures *viz*., 28 °C (control), 10 °C, 12 °C and 15 °C (cold) revealed that among the genotypes used for the study, Thanu, Daksha, KRH 4, NLR 3042, BPT × BR 6, GVT 501, GVT 4, Jyoti, Raksha, KMP 149 and IR 64 found superior for physiological parameters like germination percentage, seedling length, changes in coleoptiles length etc. further the promising rice varieties found in laboratory screening were evaluated in the field for cold tolerance, conducted during late *kharif*, (2019-20) in V.C. Farm, Mandya under three different dates of sowing. The genotypes had shown different responses in three dates of sowing. The genotypes Thanu, Daksha, Raksha, BPT × BR 6, KRH 4, Jyoti, GVT 501, KMP 128 and KMP 200 were found to be better for cold tolerance in the laboratory as well as in field condition for yield grain, panicle exertion, spikelet sterility, relative chlorophyll content, proline content, electrolyte leakage etc. The new genotypes used in the study performed better than the tolerant check varieties CTH 1 and CTH 3 in terms of yield, physiological and biochemical parameters, they can be used for further studies like QTL and Marker assisted selection for further crop improvement in breeding programme.

Metabolite Diversity Studies in Ovaries of Monoembryonic and Polyembryonic Mango (*Mangifera indica* L.) Varieties

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MANGO varieties can be classified as monoembryonic or polyembryonic. To exploit the role of metabolites in the ovaries for polyembryony formation, the present study was conducted. In this regard, the metabolite diversity was assessed in ovaries of monoembryonic and polyembryonic mango varieties at various stages and also attempted to identify the stages of segment formation in the ovary of polyembryonic varieties. The study on segment formation was carried out in polyembryonic varieties Vellaikolumban and Olour at different stages of ovary development *i.e.,* before anthesis, one day after anthesis, 1st, 2nd and 3rd week after anthesis. Clear segments were observed in one month old fruits. No segments were visible before that. Therefore, the segment formation may occur in between 3rd week to 4th week after anthesis. Profiling of metabolites was done in two monoembryonic and two polyembryonic varieties at different stages of development of ovary *i.e.,* before anthesis, one day after anthesis, 1st, 2nd and 3rd week after anthesis. All the polyamines, amino acids and sugars were more in monoembryonic varieties indicating that these metabolites may not be responsible for the formation of multiple embryos. The phytohormones such as SA, IAA, IBA, GA7, GA4 and zeatin were found to be high in polyembryonic mango varieties except ABA and ACC. ABA and ACC were high in monoembryonic mango varieties. The metabolite analysis of ovaries in polyembryonic varieties indicated that the formation of multiple embryos in mango may be more closely related to the higher concentration of IAA, IBA and SA.

Search for Actinobacteria for Plant Growth Promotion and Yield in Cowpea (*Vigna unguiculata* L.) and Finger Millet (*Eleusine coracana* L.)

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A study was conducted to isolate, screen of actinobacterial isolates for the growth promotional, biocontrol efficiency and evaluation of efficient isolates on growth and yield of cowpea and ragi under greenhouse conditions. Forty actinobacterial isolates were isolated. Biochemical characterization of actinobacterial isolates showed 12 isolates are positive for case in hydrolysis, 11 isolates for tyrosine, 20 isolates for H_2S production, eight and seven isolates could produce melanin and citrate, respectively and negative for HCN and urease production. Among them, 26 isolates produced IAA and GA. UASBA 46 and UASBA 50 isolates showed the highest P, K and Zn solubilization with positive for siderophore, ammonia production. Highest concentration of ACC-deaminase activity and also production of hydrolytic enzymes observed in both the isolates. *In vitro* studies showed that 15 isolates were antagonistic against fungal pathogens *Sclerotium rolfsii* and *Pythium* spp. 13 isolates were antagonists against *Fusarium oxysporum*. Further, actinobacterial isolates were identified as *Streptomyces antibioticus* (UASBA 50) and *Streptomyces* sp. (UASBA 46) by 16s rRNA partial genome sequencing. Significant increase in plant growth and yield parameters was observed in the treatment receiving dual inoculation of actinobacterial isolates with RDF in cowpea and finger millet. Significant increase in soil enzymes activity and total microbial population was also recorded. Jaggrey solution with NaCl + $MgSO_4$ + $CaSO_4$ found to be the best substrate for mass multiplication of actinobacterial isolates. Hence, the application of actinobacterial isolates has multiple growth and yield promotional activity as biofertilizers could serve as promising solution for improving soil health in sustainable crop production.

Evaluation of Bacterial Endophytes from *Coleus aromaticus* for Biocontrol and Growth Promotion Activities in *Coleus forskohlii*

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BACTERIAL endophytes occur inside a plant which does not exhibit harmful effects for plants. The present study was carried out to isolate and characterize endophytic bacteria residing inside the *Coleus aromaticus* and evaluate their role as plant growth promoters, their antagonistic capacity under *in vitro* conditions and greenhouse studies using *Coleus forskohlii*. Totally forty-five bacterial endophytes were isolated from roots, shoots and leaves of *Coleus aromaticus*. Thirty isolates were selected based on their morphological characteristics for further screening. Most of the isolates showed plant growth promoting activities like nitrogen fixing and phosphorus solubilization. Index for phosphorus solubilization was found in the range of 4.00 - 2.05. Among thirty isolates, MR 2R showed maximum inhibition against *Fusarium oxysporum* (59.30 %), whereas MS PS 1 exhibited maximum inhibition against *Pythium aphanidermatum* (50.59 %) and *Sclerotium rolfsii* (46.66 %). Based on dual plate assay and plant growth promotional activities, ten efficient isolates were selected and screened for the production of ammonia, siderophore and phytohormones among the selected isolates MR 9R showed maximum production of IAA (28.49 µ/ml) and GA (30.20 µg/ml). Three isolates *viz.,* MR 9R, MR 2R and AAS 5 were subjected to molecular characterization through 16S rRNA sequencing using specific primers and isolates were identified as *Bacillus pumilus* (MR 9R), *Bacillus licheniformis* (MR 2R) and *Bacillus australimaris* (AAS 5). In the greenhouse studies on *Coleus forskohlii,* the treatment T_9 (Consortia + RDF + pathogen) noticed better results in all the parameters recorded followed by T_5 (Consortia + pathogen) and lowest results was shown in the treatment T_{10} (Pathogen control). The present studies strongly suggest that endophytic bacteria characterized can be successfully used for promoting plant growth and inducing fungal resistance of plants.

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Development of Coat Protein Mediated Gene Construct to Obtain Resistance Against *Tomato leaf curl New Delhi virus* (G: Begomovirus, F: Geminiviridae) in Ridge Gourd [*Luffa acutangula* (L.) Roxb]

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Ridge gourd is one of the important vegetable crops of cucurbit species. The recent emergence of ridge gourd yellow mosaic disease (RgYMD) caused by ToLCNDV is becoming the major constraints in ridge gourd production. In present investigation, the preliminary work has been carried out in the process of development of transgenic ridge gourd to confer resistance against ToLCNDV using coat protein mediated resistance (CP-MR) strategy. The survey was conducted in southern parts of Karnataka to assess the economic importance of ToLCNDV infection. The results of survey revealed the ToLCNDV is predominant in all surveyed areas and all varieties were found susceptible to virus. The total DNA from infected leaves of ridge gourd and coat protein gene was amplified using gene specific primers. The purified CP gene was successfully cloned to pTZ57R/T vector. Further, CP gene was moved into plant expression vector pBI121 with the help of the pET32a vector. Subsequently, the vector pBI121 having CP gene construct was transformed into *Agrobacterium tumefaciens.* For bacterial expression studies, the CP gene was cloned into pET28a and expressed in *E. coli* BL21 cells. The presence of distinct protein band of size ~34 kDa in the recombinant cells confirms the over-expression of protein. The efforts were made to standardize the growth media for *in vitro* regeneration of ridge guard. The best organogenic callus was obtained in 2.5 mg/L of 2, 4- D + 0.5 mg/L of BAP. These research findings will be helpful for the development of transgenic ridge gourd.

Transformation and Expression Studies of Antiviral Protein Gene Against *BmNPV* in Mulberry (*Morus alba* L.)

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Mulberry (*Morus alba* L.) belongs to the family of Moraceae which is a sole food of silkworm (*Bombyx mori* L.). Mulberry silk production is affected by various diseases among which grasserie a major viral disease caused by *BmNPV* causes major economic loss to the silkworm rearing farmers. Silkworm known to produce many antiviral proteins upon viral infection in which Bmlipase and Bmserine protease found to be more effective against *BmNPV*. The present research work was undertaken to transform and express the antiviral protein gene/s *lipase* and *serine protease* genes in mulberry. The total RNA was isolated from *BmNPV* infected silkworms followed by cDNA synthesis. *Lipase* and *serine protease* genes were amplified from the cDNA and were cloned into T cloning vector. Recombinant T- vector having *lipase* and *serine protease* genes were double digested with *Xba* I and *Sac* I and cloned into plant expression vector pBI121 individually. Further, plasmid construct with genes successfully transformed to *Agrobacterium tumefaciens* strain LBA4404 and mulberry plants were transformed with recombinant *Agrobacterium* with antiviral protein gene/s using agro-infiltration and *in planta* transformation methods. Gene integration was confirmed by PCR using gene specific primers and gene expression was confirmed by SDS-PAGE analysis. 100 per cent transformation was achieved using agro-infiltration method, whereas *in planta* transformation method two out of twenty plants confirmed the stable gene integration for both *lipase* and *serine protease* genes. Further, the development of stable transgenic mulberry plants enriched with antiviral proteins will be helpful to combat against viral disease of silkworm.

Analysis of Stress Responsive Up-Regulated Sequences in *Medicago truncatula*

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ONE of the major constraints in agricultural production is abiotic stress. The mechanisms of these stresses so far understood backed up by proper bioinformatics understanding can be a boon to agriculture. In this context this study employed biocuration of literature, data mining and collection of abiotic stress up regulated genes (Salinity, Drought, Cold and Freezing) from the expression studied dataset in the model legume plant *Medicago truncatula* curated from literature. Further, an in-house algorithm named STIF was used to predict the TFBS (transcription factor binding site) of these stress-up regulated genes. Mapping of these TFBS on a gene was also done manually. The study finds that the most abundant TFBS are MYB and WRKY under both drought and salinity stress condition. The second part of the study includes functional enrichment of these genes in which proteins were enriched, which gave an idea of the dominating proteins that are associated with these genes. Transcription factor (TF) classification was done to find out the occurrence of various kinds of TFs under different stresses. MYB- HB -Like TFs and C2H2 TFs were abundant in drought and salinity, respectively, while both cold and freezing showed the abundance of AP2-EREBP TFs. Ultimately, this study on *M. truncatula*, which is a model legume plant can lead to the findings that may help us to study various other stress related sequences in different legumes which in turn help to develop stress-tolerant crop varieties.

Cloning and Characterization of *Bacillus thuringiensis cry* Genes Active Against the Fall Armyworm

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THE fall armyworm (FAW) was discovered in India after leaving a path of ruined plants in Africa and the Americas. Bt was re-isolated successfully from the dead larvae of FAW. A total of 10 putative *B. thuringiensis* isolates were acquired. All of the isolates were discovered to be gram positive and crystalliferous. Majority of the isolates exhibited the bipyramidal crystal (crystals know to be effective against lepidopteron insects). A new *cry1I* gene from the *B. thuringiensis* re-isolated from dead FAW larva were cloned and expressed in pRSET. Cloned FAW *cry1I* gene sequence showed a typical *Bt cry* gene with significant homology to *cry1I* genes with toxic region differences. Predicted using Phyre2 homology modeling, the deduced 3-D structural model of the new FAW *cry1I* shows that the gene contains three domains that participate in the formation of a pore and determine the binding specificity of the receptor. We also assessed the insecticidal activity of *cry1I* gene for the effective FAW management. FAW larvae were evaluated in the first, second, third and fourth instars. The bioassays revealed that the larvae of the FAW were susceptible to indigenous Bt Cry toxins. Compared with the normal HD1 reference strain at 15.5 µg / mL, the purified Cry1I gene was lethal to FAW. The death percentage was observed at 100 per cent. At the end of the toxicity test, all the treated larvae were dead, while most control larvae were found to be healthy and successfully complete the life cycle.

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Morphometric Evaluation of Bitter Gourd (*Momordica charantia* L.) Local Accessions and Molecular Diversity Analysis Based on SSR Marker Assay

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Bitter gourd (*Momordica charantia* L.) is gaining popularity as a vegetable with medicinal value. The antidiabetic bitter principles such as charantin and momordicine are highly useful in keeping blood sugar level under control. Bitter gourd exhibits huge diversity with respect to morphological characters such as fruit length, fruit diameter, individual fruit weight, total yield per plant etc. Thus, the above study aimed at identifying the genetic diversity present in bitter gourd local accessions collected from different regions of Karnataka and Andhra Pradesha. Among the twentythree bitter gourd accessions along with check variety Arka Harith studied, the fruit length was higher in BGS III (26.48 cm), followed by BGGLB (23.19 cm). Fruit diameter was higher in BGS II (15.98 cm) followed by BGS III (15.79 cm). Individual fruit weight was higher in BGV II (115.50 g) followed by BGGLH (101.13 g). Fruit pericarp thickness was higher in BGS II (4.68 cm) followed by BGS III (4.42 cm). Significantly higher total yield per plant was recorded in the genotype BGS III (539.24 g) followed by BGR (532.45 g). Over all the bitter gourd local accessions collected from Shivamogga, Rayadurga, Hubli and Vizag showed higher significant variations in morphological characters. Molecular diversity analysis was carried out using 12 SSR primers, among them four primers (JY002, S9, S13 and S26) showed polymorphism with PIC values ranging from 0.32, 0.15, 0.21 and 0.35, respectively and gene diversity values ranging from of 0.40, 0.17, 0.24 and 0.45, respectively. Thus, from the above study the following local accessions BGS III, BGGLB, BGS II, BGV II and BGR can be screened further for selection of best local accessions for commercial purpose.

Genetic Investigation on Mung Bean Yellow Mosaic Virus (MYMV) Resistance, Seed Yield and Related Traits in Interspecific Crosses of Mung Bean [*Vigna radiata* (L.) Wilczek] and Rice Bean (*Vigna umbellata* Thunb.)

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Present investigation involved interspecific hybrids of mung bean and rice bean to study the crossability, pollen fertility, seed viability, hybrid lethality and hybrid breakdown per cent. Four mung bean lines *viz*., KKM 3, LG 572, PS 16 and BGG 5 susceptible to MYMV and seven rice bean varieties *viz*., RBL 35, EC 181771, KBR 1, EC 108873, RBL 6, IC 521148 and BRBM127 highly resistant to MYMV was used. Out of 28 interspecific crosses attempted only 16 were successful in producing interspecific hybrids. The interspecific cross KKM 3 x KBR 1 was found better as revealed by higher crossability per cent, high hybrid pollen fertility, high seed germination percentage, lower hybrid lethality and lower hybrid break down. Two F2 populations (KKM 3 × KBR 1 and KKM 3 × RBL 6) were scored and evaluated to study the genetics of MYMV resistance, variability and inter relationship for ten yield and yield contributing characters respectively. In genetic studies done a good fit of 3:1 (Resistant : Susceptible) ratio was observed. In another study, segregating generations (F_5 and F_6) of the interspecific crosses of mung bean and rice bean (Selection 4 × RBL 1, Yellowmung × KBR 1, BGS 9 × RBL 35) was used to study genetic variability, heritability, genetic advance, interrelationship between yield and yield contributing traits. Number of branches per plant, number of clusters per plant, number of pods per plant and number of pods per cluster recorded high PCV, high GCV, high broad sense heritability coupled with genetic advance. Path analysis results revealed direct effect of number of pods per plant, number of branches per plant, number of seeds per pod, number of clusters per plant and number of seeds per pod on seed yield and these traits exhibited significant and positive correlation with seed yield. The information generated in the present study may help in genetic improvement of mung bean in general and to develop MYMV resistant greengram genotypes in particular.

Identification and Validation of QTL Controlling Traits Related to Drought Tolerance in the Recombinant Inbred Population of the Cross NRCG 12568 × NRCG 12326 in Groundnut (*Arachis hypogaea* L.)

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AN investigation was carried out with the experimental material consisting of 147 RILs developed from the cross NRCG 12568 × NRCG 12326 during summer 2017 and 2018 at GKVK, Bengaluru under four different conditions *viz*., Well-watered (WW), Water stress (WS) I -with holding irrigation from 30 - 45 DAS (flowering period), Water stress II -with holding irrigation from 45 - 65 DAS (flowering and peg initiation stage), water stress III -with holding irrigation from 65-85 DAS (peg penetration and pod development stage) in augmented design including checks; TMV 2 and GKVK 5. Significant differences among RILs were observed for most of the traits in both the conditions. SCMR, SLA, pods plant^{-1} and pod yield plant^{-1} showed more genetic variation exhibiting moderate to high heritability with high genetic advance. Four out of 15 drought tolerant indices tested *viz*., MP, GMP, HMP and STI were found to be better indicators of drought tolerance. RIL 133, RIL 126, RIL 145 and RIL 25 showed higher pod yield in WW and WS conditions in comparison to GKVK 5 across years and locations based on per se performance, biplot analysis and ranking method. A linkage map was developed with 172 SSR markers on 20 linkage groups using genotypic data of 147 RILs. The length of linkage map spanned 2212.87 cM with an average of 11.12 cM inter-maker distance. Twenty-one QTLs were detected with 6.27-13.55 per cent of phenotypic variance explained (PVE) in WW and WS environments. Two major QTLs each for SCMR and days to 50 per cent flowering, three major QTLs for SLA were detected in WS condition at LOD 3.0. A total of 38 Di-QTL interactions with more than five per cent PVE were identified at LOD 5.0. The QTLs identified in the study can be utilized for marker assisted back cross breeding after validation. Stable RILs can be tested in multilocations or could be used in future breeding for drought tolerance.

Genome-wide Association Mapping of Genes / QTLs for Salinity Tolerance in Rice (*Oryza sativa* L.) Landraces

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RICE is sensitive to salinity at early vegetative stage and increased salinitysignificantly reduces the rice productivity. In this study, 160 rice landraces were screened for salinity tolerance at various NaCl salt concentrations of 50, 100, 150 mM using hydroponic system and 14 traits were phenotyped. The rice landraces showed tremendous variation for most of the traits and nine landraces (GP003, GP048, GP059, GP086, GP165, GP166, GP167, GP170 and GP212) were identified as salt tolerant. Genome-wide SNPs based association for 14 traits enabled us to identify 534 SNPs significantly associated with traits measured. These SNPs were distributed on 253 genes, out of which 14 genes were associated with more than one SNP. Among these genes about 80 loci coded for retrotransposon (Ty3 gypsy / Ty1 copia subclass).The locus Os10g25010 (*OsCML-8*) encoding calmodulin related calcium sensor protein reported previously known to have positive role in salt tolerance. In addition, novel loci coding retinoblastoma- related protein (RBR), transposon (CACTA, En/Spm sub-class), fimbrin-like protein 2, C4-dicarboxylate transporter/malic acid transporter, disease resistance RPP13-like protein 1, ras-related protein, helix-loop-helix DNA-binding domain containing protein, coiled-coil domain-containing protein 90A, mitochondrial precursor protein, mTERF domain containing protein etc. were found associated with salt tolerance. Interestingly, more SNPs were associated with root related traits like root sodium-potassium ratio, root sodium concentration and root length compare to other traits. Thus novel loci identified in this study can be used for improvement of salinity tolerance in rice in near future through molecularbreeding approach.

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Assessment of Genetic Variability and Identification of Genotypes Suitable for Wet and Dry Direct Seeding in Rice (*Oryza sativa* L.)

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Rice is the most important cereal crop and main source of energy for majority of the world population. An investigation was carried out to assess the genetic variability among 64 rice varieties sown during *kharif*- 2019 with an objective to identify the genotype with superior grain yield under both wet and dry direct seeding. The genotypes were evaluated for variability, character association traits. Analysis of variance revealed high significant difference for all the characters studied. high estimates of GCV, PCV and heritability were observed for number of productive tillers, panicle length, test weight indicating that these traits contribute more towards achieving more grin yield. Correlation studies revealed that, grain yield exhibited positive significant correlation with panicle length, spikelet fertility and number of grains per panicle. Path coefficient analysis exhibited positive direct effects for number of grains per panicle and panicle length with yield in both wet and dry direct seeding. Superior variety selected was KMP 175 followed by KMP 128 and IR 64 in case of dry-DSR while variety Navara followed by Puttabatta, KMP 175 and IR 64 in case of wet-DSR. Efforts were made to assess the grain quality parameters such as grain length, grain breadth, L/B ratio, gel consistency, alkali spreading value, cooking time, cooked yield, water uptake ratio and grain elongation after cooking for superior genotypes identified under both wet direct seeding and dry direct seeding. KMP 175, KMP 128 showed good physical, chemical and cooking quality of the grain.

Genome-Wide Detection and Assessment of Natural DNA Methylation Variation in Dolichos Bean (*Lablab purpureus* L. Sweet var. Lignosus) Germplasm Accessions using AMP-PCR Technique

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As a prelude to exploit DNA methylation-induced variation, we tested the hypothesis that there exists substantial natural DNA methylation variation and this variation is associated with economically important traits in dolichos bean using amplified methylation polymorphism polymerase chain reaction (AMP-PCR) assay. DNA methylation patterns such as internal-, external-, full- and non-methylation were amplified in a set of 64 genotypes using 26 customized randomly amplified polymorphic DNA (RAPD) primers containing 5'CCGG3' sequence. The 64 genotypes included 60 germplasm accessions (GA), two advanced breeding lines (ABLs) and two released varieties. The ABLs and released varieties are referred to as improved germplasm accessions (IGA) in this study. We explored the association of DNA methylation patterns with economically important traits such as days to 50 per cent flowering, raceme length, fresh pods plant^{-1}, fresh pod yield plant^{-1} and 100-fresh seed weight. At least 50 genotypes were polymorphic for DNA methylation patterns at 10 loci generated by seven of the 26 RAPD primers. The GA and IGA differed significantly for total-, full- and external-methylation and the frequency of methylation was higher in GA compared to that in IGA. The genotypes with external methylation produced longer racemes than those with full-, internal- and non-methylation in that order at polymorphic RAPD-11-242 locus. High pod yielding genotypes had significantly lower frequency of full-methylation than low yielding ones. On the contrary, the genotypes that produced heavier fresh seeds harboured higher frequencies of total and externally methylated loci than those that produced lighter fresh seeds.

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Assessment of Molecular Diversity and Combining Ability for Forage Traits in Maize (*Zea mays* L.)

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An investigation was carried out to estimate molecular diversity, combining ability and to assess the relationship between molecular diversity and heterosis in inbred lines of maize (*Zea mays* L.) developed at AICRP (FCU), Zonal Agriculture Research Station, V.C. Farm, Mandya during 2019-2020. Thirty inbred lines were analysed for their molecular diversity using SSR markers and grouped into four clusters. Among them cluster II accommodated maximum number of inbred lines (15) followed by cluster I (11) inbred lines. The PIC value ranged from 0.062 (*bnlg198*) to 0.54 (*bnlg589*). Combining ability analysis using diallel mating design was conducted in eight inbred lines. The ratio of GCA to SCA variance revealed that there was preponderance of non-additive gene action in the expression of all the traits under study. The lines MAI 3, P 12 and 1-63-5 were identified as best combiners for Green forage yield and yield related characters. Among crosses, MAI 3 × 5-16-1, MAI 3 × 5-6-1,CML 451 × 5-16-1, CML 451 × P 12 and MAI 267 × MAI 3 exhibited highest significant *sca* effects and none of the crosses shown significant positive heterosis over checks (African tall and J-1006). These hybrids need to be further evaluated across locations to select best hybrids for commercial exploitation. Mid-parent heterosis, *sca* effects and mean plot yield of hybrids regressed over simple matching coefficient were not significant indicating lack of relationship between parental diversity and heterosis.

Studies on Spread and Distribution Pattern of Fall Armyworm, *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera : Noctuidae) within the Maize Field and Assessment of the Efficacy of Seed Treatment for Its Management

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Fall armyworm, *Spodoptera frugiperda* (J. E. Smith) is a serious pest of maize all around the world. This pest also has been reported recently from India in 2018. The spread and distribution behaviour of the pest along with the efficacy of seed treatment for its management was estimated in the current study. Distribution of *S. frugiperda* larvae in the field followed both negative binomial and poisson distribution. Negative binomial distribution was the best fit in case of early instar caterpillars whereas, the late instar caterpillars showed best fit towards random distribution. The distribution analysis in caged condition indicated the non-directional movement of *S. frugiperda* larvae. The larvae moved from artificially infested plant in different directions and maximum distance travelled was 1.5 m. With regard to efficacy of seed treatment, maize seeds treated with diamides resulted in 100 per cent mortality of first and third instar caterpillars at seven DAE in laboratory bioassays. Chlorantraniliprole 62.5 FS exhibited superior and long-lasting effect with 29.9 and 24 per cent mortality of first and third instar larvae of *S. frugiperda,* respectively at 35 DAE. When insecticide treated seeds were sown in the field, the least leaf damage was observed in seed treatment with chlorantraniliprole 62.5 FS followed by cyantraniliprole 19.8 per cent + thiamethoxam 19.8 per cent FS. Spinetoram followed by chlorantraniliprole and emamectin benzoate were found effective in case of foliar spray. The present study revealed seed treatment with diamides as an economic and effective alternative to multiple insecticide sprays for the management of *S. frugiperda*.

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CRISPR/Cas9 Based Editing of Some Important Genes of Mango Fruit Fly, *Bactrocera dorsalis* (Hendel) (Diptera : Tephritidae)

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THE utility of genome editing in the *Bactrocera dorsalis* by CRISPR/Cas method was evaluated. We used ribonucleoprotein (RNP) complexes assembled with Cas9 endonuclease as a single guide RNA (sgRNA) engineered with the target pigmentation gene (*white*) and spermatogenesis (*per*). The embryos, along with the white gene sgRNA - AS443 (ACCGTTCAGCAAGCGTACGG) (100 pmol), Cas9 (400 pmol) and Tris Buffer (10 mM) were subjected to electroporation with 800 V@500 µs. In contrast to the wild brown reddish eye type, the developing adult flies displayed a blackish green eye colour with altered head pigmentation. Compared to the wild style with different spots, all the head spots were indistinct in the edited type. With lighter pigmentation, the thoracic plate in the edited form was yellowish, while in the wild type it was more melanized and whitish yellow. In order to obtain more G_0 phased embryo numbers, optimization of egg laying was carried out, which showed that the banana pulp was *B. dorsalis* most favoured oviposition substrate. There was no significant difference between water media and 0.5 per cent solidified agar media for egg processing, while after incubation, survivability in water media was found to be higher. The peak time of egg laying was found in the 21 - 43 days (23.93 ± 10.10 eggs) age range. Five flies per box with an average number of eggs of 162.83 ± 75.80 in the first hour, 107 ± 92.19 in the second hour and 142.66 ± 29.27 in the third hour is deemed better handling. The research reveals that synthetic RNP complexes constructed *in vitro* can be used in studies of genetic manipulation.

Seasonal Incidence, Crop Loss Assessment and Management of Fall Armyworm, *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera : Noctuidae) in Maize

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THE investigation on seasonal incidence, crop loss and evaluation of efficacy of new insecticide molecules against fall armyworm was carried out at College of Agriculture, V.C. Farm, Mandya and at farmers field during *kharif* and *rabi* 2019-20. The peak incidence of fall armyworm population and higher per cent damage was noticed at 29th standard meteorological week (July) of *kharif* 2019 with the significant positive correlation with maximum temperature and minimum temperature. During *rabi* 2019, the peak incidence of fall armyworm population and higher per cent damage was noticed at 10th standard meteorological week (March) of 2020 with positive correlation with maximum and minimum temperature. The crop loss assessment was carried out at different levels of infestation by fall armyworm during *kharif* and *rabi* 2019-20 indicated that, there was no notable lower growth and yield was noticed up to 20 per cent level of infestation by fall armyworm. But when infestation level crossed 20 per cent, then significant lower growth and yield were noticed. Among the different new insecticide molecules evaluated, chlorantraniliprole 18.5 SC @ 0.13 ml l^{-1}, spinosad 45 SC @ 0.15 ml l^{-1} and spinetorum 11.7 SC @ 0.30 ml l^{-1} were found effective in controlling fall armyworm and recorded higher yield, net returns and b:c ratio when compared to other treatments.

Rice Gall Midge : Pest Status, Source of Resistance and Management in Cauvery Command Area

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The investigations on pest status of Asian rice gall midge, *Orseolia oryzae* (Cecidomyiidae : Diptera), identification of prevailing biotype population through standard rice differentials, source of resistance and management through nursery application of granular insecticides were carried out at 'A' block, College of Agriculture, V.C. Farm, Mandya, Karnataka during *kharif* and summer season of 2019 - 2020. Among different locations under three districts in southern parts of Karnataka surveyed for the incidence of rice gall midge during *kharif* 2019, the highest per cent silver shoot (9.03) was recorded in Mandya followed by Kabini command area of Chamarajanagar (8.70 % SS) and the least per cent silver shoot (6.95) was observed in Mysore. The reaction pattern of 16 standard rice differentials under four groups tested against local population of gall midge indicated R-R-R-S reaction and this confirmed the existence of homogenous population of biotype-1 in Cauvery command area. The field evaluation of 50 local landraces against gall midge resulted in identifying five highly resistant, 10 resistant, 7 moderately resistant, 15 moderately susceptible and 22 landraces as susceptible. Among biochemical constituents total sugar, reducing sugar, crude proteins and nitrogen were found positive association with midge infestation while, total phenols, total free amino acids, tannins, phosphorous and potassium were found negative. Among seven insecticides evaluated, benfuracarb 3G @ 3.30 kg ha^{-1} seedlings, chlorantroniliprole 0.4G @ 1.00 kg ha^{-1} and fipronil 0.3G @ 2.50 kg ha^{-1} was found effective against gall midge. However, benfuracarb 3G @ 3.30 kg ha^{-1} was found to be superior in recording higher grain yield, net return and C : B ratio (1 : 3.04) compared to other treatments.

Characterization and Management of Early Blight of Tomato

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Early blight caused by *Alternaria solani* is a predominantly occurring disease of Tomato. Roving survey results of *rabi* 2018-19 and 2019-20 in major tomato growing areas of southern Karnataka revealed that the maximum mean disease severity was recorded in Kolar district (38.63 %) followed by Chikkaballapur (38.36 %) district during fruiting stage. Among the 23 isolates, isolates AMaNaL and AMaNaS recorded maximum radial growth on six solid media out of the nine media. The isolate AHaBeL showed highest number of horizontal septation (5 - 7) on oatmeal agar medium and the highest number of vertical septation of 2 - 3 were observed in AKoMaL (host leaf extract) and AMyNjL (oatmeal agar). Sporulation was observed only in five isolates *viz*., AHaBel, AHaCrl, AHaHaL, AKoMaL and AMyNjL. The PCR amplification of 23 isolates using universal primer pair revealed that, ITS region of the isolates showed highest nucleotide identity varying from 91.2 to 94.2 per cent to the *Alternaria solani* infecting Tomato. The epidemiological studies revealed that per cent disease index (PDI) progressed in linear rate as the age of the plant advances and weather parameters like minimum temperature, evening relative humidity, morning relative humidity rainfall, number of rainy days were found significant and in negative correlation with disease development. Among the three contact fungicides evaluated, the highest per cent inhibition (78.61) was recorded in mancozeb 75 per cent WP. Among the different antagonists evaluated maximum mycelial inhibition was noticed in *Trichoderma asperellum* (69.69 %). Hexaconazole five per cent EC @ 0.1 per cent was found effective both under laboratory and field condition against *A. solani*. Among the 50 commercial varieties / hybrids evaluated, three varieties / hybrids *viz*., (ArkaSurabh, Arka Samrat and Arka Vikas) showed moderately resistant (MR) reaction.

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Studies on Mungbean Yellow Mosaic Virus (MYMV) Relationship With It's Vector Whitefly (*Bemisia tabaci* Genn.) and It's Management

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Mungbean yellow mosaic virus (MYMV) is one of the major constraints for the cultivation of mungbean in Indian sub-continent. Virus-vector relationship studies show that single whitefly (*Bemisia tabaci* Genn.) was not able to transmit transmission of MYMV, whereas two whiteflies are required for its transmission. Highest transmission (70 and 80 %) of MYMV was recorded when the vector was given a pre-acquisition starvation period, access feeding period and inoculation access feeding period of 24 hr. Among the four elicitors sprayed on mungbeanto study the various biochemical changes salicylic acid @ 1 mM recorded highest phenol content (3.874 mg/g), peroxidase (0.411 ΔAbs/min/g), phenylalanine ammonia lyase (0.680 µ of transcinnamic acid / min / g) and polyphenol oxidase (0.280 ΔAbs / min / g) enzyme activity at three weeks after spraying. This treatment also recorded lowest disease incidence of 44.44 per cent compared to others. The presence of the virus in infected plants and viruliferous insect vector was confirmed through molecular detection technique. Among the different treatments used to manage the MYMV disease on mungbean, Dimethoate 20 EC (2 ml / l) two sprays at 10 and 30 DAS recorded significantly lowest mean disease incidence, less whitefly population per plant and highest seed yield of 7.99 q ha^{-1}.

Studies on *Helminthosporium* Leaf Blight of Browntop Millet [*Brachiaria ramosa* (L.) Stapf]

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Browntop millet was recently introduced into millet system in India. In *kharif* 2018, leaf blight was observed at Bangalore, India. Spots were brown in colour with small yellow halo eventually enlarged with light brown centre. Spots coalesce causing blight. Maximum disease severity was recorded in Bengaluru (8.46 G) and minimum in Mandya (4.80 G). Morphologically the pathogen was identified as *Bipolaris* sp.by comparing with standard descriptions of *Helminthosporium* species. $BTMH_5$ isolate was identified as more virulent. Pathogen was able to infect only browntop millet.Czapek Dox agar (CDA) and host leaf decoction agar with sucrose (2 %) and pH 6.0 to pH 7.0 were found to be ideal for radial mycelial growth and sporulation. In vegetative compatibility, $BTMH_2 \times BTMH_6$ showed compatibile reaction where H-shaped hyphal anastomosis was observed. Barren pseudothecia are produced on Sach's agar medium. BLAST results of GPDH sequences confirmed that *Bipolaris setariae* as the causal organism of browntop millet leaf blight in India. Specific primers were designed and validated. Among the botanicals, maximum per cent inhibition was noticed in a gave with no inhibition in calotropis. *Trichoderma viride* along with *T. harzianum* strain 14 among the fungal bio agents and P_{42} strain of *Bacillus velezensis* among the bacterial bio-agents accounted maximum per cent inhibition. Mancozeb (96.54 %) among the contact fungicides, propiconazole (100.00 %) among the systemic fungicides and cymoxanil + mancozeb among the combi-product fungicides exhibited maximum inhibition of mycelial growth. Amongst the 40 germplasm screened, none of the germplasm showed resistant reaction.

Studies on *Fusarium* Wilt in Scented Geranium [*Pelargonium graveolens* (L.) Herit]

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SCENTED geranium is an important, perennial aromatic herb affected by several diseases of which wilt caused by *Fusarium oxysporum* is becoming a major constraint in production. Wilt symptoms such as yellowing, drooping of plants and vascular discolouration were observed in the infected stems. Maximum wilt incidence recorded in Tumakuru district (36.73 %). The wilt causing pathogen was isolated from infected plant samples collected from different geranium growing areas of southern Karnataka and pathogenicity was proved under greenhouse conditions. The re-isolated pathogen was identified as *F. oxysporum* based on its morphological characters by comparing with standard descriptions of *Fusarium* species and also confirmed the pathogen through molecular characterization of isolates by using universal fungal ITS-1 and ITS-4 primers. Sabouraud's dextrose agar (SDA) and corn meal agar (CMA) were found to be ideal for radial mycelial growth and sporulation. The maximum growth and sporulation of the pathogen was found at temperature 25 ^{0}C and pH of 6.5. Among the botanicals and bioagents evaluated under *in vitro* condition against *F. oxysporum*, agave (59.31 %), *Trichoderma viride* Tv- 8 (71.12 %), *Bacillus pumilis* (54.66 %) and *B.velezensis* Bv-P_{42} (53.61 %) were effective in inhibition of mycelial growth of the pathogen. Among the fungicides evaluated, systemic fungicides carbendazim and propiconazole shower 100.00 per cent, combi products hexaconazole + captan 84.51 per cent and contact fungicide copper oxychloride 56.48 per cent were effective as evidenced by maximum mycelial growth inhibition compared to other fungicides under *in vitro* condition.

Evaluation of Elite Tissue Culture Raised Banana Varieties for Growth, Yield and Quality Under Southern Dry Zone of Karnataka (Bengaluru Condition)

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A field experiment was carried out on 'Evaluation of elite tissue culture raised banana varieties for growth, yield and quality under southern dry zone of Karnataka (Bengaluru condition)' during 2018 to 2020 at Department of Horticulture, UAS, GKVK, Bengaluru. The healthy, vigorous and uniform sized twelve tissue culture raised banana varieties were collected from different locations and planted at spacing of 1.8 m × 1.8 m with trench method and the experiment was laid out in randomized complete block design. Among the varieties, highest plant height (342.73 cm), pseudostem girth (88.93 cm) and number of leaves per plant (24.67) was obtained in Udhayam at shooting stage. The time taken for an early shooting (228.40 days), shooting to harvesting (118.53 days) and least crop duration (346.93 days) was noticed in Grand Naine and it was followed in Williams. Among the varieties, the more number of hands per bunch (13.60), number of fingers per bunch (200.13), length of bunch (78.67 cm), weight of bunch per plant (26.34 kg), yield per hectare (81.32 t/ha), highest level of TSS (21.40 ^{0}B), reducing sugar (16.20 %), non reducing sugar (3.93 %) and total sugar (20.13 %) was recorded in Grand Naine. The sensory parameters and pulp to peel ratio was superior in Yelakki bale. The cost benefit ratio was highest in Grand Naine (1:3.45) and Williams (1:3.05). The varieties such as Grand Naine, Williams and Yelakki bale were considered as most suitable for cultivation under southern dry zone of Karnataka.

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Studies on Standardization of Irrigation and Fertilizer Levels on Growth, Yield and Quality of Papaya (*cv.* Red Lady) under Protected and Open Field Conditions

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STUDIES on growth, yield and quality of papaya (*Carica papaya* L.) *cv.* red lady as influenced by different irrigation and fertilizer levels were conducted separately under open field and protected condition at PFDC, Department of Horticulture, UAS, GKVK, Bengaluru during 2018-19 to 2019-20. Under open field conditions, drip irrigation @ 60 ,90 and 120 per cent E pan (mm/day) + 125 per cent RDF (250 : 250:500 g NPK / ha / plant). The plants registered significantly the highest vegetative parameters like plant height (255.62 cm), stem girth (58.47 cm) and total leaf area (26.99 m^2). With respect to yield parameters, plants showed significantly the highest fruit yield per plant (39.64 kg) and fruit yield per hectare (122.32 t/ha) at an irrigation level @ 50, 80 and 100 per cent E pan (mm/day) + 125 per cent RDF. Under protected condition, the plants registered significantly the highest vegetative parameters of plant height (388.51 cm) stem girth (74.91 cm) and total leaf area (41.58 m^2) at an irrigation level @ 60, 90 and 120 per cent E pan (mm / day) combined with 150 per cent RDF, while the highest yield parameters like fruit yield per plant (77.70 kg) and fruit yield per hectare (239.77 t / ha) were recorded at an irrigation level of 50, 80 and 100 per cent E pan (mm/day) + 125 per cent RDF. As high as 101 per cent more yield and good marketable appearance of fruits produced under protected conditions fetched a cost to benefit ratio of 1:3.03 with the highest return of Rs.14.26 lakhs per hectare as against Rs.7.79 lakhs per hectare under open field conditions.

Induction of Variability in *Zamioculcas zamiifolia* Engl. for Ornamental Scapes

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Zamioculcas zamiifolia Engl. (ZZ) is an ornamental foliage plant, recently introduced to the world of interior plant scape. The present study aimed at induction of variability in ZZ plants. Immature and mature leaflets or petiole, rhizomes and two leaf stage plantlets were irradiated with 15, 25, 35 and 45 grays of gamma dosage under *in vivo* condition. Callus, GLS and two leaf stage *in vitro* plantlets were irradiated with 15, 20, 25 and 30 grays of gamma dosage. Both irradiated and control immature leaflets or petioles showed mortality due to juvenility and high dose of gamma rays but new shoot initiation was seen in untreated mature petioles. Number of roots was highest in mature leaflets in control. No rhizome initiation was noticed in irradiated leaflets. In 15 Gy irradiated rhizomes, new shoot initiation was seen at 120.40 days. In two leaf stage plantlets, early new shoot initiation was seen in 15 gray treated plantlets at 30 days. Under *in vitro* conditions, fresh weight gain of callus, callus diameter and number of roots was highest in control. In globular like structures, new shoot initiation was seen in control and irradiated but initiation of cotyledonary leaves was seen early in 20Gy and 30Gy. In two leaf stage plantlets, mortality was observed due to effect of high dose of gamma irradiation. In present study, higher irradiation doses resulted in increased mortality. Hence, further studies with lower doses of gamma rays must be tried to get better survival and variations.

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Influence of Humic Acid on Growth, Yield and Quality of Chrysanthemum (*Dendranthema grandiflora* T.) cv. Marigold

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HUMIC acid is an organic substance which possess phytohormone like activity that is beneficial to both soil and plants. The present study was conducted to test the effect of different levels of humic acid by soil application and foliar spray either alone or in combination on growth, yield and quality of chrysanthemum cv. Marigold. The experiment was laid out in Randomised complete block design (RCBD) with nine treatments and three replications at a spacing of 60 cm x 30 cm. Two levels of humic acid (10 ml, 15 ml) applied as a soil drench at the time of transplanting, sprayed at 20 days of transplanting and in combination of both was imposed. The results of the investigation revealed that, the treatment combination with soil application of HA 15 ml / l + foliar application of HA 15 ml / l (T_9) recorded significantly higher plant height, more number of branches, larger plant spread and leaf area, highest chlorophyll content in the leaves and yield and quality parameters with respect to number of flowers per plant, average flower weight, flower diameter, flower yield per plant, flower yield per hectare and vase life of flowers were found maximum. The soil sample analysed from the same treatment (T_9) observed higher available nutrients (N, P_2O_5, K_2O) and their uptake by plants. The economics analysis clearly reflects that, the higher returns obtained (B:C ratio - 2.70) in the treatment (T_9) and this might will get higher profits for commercial chrysanthemum production.

In Vitro Regeneration in Chrysanthemum (*Dendranthema grandiflora* T.) cv. Marigold

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AN efficient protocol for chrysanthemum (*Dendranthema grandiflora* T.) cv. Marigold was developed by using shoot tips and nodal segments as explants. Nodal segments responded more positively with growth harmones. Mercuric chloride (0.1 %) for two to three minutes was found as best sterilant for both nodes and shoot tip explants. In the present study, different auxins (IAA and NAA) and cytokinins (BAP and TDZ) were used alone and also in combination for shoot regeneration. Among these different concentrations of growth harmones, MS medium supplemented with BAP 1.0 mgL^{-1} + IAA 0.1 mgL^{-1} was found to be the best harmone concentration with respect to early shoot initiation as it showed shoot initiation in 11.00 days. Whereas, more number of shoots per explant (5.25, 8.65 and 11.90) and maximum shoot length (4.45, 5.55 and 7.45cm) at 30, 60 and 90 DAS, respectively, was recorded with BAP 1.5 mgL^{-1} + TDZ 0.4mgL^{-1}. MS medium supplemented with BAP 0.5 mgL^{-1} + NAA 0.5 mgL^{-1} was early (12.20 days) in callus formation and showed highest callus intensity (4.0). Further, the regenerated shoots were transferred to the half strength MS medium containing different concentrations of IAA and IBA for rooting. Among them, IBA 0.2 mgL^{-1} showed early root initiation (5.20 days), more number of roots per shoot (4.49, 6.10 and 8.21) and maximum root length (3.85, 5.54 and 6.42cm) at 15, 30 and 45 DAR, respectively. The established protocol may utilize for production of virus free, true to type and for large scale multiplication of quality planting material of chrysanthemum cv. Marigold.

Marginalization of Agriculture Vis-a-Vis Urbanization and its Implications on Food Security Across Rural Urban Interface of North of Bengaluru

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THE present study on assessing the extent of marginalization of agriculture as influenced by urbanization and its impact on investment, production, occupation diversity, income and food security of farm households was undertaken in rural urban interface of North of Bengaluru. Data were collected from 80 farmers each from rural, transition and urban areas. Majority of farmers were marginal (>60 %) in all the three gradients. Sale of agriculture land was high among urban (50 %) farmers followed by transition (46.25 %) and rural (35 %) farmers. The per ha land value during 2020 was Rs.66.04, Rs.162.56 and Rs.251.4 lakh in rural, transition and urban areas, respectively. Fragmentation of agricultural holdings and sale of agriculture land due to urbanization were the major factors influencing agriculture marginalization. Per farm investment was relatively higher on irrigation structure in all areas. The next highest investment was on animal husbandry in rural area, horticulture in transition and urban areas. Crop diversification was more in transition (0.21) compared to rural (0.25) and urban (0.29) areas. Over past five years, increase in average farm income of households was more in urban (143.8 %) compared to rural (140.5 %) and transition (110.50 %) areas. The annual income of households was higher in urban area (Rs 7,61,267) followed by transition (Rs.7,10, 411) and rural (Rs.5,84,598) areas, because of higher occupational diversity. The percentage of food secure households was highest in urban area (76.25 %) compared to transition (63.75 %) and rural (58.75 %) areas. The urban households showed higher dietary diversity (0.81) than transition (0.80) and rural (0.77) areas. Education and monthly income were the significant factors influencing the farm household food security in rural-urban interface. Urbanization and commercialization have led farmers to shift from traditional to commercial enterprises, increased income, employment and food security.

Dynamics of Labour Migration and It's Impact on Agriculture in Karnataka: An Economic Analysis

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PRESENT study on nature of labour migration in rainfed and irrigated situations, socio-economic dimensions, impact of labour migration on land use, crop production and income, livelihood security of agricultural labour was conducted in Raichur and Yadgir districts of Karnataka. Total of 280 sample respondents were considered, comprising 120 farmers, 80 migrated labours and 80 non-migrated labours. Discriminant function, linear regression, markov chain, composite livelihood security index and Garret ranking, techniques were used for analysis of data. Results showed that majority of the labourer were migrated from rural to urban and the frequency was the highest (80 %) in rainfed situation. Supply of female labourers offered in both districts was more to the agricultural activities. The agricultural labour supply was 1779.01 lakh man-days per year while demand was 621.88 lakh man days, thus there exists excess availability to the tune of 1169.12 lakh man-days during 2018-19 in Karnataka. Positive influence of education and indebtedness were observed on migration as revealed by the discriminant function analysis. Number of persons migrated per household in both the situations has been significantly influenced by wage rate, land holding and family size. Shift in the cropping pattern was observed among the different groups of crops from high labour intensive to low labour intensive crops. Pulses and commercial crops were more stable and reliable in the Raichur and Yadgir districts, respectively. Estimated productivity difference in the case of both 'labour scarcity affected' and 'labour saving technology' adopted farms showed higher difference in paddy (570 kg/ha) cultivation compared to other crops. Annual household income earned was high in migrant households in both situations and major portion was from agricultural wages and remittance. Livelihood security index comprised of food, economic, education, health, habitat and social network security that households migrated labour households were relatively better secured.

An Economic Impact Assessment of Supplying Treated Sewage Water to Irrigation Tanks on Farming in Kolar District under KC Valley Project

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SUPPLYING treated sewage water for farming is an effort to address the issue of irrigation water distress. To analyse its impact on farming, the present study was conducted with randomly selected 120 farmers using descriptive statistics, composite externality index, partial budgeting and crop diversification index tools for analysis. The results revealed that, project implementation changed the cropping pattern with higher diversity as indicated by a Simpson's index value of 0.85 in the KC valley project area (KCVP) when compared to the value of 0.77 in non-project area (NKCVP). Total income per year from crop production was higher in KCVP (Rs.8,42,810) per farm than in NKCVP (Rs.5,28,893) per farm. Livestock enterprise yielded a return of Rs.19,729 per annum in KCVP, while the figure for NKCVP was Rs.21,638 per annum. The non-farm income realised in KCVP (Rs.98,134) was higher than that in NKCVP (Rs.83,630). KCVP farmers realised from all the activities, 34 per cent higher income than NKCVP farmers. Employment generation in KCVP was higher by four per cent (301 man-days) compared to 289 man-days in NKCVP. The net return per rupee of irrigation cost was found higher in both tomato and mulberry (Rs.135 and Rs.12) in KCVP as compared to that in NKCVP (Rs.105 and Rs.9, respectively). In essence, implementation of KCVP increased irrigated area as well as farmers' annual income. The farmers consider treated waste water resource as a boon which ensures irrigation throughout the year and enhances their income and employment.

Assessing the Impact of Water Users' Cooperatives Initiative on Economic Efficiency of Irrigation Water Use in Bhadra Command Area of Shivamogga District, Karnataka

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THE present study was undertaken in southern transition zone of Karnataka to estimate the impact of water users' cooperatives (WUCs) initiative on economic efficiency of irrigation water use. Four villages of Bhadravathi taluk were selected, two having active WUCs *i.e.,* Kagekodamagge and Dananayakapura and remaining two having flaccid WUCs *i.e,* Sriramanagara and Tiplapura. The required data was collected from 30 farmers from each WUCs. There exists equity in distribution of canal water in areas under active WUCs. Whereas, in areas under inactive WUCs there was non-equity in the distribution of canal water. The net returns per ha was higher in farms under active WUCs (Rs.6,45,094, Rs.7,07,192, Rs.8,08,093, Rs.8,166 and Rs.54,931) than flaccid WUCs (Rs.4,26,072, Rs.4,50,459, Rs.5,28,057, Rs.7,284 and Rs.39,740) in arecanut, arecanut + coconut, arecanut + coconut + banana, paddy and sugarcane, respectively. Partial budgeting of active WUCs over inactive WUCs in arecanut revealed that, net gain from active WUCs was Rs.84,703 per ha. The economic water use efficiency was higher in active WUCs (Rs.1,634, Rs.1,786, Rs.1,826, Rs.101 and Rs.75) than the flaccid WUCs (Rs.1,122, Rs.1,185, Rs.1,374, Rs.93 and Rs.57) and physical water use efficiency was also higher in active WUCs (0.98, 1.01, 1.15, 0.49 and 0.43 q per ha cm of water used) than the flaccid WUCs (0.69, 0.70, 0.84, 0.22 and 0.34 q per ha cm of water used) in arecanut, arecanut + coconut, arecanut + coconut + banana, paddy and sugarcane, respectively. The study emphasizes the need for activating flaccid WUCs to achieve equitable distribution of canal water and realize higher net returns.

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An Economic Analysis of Production and Marketing of Papaya under Different Irrigation Methods in Bellary District of Karnataka

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THE present study on 'An economic analysis of production and marketing of papaya under different irrigation methods in Bellary district of Karnataka' was carried using data collected from 40 papaya growers each practicing drip and flood irrigation methods. Data were collected on costs, returns, marketing channels, marketing costs, marketing margins and problems in the production and marketing of papaya using pre-tested schedule. The results of the study revealed that farmers incurred per acre establishment cost of Rs.1,16,111 and Rs.84,974 under drip and flood irrigation methods of planting. The respective per acre annual maintenance cost of papaya was Rs.1,49,228 and Rs.1,26,466 with corresponding yield of 42.32 quintals and 30.26 quintals with 39.85 per cent higher yield under drip irrigation. Famers realized net returns of Rs.2,21,199 and Rs.1,38,400 with per rupee net returns of 1.48 and 1.10 from papaya cultivated under drip and flood irrigation method. The results of production function analysis showed that fertilizers and plant protection chemicals under drip and fertilizers and human labour under flood irrigation methods were found to be significant variables contributing to papaya production. In the study area four marketing channels were existed for papaya with the producers share in consumer rupee ranging from 27.36 to 92.36 per cent. High initial investment, damage due to pest and diseases, high cost of labour, frequent price fluctuations, more number of middlemen, lack of organised marketing system, lack of availability of market information and high marketing cost were the major constraints in production and marketing of papaya.

Utilization of Food Processing Waste for the Production of Biogas and Energy Generation

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THE present study was undertaken to investigate the utilization of food processing waste for the production of biogas and energy generationin INDUS bio product plant. For investigation of biogas and energy generation, the food waste coming out of the plant namely wastes of carrot, tomato, gherkins, watermelon, papaya, jamun, rasgulla, nippattu and cooked food were collected. The physico-chemical characteristics of the food waste namely moisture, total solids, volatile solids, pH, carbon, nitrogen and carbon: nitrogen were investigated in order to study the biogas production. Characteristics of the food waste by keeping the food waste in anaerobic condition and the gas production was monitored and recorded for every week up to two months. Further, the biogas plant located at Indus bio plant was evaluated in order to check its performance by recording the volume of biogas production by feeding eight tonnes of selected food waste. The daily gas production was recorded for duration of three months and the average daily gas production 561.47 m^3 was observed. The maximum gas production of 581 m^3 was recorded at a temperature of 34 ^{0}C and this was further purified by removing the CO_2 and H_2S using water scrubbing. An average of 645 kWh of electricity was generated out of the produced purified gas and used for various purposes. It was concluded that the plant was economically viable and environmentally suitable with a payback period of 2.1 year.

Development of Solar-cum-Biomass Energy Hybrid Dryer for Simarouba Leaves

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SOLAR-cum-biomass energy hybrid dryer, an integration of both solar and biomass energy dryer was developed for bulk drying of simarouba leaves especially in non-electrified areas. The major components of the dryer are drying chamber, solar energy collection chamber and heat exchanging unit. Glazing materials (Acrylic sheet, Ethylene vinyl alcohol film, Fibre glass, Polyethylene film, Polycarbonate sheet and Polyvinyl chloride sheet) for effective harness of solar energy was selected based on an effective temperature profile inside the solar energy collection chamber. Polycarbonate sheet was found to be best due to its high temperature profile, average maximum temperature of 43.1 ^{0}C and average daily temperature of 38.4 ^{0}C.Drying of simarouba leaves using hybrid dryer was carried out and compared with sun drying, shade drying, tray drying, solar drying and biomass drying methods. Leaf moisture content was reduced approximately from 64 to 10 per cent in all drying methods. Drying period in hybrid drying (20 h) was found to be shorter as compared to sun (32 h), shade (56 h) and solar drying (34 h). Fuel requirement for combustion of briquette for energy source was found 33 per cent lower for hybrid dryer as compared to biomass dryer. Total cost of hybrid dryer was lower as compared to tray dryer of the same capacity. Simarouba leaves dried under hybrid dryer retained about 74.65 and 76.84 per cent of total phenols and total flavonoids, respectively as compared to fresh leaves. Therefore, solar-cum-biomass energy hybrid dryer would be cost effective and well suitable to dry simarouba leaves in non-electrified areas.

Rainfall Characteristics Induced Soil Moisture Availability under Organic Mulching in Rainfed Area of Southern Karnataka

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A field experiment was conducted at College of Agricultural Engineering, University of Agricultural Sciences, GKVK, Bengaluru during *kharif* 2019 to study the 'Rainfall characteristics induced soil moisture availability under organic mulching in rainfed area of southern Karnataka'. The experiment was laid out in randomised complete block design with seven treatments replicated thrice. Growing maize crop in dry leaves mulching resulted in better soil moisture content 24.07, 25.13, 18.73, 18.90, 24.07, 22.13, 21.70, 21.23, 21.00 20.73 and 20.10 per cent at 0-15 cm depth and 24.83, 27.48, 21.07, 20.87, 24.83, 23.40, 22.90, 22.57, 22.10, 21.80 and 21.17 per cent at 15-30 cm depth at 30, 37, 44, 51, 58, 65, 72, 79, 86, 93 and 100 DAS respectively. After crop harvest, the higher infiltration rate (5.79) cm hr^{-1} with lower bulk density (1.43 g cc^{-1}), plant growth and yield of maize (7228 kg ha^{-1}), higher gross returns (Rs.86745 ha^{-1}), net returns (Rs.56556 ha^{-1}) and B:C ratio (2.87) was documented under mulching with dry leaves. It can be inferred from the experimentation that mulching with dry leaves in maize crop at 30 DAS can be enhanced significantly with higher economics / returns in maize besides, increased soil moisture availability, infiltration rate and improved soil fertility.

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A Study on Entrepreneurial Behaviour and Readiness Among Agriculture Students of Farm Universities in Karnataka

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LEARNING entrepreneurship will become integral part of agriculture education which provides employment opportunities besides decent livelihoods. The present study was carried out in four farm universities of Karnataka *viz.,* Bengaluru, Dharawada, Raichuru and Shivamogga during 2019-20 to analyze entrepreneurial behaviour and readiness among agriculture students. Data was collected from 200 final year students from among four agricultural colleges located at headquarters of farm universities. Standardized scale to measure entrepreneurial behaviour was developed and used in the study. The study revealed that two fifth of the students (38.50 %) belongs to low level, followed by 36.00 and 25.50 per cent of the students had medium and high entrepreneurial behaviour, respectively. Among the student respondents 41.50 per cent were had low level of readiness towards entrepreneurship, followed by 37.50 and 21.00 per cent had medium and high level of readiness, respectively. The study also enunciated that annual income of the family, cosmopoliteness, aspiration, information seeking behaviour, perception, technical and scientific orientation had contributed significantly towards entrepreneurial behaviour and readiness. The R^2 value indicated that all the 15 independent variables had contributed to the tune of 79.90 per cent of variation in entrepreneurial behaviour and 73.40 per cent of variation in readiness among agriculture students, respectively. Initial financial hurdles to start an enterprise (94.50 %), lack of business orientation (92.50 %) and lack of communication skills (88.50 %) were the common constraints faced by agriculture students in opting entrepreneurship as their future career.

Impact of National Food Security Mission on Socio Economic Status of Farmers of Selected Districts of Karnataka

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THE present study was undertaken to assess the impact of National Food Security Mission on socio economic status of beneficiary farmers and their extent of adoption of NFSM interventions. Data was collected from 180 beneficiaries of NFSM from two selected districts *viz.,* Belagavi and Haveri in Karnataka state. Dataset retained an equal representation of beneficiaries in the selected NFSM components *viz.,* NFSM - Rice, NFSM - Pulse and NFSM - Coarse cereal. Standardised index for socio economic status was developed and used in the study separately for each NFSM component. The data was collected using structured pre-tested interview schedule. The overall mean index score of socio economic status for NFSM -Rice beneficiaries was found to be 2.008 before NFSM and 3.117 after NFSM. With regard to NFSM-Pulse beneficiaries the mean index score of socio economic status was 1.951 and 3.379 before NFSM and after NFSM, respectively. In case of NFSM-Coarse cereal beneficiaries 2.069 and 3.570 was the mean score of composite index before NFSM and after NFSM. Assessment on impact of NFSM on socio economic status revealed a significant difference at one per cent level in the socio economic status of the beneficiaries before and after NFSM with respect to all the studied components of NFSM. The results of adoption quotient index revealed that, before NFSM considerable number of beneficiaries belonged to medium adoption level whereas; in case of after NFSM the beneficiaries belonged to high adoption level category. The result concludes that the programme has made a significant impact on beneficiary farmers.

Participation of Farmers in Water Users' Associations in Tungabhadra Command Area of Koppal District

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THE present study was conducted in Tungabhadra command area at Koppal district of Karnataka during 2019-20. Data was collected from a sample of sixty head reach and sixty tail-end farmers. The results revealed that, majority of the head reach farmers had moderate (51.70 %) followed by poor (28.30 %) and better (20.00 %) level of participation in water users' associations. In tail-end location, 55.00 per cent of farmers had moderate followed by better (27.70 %) and poor (17.30 %) level of participation. The head reach farmers were having better participation with regard to the dimension of responsibility sharing whereas, in case of tail-end farmers, the participation was high with respect to crop planning activities. Inadequate training programmes conducted by WUAs and lack of knowledge on integrated crop management were major constraints expressed by head reach farmers. Whereas, lack of support from irrigation department and obstruction to water flow from head reach farmers were the prime constraints expressed by the tail-end farmers. Adequate training programmes to be conducted on water management and to provide information on integrated crop management practices were the important suggestions expressed by the head reach farmers. Whereas, proper support from irrigation department and coordination among the farmers to share water were the suggestions expressed by the tail-end farmers.

Comparative Evaluation of Entrepreneurial Behaviour of Fish Seed Rearing Farmers and Fish Producing Farmers in Shimoga District of Karnataka

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FISHERIES is a sunrise sector of our economy. Amidst the urbanization and globalization, entrepreneurship has strategic role for the overall development of the sector. The current study was conducted to comparatively evaluate entrepreneurial behaviour of fish seed rearing farmers and fish producing farmers in Shimoga district of Karnataka. Forty fish seed rearers and forty fish producers were selected from Shimoga and Bhadravathi taluks, respectively to constitute total sample size as 80 fish farmers. The data was collected by personal interview method and was analyzed using appropriate statistical tools. The findings revealed that entrepreneurial behaviour among fish seed rearing farmers was high (62.50%) and was medium (45.00%) among the fish producers. The variables for instance education, family size, pond size, annual income, mass media exposure and self-reliance were found to be significant at five per cent level. Use of recommended fish varieties was fully adopted (80.00 %) by both fish seed rearers and fish producers. Un-remunerative and fluctuating prices (80 %) was the major constraint faced by the fish seed rearers whereas loss of fish due to theft (80.00 %) was the major constraint faced by fish producers. The study evidences immense potential to develop entrepreneurial behaviour among fish farmers hence there is a thrust need to promote and develop the same.

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Analysis of Supply Chain Management of Green Leafy Vegetables in Bengaluru

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SUPPLY chain management is important in agribusiness sector. The most of the agricultural products are perishable and have a short shelf life. Bengaluru district is selected as the study area and there are many green leafy vegetables cultivated in and around Bengaluru district out of which the major green leafy vegetables such as amaranths, spinach, fenugreek, coriander and dill. The study aimed at analyzing cost of cultivation and marketing and to map the supply chain of these green leafy vegetables, apart from studying problems faced by retailers and consumers. Tabular analysis and Garrett's ranking technique were used to analyze the data, collected from 40 farmers, 30 consumers and 20 retailers involved in marketing of green leafy vegetables. The study revealed that among the selected green leafy vegetables, the total variable cost incurred is Rs.12,003.11 (74.34%) per acre. Per acre cost of cultivation worked-out to be, Rs.16,145.64 and the magnitude of B:C ratio was 3.32 : 1 there by indicated higher returns for every rupee invested in cultivation of amaranths, spinach, fenugreek, coriander and dill. The major marketing channel followed by the farmers involved APMC - commission agent / trader - wholesalers' - retailers - consumers (channel-I), procurement centers - company retail outlets - consumers (channel-II) and on farm sales to consumers (channel-III). This study discussed about the major constraints faced by retailers were more physical loss of produce and reduction in storage facilities. The study discussed about the major constraints faced by consumers *i.e.*, unhygienic conditions and improper packaging of green leafy vegetables in Bengaluru districts.

An Analysis of Consumer Behaviour and Purchasing Pattern of Organic Products in Bengaluru Urban District

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THE study was conducted in the Bengaluru urban district of Karnataka to assess the consumer behaviour and purchasing pattern towards organic products. The primary data was collected from 90 respondents. Among them, 45 respondents were selected from Bengaluru north and 45 respondents from Bengaluru south taluk of Bengaluru urban district from six organic outlets. The findings of the study revealed that 51.11 per cent of the respondents belonged to medium consumer behaviour category followed by high (35.56 %) and low (13.33 %) category. With respect to the frequency of purchasing 54.44 per cent of consumers purchased the organic products on a weekly interval followed by once in a while (36.67 %) and fortnightly (8.89 %). With respect to preferred place for buying organic products, more than two-third of the consumers (72.22 %) preferred to buy at exclusive organic outlets, followed by the super market (46.66 %), online (30.00 %), local markets (16.66 %), street vendors (14.44 %) and farmgate (6.66 %), respectively. Regarding consumer perception towards organic products, it was found that 46.67 per cent of consumers had an average perception towards organic products and 40 per cent of consumers had a better perception and 13.33 per cent of consumers had a poor perception towards organic products. Among socio-economic profiles, the variables like annual income, education and food habits show a positive relationship with consumer behaviour.

Performance Analysis of Custom Hiring Centres of Agricultural Implements in Chikkaballapur District of Karnataka

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A present study was conducted in Chikkaballapur district of Karnataka during 2019-20 with a sample of 66 respondents, among 60 samples were collected from custom hiring service providers and six samples from custom hiring service users. The data was collected by personal interview method using pre structured schedule to assess the function, status of usage of farm machineries and implements, economic feasibility of custom hiring services and constraints faced by the custom hiring service providers and users. The results revealed that CHCs of Chikkaballapur district were equipped with modern and advanced farm machineries and implements and all six CHCs, were running under profit. Majority of the farmers using tractor and power tiller about 96.67 and 90.00 per cent, respectively. Investment made on the purchase of tractor and power tiller by the custom hiring service providers was found to be economically feasible and in the case of mini tractor economically infeasible. High initial investment, high maintenance cost and seasonal demand for machineries were the major constraints faced by custom hiring service providers. Non availability of machineries during peak period, high hiring charges of custom hiring service and lack of skilled drivers were the major constraints faced by the custom hiring service users.

Studies on Sustainable Modules for Year Round Green Fodder Production under Irrigated Condition

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A field experiment entitled 'Studies on sustainable modules for year round green fodder production under irrigated condition' was conducted during *kharif, rabi* and summer seasons of 2018-19 and 2019-20 at Zonal Agricultural Research Station, Vishweswaraiah Canal Farm, Mandya. The experiment was laid out in randomized complete block design with fifteen fodder cropping system modules and replicated thrice. Pooled data revealed that, perennial system of B × N hybrid + Lucerne (2:8) recorded significantly higher green fodder yield (1636 q ha^{-1} $year^{-1}$), dry fodder yield (321 q ha^{-1} $year^{-1}$), carbon sequestration (24.87 Mg ha^{-1}) and net returns (Rs.2,14,232 ha^{-1} $year^{-1}$) followed by B × N hybrid + Cowpea (2:8) (1552 q ha^{-1} $year^{-1}$, 308 q ha^{-1} $year^{-1}$, 24.35 Mg ha^{-1} and Rs.1,96,354 ha^{-1} $year^{-1}$, respectively) and B × N hybrid + Sesbania (2:8) systems (1440 q ha^{-1} $year^{-1}$, 313 q ha^{-1} $year^{-1}$, 24.49 Mg ha^{-1} and Rs.1,66,528 ha^{-1} $year^{-1}$, respectively). However, B × N hybrid + Sesbania (2:8) system resulted higher quality fodder interms of crude protein (61.8 q ha^{-1} $year^{-1}$), ash (35.0 q ha^{-1} $year^{-1}$) and ether extractable fat yield (11.8 q ha^{-1} $year^{-1}$) but which was found on par with B × N hybrid + Lucerne (2:8) (60.2, 34.8 and 10.5 q ha^{-1} $year^{-1}$, respectively) and B × N hybrid + Cowpea (2 : 8) systems (56.0, 34.6 and 9.3 q ha^{-1} $year^{-1}$, respectively). Thus, farmers can adopt B × N hybrid + Lucerne (2:8) or B × N hybrid + Cowpea (2:8) or B × N hybrid + Sesbania (2 : 8) systems as a viable and profitable module for year round fodder production.

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Performance of Nutri-Cereals and Pulses under *Melia dubia* Based Agroforestry System

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FIELD experiment was conducted at Zonal Agricultural Research Station, GKVK, Bengaluru during *kharif* 2019 to study the 'Performance of nutri-cereals and pulses under *Melia dubia* based agroforestry system'. The experiment was laid out in randomized complete block design with ten treatments replicated four times. Treatments comprised of finger millet, foxtail millet, little millet, green gram and cowpea as intercrops with *Melia dubia* and their respective sole crops. The results of field experiment revealed that finger millet as intercrop performed better under *Melia dubia* in terms of grain (1850 kg ha^{-1}) and straw (2442 kg ha^{-1}) yield. The *Melia dubia* equivalent yield was higher in finger millet with melia based agroforestry system (4518 kg ha^{-1}) followed by sole finger millet (4395 kg ha^{-1}). The reduction in grain yield of intercrops of finger millet, foxtail millet, little millet, cowpea and green gram over their sole crops was to the extent of 8.05, 15.66, 16.32, 7.57 and 4.10 per cent, respectively. The biomass obtained from *Melia dubia* was 599 kg ha^{-1} and the average amount of carbon sequestered was1097 kg ha^{-1}. Finger millet crop associated with *Melia dubia* tree gave higher gross returns (Rs. 67,767 ha^{-1}) and B : C ratio (3.1) when compared to other treatments.

Response of Chia (*Salvia hispanica* L.) to Different Sources and Levels of Organics in Southern Transitional Zone of Karnataka

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A field experiment was conducted at College of Agriculture, Hassan during *kharif*-2019 on 'Response of chia (*Salvia hispanica* L.) to different sources and levels of organics in southern transitional zone of Karnataka'. The experiment was laid out in RCBD with nine treatments and three replications. The treatments comprised of different sources and levels of organics *viz.*, FYM (5, 10 and 15 t ha^{-1}), vermicompost (5, 10 and 15 t ha^{-1}) and pressmud (5, 10 and 15 t ha^{-1}), respectively. The results indicated that application of pressmud @ 15 t ha^{-1} recorded significantly higher growth, yield parameters and grain yield (1277 kg ha^{-1}) and it was on par with the treatment receiving vermicompost @ 15 t ha^{-1} (1137 kg ha^{-1}). Lower yield was recorded with application of FYM @ 5 t ha^{-1} (540 kg ha^{-1}). Higher soil nutrient status was also seen in the treatment receiving pressmud @ 15 t ha^{-1} (Nitrogen, Phosphorus and Potassium). Higher net returns and B : C ratio were also realized with application of pressmud @ 15 t ha^{-1} (Rs.1,71,154 ha^{-1} and 6.1, respectively) and it was on par with the application of vermicompost @ 15 t ha^{-1} (Rs.1,47,885 ha^{-1} and 5.3).

Studies on the Pollinator Fauna of Pomegranate, *Punica granatum* L. (Lythraceae)

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THIS investigation was carried at the Departments of Apiculture and Horticulture, UAS, Bangalore and farmers field Koramangala, Devanahalli during 2019-20. Flower initiation in pomegranate (var. : 'Bhagwa') commenced at 21.11± 1.86 days after bud development. Staminate: hermaphrodite flower ratio was 0.40 ± 0.831, with mean of 20.66 ± 6.12 staminate and 27.53 ± 6.95 hermaphrodite flowers. Staminate and hermaphrodite flowers opened during 0800-1300 and 0800-1400 hours, respectively. Anthers dehisced at 0800-1300 (staminate) and 0900-1200 (hermaphrodite) hours after anthesis. Fruit set was highest in the plants when flowers were kept in unbagged condition (10.7 ± 2.08) compared to the bagged condition (3.85 ± 1.22). Totally 20 insect species were found foraging on the inflorescence of pomegranate and they belonged to three insect orders *viz.,* Hymenoptera (40 %), Lepidoptera (55 %) and Hemiptera (5 %). Shannon-Wiener diversity index (H) values ranged from 0.05-0.23 during different hours of the day, with peak 'H' values during 0900 - 1100 hrs (0.54-0.52). Berger-Parker dominance index (d) was highest for *A. dorsata* (d=0.38). *A. dorsata, A. cerana*, *A. florea* and *T. iridipennis* spent upto 11.24 ± 1.31, 12.61 ± 1.29, 16.86 ± 2.08 and 25.73 ± 1.88 sec / staminate flower and 7.94 ± 0.87, 10.30 ± 0.98, 14.55 ± 1.21and 24.13 ± 1.68 sec / hermaphrodite flower, respectively. All four species of honey bees spent maximum foraging time during 1100-1200 hrs. *A. dorsata* (5.95 ± 1.00) *A. cerana* (5.18 ± 0.68), *A. florea* (4.39 ± 0.67) and *T. iridipennis* (4.20 ± 0.82) visited more number of staminate flowers as compared to hermaphrodite flowers (4.81 ± 1.06, 4.12 ± 0.84, 3.55 ± 0.38 and 3.44 ± 0.59), respectively. Significantly highest yield and qualitative parameters were recorded in the fruits obtained from open pollinated flowers, followed by pomegranate plants enclosed with *A. cerana* colony.

Development of Nutritionally Enriched Gluten Free Pasta Using Quality Protein Maize (QPM)

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A study was conducted on development of nutritionally enriched gluten free pasta using quality protein maize (QPM). Gluten free pasta was developed using QPM (Q), black gram flour (B) soya flour (S), spirulina (Sp) and guar gum (G) in different proportions by taking whole wheat flour (100 %) as control. The different ratios of QPM and spirulina incorporated pasta were evaluated by subjective and objective methods. The best accepted ratio of QPM and spirulina incorporated pasta along with control were evaluated by assessment of characteristics such as cooking quality, physico-chemical properties, nutritional quality, storage stability, micro structural and consumer acceptability studies. Among the various blends studied, Q_2 (60Q:30B:8S:2G) and S_3 (60Q:30B:2S:6Sp:2G) had better acceptance as compared to other combinations tested. Incorporation of spirulina powder improved the cooking and physical parameters as compared to QPM and control pasta. Spirulina pasta was found to be nutritionally superior compared to control pasta due to increased nutrient content-protein (53 %), calcium (35 %), iron (46 %), zinc (17 %) and carotenoid contents (94 %). Incorporation of spirulina powder has lead to the improvement in microstructure of spirulina pasta as compared to QPM and control. Thus, study demonstrated that acceptable nutritionally enriched gluten free pasta suitable for all age group of people who are allergic to gluten can be prepared by combination of QPM, pulses and spirulina. Even the product provides dietary diversity to normal consumers.

Studies on Performance of Sorghum [*Sorghum bicolor* (L.) Moench] Genotypes on Seed Yield, Quality and Longevity

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FIELD experiment was conducted to determine the performance of sixteen sorghum genotypes for seed yield and also to study the seed and plant morphological characteristics at AICRP on sorghum, Haradanahalli farm, Chamarajanagara, during *kharif* 2019 and the laboratory experiment on seed quality and longevity at the Department of Seed Science and Technology, UAS, GKVK, Bengaluru. The results indicated that, among the genotypes significant differences were noticed plant height, days to 50 per cent flowering, days to maturity, peduncle length, ear head length and ear head width, seed yield / plant and seed yield (kg / ha) which varied from 133.47 to 319.47 cm, 52 to 75 days, 91 to 117 days, 28.93 to 38.33 cm, 17.80 to 26.60 cm, 4.63 to 6.77 cm, 13.04 to 28.93 g and 1933 to 4285 kg / ha, respectively. Similarly, genotypes showed variations in seed morphological characteristics (seed size, colour, shape and luster) and seed coat colour rection to different chemical tests (KOH, NaOH and KOH-Bleach). Among the 16 genotypes were observed for growth, seed yield and quality traits and also for seed coat colour reactions. Among 16 genotypes SPV 462, CSV 15, CSV 27 and CSV 23 are best performers for seed yield attributing characters. The genotypes CSV 15, CSV 23, CSV 17, DSV 6, SSV 84 and Gundlupet Local proved as good storers.

Influence of Planting Geometry on Growth, Seed Yield and Quality of Velvet Bean (*Mucuna pruriens* var. *utilis*)

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A field investigation was conducted on 'Influence of planting geometry on growth, seed yield and quality of velvet bean (*Mucuna pruriens* var. *utilis*)' during *kharif* season of 2019 at ZARS, GKVK, Bengaluru. The experiment was laid out in factorial randomized block design and replicated thrice. The experiment consists of five planting geometries (60 × 45 cm, 60 × 60 cm, 90 × 45 cm, 90 × 60 cm, 45 × 45 cm,) and two varieties (Arka Daksha and Arka Ashwini). The planting geometries and varieties significantly influenced the growth, yield and seed quality parameters. Among the planting geometries, significantly higher plant height at harvest (282.2 cm) was observed under 60 × 45 cm while significantly higher trifoliate leaves at 60 DAS (71.35) and number of branches at harvest (5.67) were recorded with 90 × 60 cm. However, significantly higher yield parameters *viz.,* number of pods (21.97 plant^{-1}), pod length (12.60 cm), 100 seed weight (143.72 g), seed yield (23.48 q ha^{-1}) and seed quality parameters *viz.,* germination (94.83 %), seedling vigour index I (2958), seedling vigour index II (450) were noticed under 90 × 45 cm. Among the varieties, Arka Daksha resulted in significantly higher plant height (268.93), number of pods (20.71 plant^{-1}), number of seeds (5.63 pod^{-1}), seed yield (21.09 q ha^{-1}), germination (92.41 %), seedling vigour index I (2704) and seedling vigour index II (399). The significantly higher net returns (Rs.1,33,308) and benefit cost ratio (4.52) were realized with Arka Daksha sown at 90 × 45 cm spacing.

Influence of Seed Enhancement Techniques on Seed Quality and Longevity in Chilli (*Capsicum annuum* L.)

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The experiment was conducted to study the influence of seed enhancement techniques on seed quality and longevity in chilli hybrid NWH 001, during 2019-2020. Initially, standardization was done for seed priming and pelleting treatments. Among 12 different priming treatments, seeds primed with KNO_3 (0.5 %), *Pseudomonas fluorescens* (1 L/kg) and vermiwash (30 %) showed highest germination (93, 94.5 and 94.5 %), speed of emergence (22.98, 22.3 and 24.77), seedling vigour index (1002, 1000 and 988), seedling emergence in protray (93.5, 93.0 and 94.5 %) and seedling height @ 30 DAS (13.7, 12.4 and 12.5 cm) over control. Among 10 different pelleting treatments, seeds pelleted with $ZnSO_4$ (3 g/kg), CaO_2 (10 % w/w) and arappu leaf powder (100 g/kg) showed highest germination (89.5, 89 and 90.5 %), speed of emergence (33.0, 33.3 and 33.9), seedling vigour index (885, 883 and 905), seedling emergence in protray (92.3, 88.0 and 87.0 %) and seedling height at 30 DAS (12.2, 12.2 and 12.3 cm). Best three priming and pelleting treatments were stored for six months under ambient and cold storage conditions for further evaluation of seed longevity. Seed quality parameters were in descending trend as storage period progresses. After one month storage, drastic reduction of 19.8 and 43.1 per cent seed germination was recorded in pelleted (arappu leaf powder) and bioprimed (*Pseudomonas fluorescens*) seeds, respectively. Chilli seeds either primed or pelleted can be stored only for shorter duration. However, seeds primed with vermiwash (30 %) maintained the seed quality even after six months (93.0 %) of storage.

Studies on Seed Yield and Quality of Paddy Genotypes Under Direct Seeded Rice Method

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Present investigation was conducted during *kharif* 2019 at I-Block, ZARS, V.C. Farm, Mandya, UAS, GKVK, Bengaluru to investigate the effect of DSR method on growth and yield of eight genotypes and also to know the influence of pre-sowing seed treatment on seed quality and yield of hybrid KRH 4. The field experiment was laid-out in randomized complete block design with three replications. The results revealed that growth and yield parameters differed significantly among paddy genotypes. The hybrid KRH 4 recorded significantly earlier days to 50 per cent flowering (89.00) and maturity (118.00), maximum filled grains panicle^{-1} (153), grain yield hectare^{-1} (59.50 q), test weight (19.11 g) and the lowest was registered in MTU 1001 (94.67, 127.67 days, 65.00, 37.5 q, 20.30g, respectively). Among the pre-sowing seed treatments, significantly higher seed germination, α-amylase activity, TDH and lower electrical conductivity was recorded in seed priming with $ZnSO_4$ @ 3 per cent (97.33 %, 1.35 mm, 1.58 (A_{480}), 109.09 µSm^{-1}, respectively) and lowest in all the seed quality was recorded in untreated control except electrical conductivity of seed leachates which was highest (89.66 %, 0.74 mm, 0.83(A_{480}), 188.44 µSm^{-1}, respectively). So also, Seed priming with $ZnSO_4$ @ three per cent expressed significantly the higher field emergence (92.33 %), earlier days to 50 per cent flowering (85.13) and maturity (114.83), more filled grains panicle^{-1} (240.06), grain set (89.17 %), grain yield hectare^{-1} (63.20 q) and the lowest was recorded in untreated control (85.00 %, 90.33, 119.89 days, 149.67, 75.33 %, 59.50 q, respectively).

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Augmenting the Productivity of Maize (*Zea mays* L.) through Designer Seed

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THE field experimentwas conducted at National Seed Project, UAS, GKVK, Bengaluru during 2019-2020 to know the influence of designer seed on seed quality, crop performance and seed yield in maize. This experimentwas laid out in randomized complete block design (RCBD) with three replications consisting nine treatment combinations. The results revealed that, all the pelleting treatments enhanced the crop performance and seed yield. Among the treatments, seeds pelleted with Polymer @ 4.0 ml / kg + Metalaxyl @3.0 g / kg + (Cyantraniliprole + Thiomethoxam) @ 4.0 ml / kg + Zinc @ 2.0 g / kg + Atrazine @ 10 g / kg + *Azotobacterchroococcum* @ 2 g / kg seeds (T_5) recorded less seed mycoflora (2.00 %), highest field establishment (76.33 %), plant height at 15, 30, 60 DAS and harvest (21.08 cm, 57.02 cm, 132.31 cm and 211.41 cm, respectively), number of leaves per plant at 30, 60 DAS and harvest (6.73, 11.53 and 13.73, respectively) and took least days to initiation of 50 per cent tasseling (54.93), least days for 50 per cent silking (58.07), early maturity (118.47), higher cob length (19.86 cm), cob diameter (19.05 cm), number of cobs per plant (1.53), number of seeds per row (19.47), 100 seed weight (35.97g), cob dry weight (317.53g), seed yield per cob (269.67 g), seed yield per plant (413.04 g), seed yield per plot (15.11 kg) and seedyield per hectare (107.59 q) with cost-benefit ratio of 1 : 2.69, followed by treatment with polymer @4.0 ml / kg + DAP @4.0 g / kg + Zinc @2.0 g / kg + Atrazine @ 10 g / kg + *Azotobacter chroococcum* @2 g / kg seeds (T_9). Magnitude of seed enhancement is higher in T_5 and T_9 with better benefit cost ratio hence, these treatments could be used in maize to enhance crop performance, seed yield and quality.

Enhancing Water Productivity in Mulberry through Different Levels of Drip Irrigation and Mulching

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THE research entitled 'Enhancing water productivity in mulberry through different levels of drip irrigation and mulching' was conducted at Department of Sericulture, UAS, GKVK, Bengaluru during *rabi* 2019. There were eight treatment combinations comprising of two mulching and four irrigation levels replicated five times and laid out in strip plot design in drip irrigation. Results revealed that growth, yield and quality parameters of mulberry and water productivity were significantly influenced by mulching and different levels of irrigation. Among different levels of irrigation 0.8 CPE recorded higher growth, leaf yield (47613 kg ha^{-1} $year^{-1}$) and leaf quality parameters like moisture content (66.80 %), chlorophyll (7.44 µg cm^2), protein (14.39 %), carbohydrate (16.50 %), nitrogen (2.32 %), phosphorous (0.57 %) and potassium contents (1.51 %) compared to lower levels of irrigation 0.5, 0.6 and 0.7 CPE. Mulching with black plastic polythene recorded significantly higher growth, leaf yield (45143 kg ha^{-1} $year^{-1}$) and quality parameters like moisture content (65.60 %), chlorophyll (6.80 µg cm^2), protein (12.63 %), carbohydrate (15.86 %), nitrogen (2.02 %), phosphorous (0.48 %) and potassium contents (1.51 %) compared to plants without mulching. Higher water productivity (589.59 kg ha cm^{-1}) and higher water saving percentage (7.41 %) found in mulching compared to without mulching. Cost-benefit ratio also found highest in 0.8 CPE along with mulching (1 : 2). These results showed that drip irrigation at 0.8 CPE along with mulching is appropriate to enhance leaf yield and water productivity in mulberry.

Genetic Variation for Vegetative, Reproductive and Fruit Traits in Mulberry (*Morus* spp) Accessions

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EVALUATION of 71 mulberry (*Morus* spp) accessions was conducted to study genetic variation for vegetative, reproductive and fruit traits during rainy and winter seasons of 2019-20. MI 232 and MI 143 recorded more leaf yield plant^{-1} (2975.61 & 2908.89 g) in rainy and winter seasons, respectively. ME 182 (male) and S 34 (female) were recorded highest inflorescence length during rainy and winter seasons. MI 556 recorded maximum fruit length and width, M 5 recorded maximum number of fruits branch^{-1} (12.66). China white recorded highest fruit weight (45.72 g) and number of fruits plant^{-1} during rainy season. In winter season MI 231 recorded maximum fruit length, width, number of seeds fruit^{-1}, *M. laevigata* recorded more number of fruits branch^{-1} (6.33). High PCV and GCV were estimated for number of branches plant^{-1}, leaf area at 45th , 60th ,75th DAP, leaf yield plant^{-1}, inflorescence length, fruit length, fruit width, fruit weight, number of seeds fruit^{-1}, fruit branch^{-1} fruit plant^{-1} in rainy and winter season. High heritability coupled with high genetic advance as per cent of mean in respect of plant height, leaf area at 45th , 60th , 75th DAP, number of branches and leaf yield plant^{-1}, inflorescence length, inflorescence breadth, fruit length, fruit width, fruit weight, number of seeds, fruits branch^{-1}, fruits plant^{-1} in both rainy and winter seasons. Leaf yield positively correlated with plant height at 45th DAP, leaf area at 45th, 60th, 75th DAP in rain and winter season. Number of fruits plant^{-1} positively correlated with leaf area at 45th, 60th DAP in rainy and winter seasons.

Effect of Leaching and Amendemnts on Reclamation and Performance of Fodder Maize in Spentwash Contaminated Soil

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THE surface soil (0-15 cm) contaminated with distillery spentwash was collected near the vicinity of NSL Sugars Limited, Koppa, Maddur, Karnataka. The soil had clay loam texture with saline soil characteristics (pH of 8.48, EC of 4.50 dS m^{-1} and ESP of 13.61). To study the possible reclamation strategies, pot culture experiments were conducted at Zonal Agriculture Research Station, V.C. Farm, Mandya during 2019-20, using gypsum (G) and elemental sulphur (S) (@ 50 % GR) as soil amendments with or without organic manure (OM) (@ 10 t ha^{-1}). Ten leachings @ 5 cm ha^{-1} leaching^{-1} was imposed commonly to all the treatments. The highest reduction in EC, Na^+, SAR and Cl^- content was observed with application of G + OM while, S + OM was most effective in reducing the pH and carbonate content of spentwash contaminated soil. The leaching curves developed for desalinization and desodification showed lowest 'k' values (0.113 and 0.160, respectively) in G + OM treatment over the control (0.169 and 0.216, respectively) indicating its higher reclamation efficiency with less quantity of water. An average amount of 37.5 cm ha^{-1} irrigation water was found to be sufficient to leach 50 per cent of initial salt load of contaminated soil. This amount of water along with amendments were used to reclaim the contaminated soil and further to study the performance of fodder maize. Application of S + OM resulted in highest germination, growth parameters, green fodder yield (298.45 g plant^{-1}), nutrient content and uptake by fodder maize, followed by application of G + OM treatment.

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Studies on Bio-enriched Farm Yard Manure (FYM) on Soil Properties and Productivity of Finger Millet [*Eleusine coracana* (L.) Gaertn] under Dryland Condition

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A field experiment was conducted during *kharif* 2019 at AICRP for Dryland Agriculture to study the effect of bio-enriched FYM *viz*., nitrogen fixers, phosphorus solubilizers, potassium solubilizers, PGPR and microbial consortia with two levels of RDF*viz*., 60 and 80 per cent on soil properties and productivity of finger millet, replicated thrice in f-RCBD comprising ten treatments. The growth and yield attributes showed an increasing trend with application of microbial consortia bio-enriched FYM + 80 per cent RDF with significantly higher grain yield (2999 kg ha^{-1}) and straw yield (4274 kg ha^{-1}) and higher B : C ratio (2.30). The combination of microbial consortia bio-enriched FYM + 80 per cent RDF proved to be the best treatment in terms of uptake of nitrogen (6.33, 21.68, 45.39 and 70.58 kg ha^{-1}), phosphorus (0.87, 3.95, 9.85 and 21.40 kg ha^{-1}) and potassium (4.28, 18.58, 41.98 and 59.84 kg ha^{-1}) at 30, 60, 90 DAS and at harvest, respectively. Similar was the trend with respect to secondary and micronutrient uptake. No significant variation was recorded in terms of soil physical parameters. However significant increase in major nutrient status of soil was recorded resulting in 4.35, 1.14 and 5.24 per cent higher available NPK content of soil over its initial value. Soil microbial biomass carbon, nitrogen, phosphorus and dehydrogenase activity was significantly higher in bio-enriched FYM + 80 per cent RDF. Thus, combined application of inorganic fertilizers and microbial consortia bio-enriched FYM was found to be the suitable nutrient management strategy for yield enhancement and soil health maintenance under dry land condition.

Soil and Foliar Application of Zinc for Different Approaches of Nutrients on Soil Properties, Nutrient Uptake, Growth and Yield of Maize (*Zea mays* L.)

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A field experiment was conducted during *kharif 2019* at Bellathur village of Gowribidanur taluk in Chikkaballapur district to study the influence of soil and foliar application of zinc for different approaches of nutrients on soil properties, nutrient uptake, growth and yield of maize. The experiment was laid out in RCBD with nine treatments and replicated thrice. The results revealed that STCR integrated (90 q targeted yield) with 10 kg ha^{-1} $ZnSO_4$ as soil application + 0.5 per cent $ZnSO_4$ as foliar spray has significantly increased the plant height (193.40 cm), number of leaves (14.90), cob length (19.00 cm), number of rows per cob (16.50), number of kernels per row (28.85) and test weight (31.30 g), kernel yield (91.83 q ha^{-1}) and stover yield (118.24 q ha^{-1}). Similarly, higher uptake of nitrogen, phosphorus, potassium and zinc (280.20 kg ha^{-1}, 46.91 kg ha^{-1}, 245.93 kg ha^{-1} and 842.95 g ha^{-1}, respectively) were recorded in STCR integrated (90 q targeted yield) with 10 kg ha^{-1} $ZnSO_4$ as soil application + 0.5 per cent $ZnSO_4$ as foliar spray. However, higher cost benefit ratio of 2.97 was found in STCR inorganics (90 q targeted yield) with 10 kg ha^{-1} zinc sulphate as soil application + 0.5 per cent zinc sulphate as foliar spray.Application of STCR based integrated nutrient with soil and foliar application of zinc enhanced the growth and yield of maize to achieve the targeted yield (90q ha^{-1}).

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Impact of Rice Husk Biochar on Adsorption, Bioavailability and Balance of Nitrogen in Differentsoils for Maize (*Zea mays* L.)

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A study was conducted to know adsorption of different forms of nitrogen by using graded levels (0, 4, 8 t ha^{-1}) of rice husk biochar (RHB) in different soils (acidic, neutral and alkaline) with urea, KNO_3 and NH_4Cl as N sources. A pot culture greenhouse study was also conducted to know the effect of graded levels (0, 2, 4, 8 t ha^{-1}) of RHB and different sources of nitrogen on balance and bioavailability of nitrogen for maize. The study revealed that, irrespective of soils, application of RHB @ 8 t ha^{-1} along with urea as N source recorded higher adsorption of NH_4^+-N compared to NO_3^--N. The pot culture experiment revealed that, application of increased levels of RHB, decreased the NH_4^+-N and increased the NO_3^--N content in all three studied soils. Higher plant height, shoot dry biomass and N uptake by maize was recorded in neutral soil with application of RHB @ 4 t ha^{-1} along with KNO_3 as N source. Application of graded levels of RHB along with different sources of N increased the N balance and decreased the net nitrogen gain in all the soils. In general, combined application of RHB at varied rates along with different sources of N decreased the nitrogen accumulation efficiency (NAE) and increased the nitrogen use efficiency (NUE) and enhanced the bioavailability of N for maize in all the soils.

Effect of Foliar Application of Micronutrients Mixture on Growth and Yield of Paddy Grown in Sodic Soil

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THE micronutrients mixtures (MM) containing Zn:Mn:Cu:B:Mo in the ratio of 14:5:4:1.4:0.2 (Grade-I) and 10:6:5:2:0.4 (Grade-II) were formulated and tested against commercial grade (CG) MM on paddy at ZARS, V.C. Farm, Mandya during *kharif* 2019-20, either as single or two sprays at 30 and 45 days after transplanting, along with RDF alone and RDF + Soil application (SA) of Zn treatments. Two sprays of G-I MM (T_4) recorded significantly higher plant height (76.30 cm), no. of tillers per m^2 (637), dry matter production (30.96 g hil^{-1}) and yield parameters *viz*., no. of panicles m^{-2} (294), panicle length and weight (23.25 cm and 3.3 g), filled grains per panicle (130), grain (47.11 q ha^{-1}) and straw yield (63.14 q ha^{-1}) with higher net returns of Rs.38721 ha^{-1} and B:C of 1.66 as compared to other treatments. Two sprays of G- II MM (T_6) has also enhanced paddy yield but, the economic benefit (B:C-1.54) was lesser than T_4. Foliar application of CG MM (Zn:Fe:Mn:B- 3:2:1:0.5) either as two (T_8) or single spray (T_7) recorded higher yield than RDF alone however, was less effective compared to RDF + SA of zinc. The highest concentration of N, P, K and Ca in index leaves, grain and straw was recorded in T_4, Mn, Cu and B in T_6 that established positive correlation with paddy yield while, Mg, S and Fe content was highest in T_8 that showed negative correlation, signifying the importance of crop and soil specific micronutrients mixture.

Effect of Soil and Foliar Application of Boron on Soil Properties, Growth, Yield and Quality of Green Gram (*Vigna radiata* L.)

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A field experiment entitled 'Effect of soil and foliar application of boron on soil properties, growth, yield and quality of green gram *(Vigna radiata* L.)' was carried out during *kharif* 2019-20 at ZARS, UAS, GKVK, Bengaluru. The experiment comprised of twelve treatments, replicated thrice with RCBD. The results indicated that significantly higher available nitrogen (275.3 kg ha^{-1}), available potassium (156.74 kg ha^{-1}), exchangeable calcium (2.88 c mol (p^{+}) kg^{-1}) and available sulphur (275.3 kg ha^{-1}) were recorded in package of practice (FYM 7.50 t ha^{-1} + NPK 12.5:25:12.5 kg ha^{-1} + $ZnSO_4$ 10 kg ha^{-1}), while significantly higher available phosphorus (28.12 kg ha^{-1}) and available boron (0.57 mg kg^{-1}) were recorded in treatment which received soil application of borax at 7.50 kg ha^{-1} along with package of practice. Whereas, soil application of borax at 2.50 kg ha^{-1} + foliar application of boric acid at 0.1 per cent along with package of practice recorded significantly higher plant height (50.82 cm), number of branches $plant^{-1}$ (8.29), seed yield (10.19 q ha^{-1}), haulm yield (2.17 t ha^{-1}) and B:C ratio (1.96). While, significantly higher crude protein content (25.38 %) in seed was noticed in treatment which received soil application of borax at 5.00 kg ha^{-1} + foliar application of boric acid at 0.1 per cent along with package of practice. However, soil application of borax at 7.5 kg ha^{-1} along with package of practice recorded significantly higher uptake of boron (36.62 and 64.33 g ha^{-1}) by seed and haulm of green gram, respectively.

Studies on Characteristics of Dumping Yard Leachate from Municipal Solid Waste and their Impact on Soil, Water, Crop and Human Health

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The leachate produced from municipal solid waste open dumping site of Bengaluru, India was examined to know leachate transfer potential, pollution potential and enumeration of microbial population to know the spatial and temporal variation in soil, ground and stream water. To know the impact of leachate at different leachate concentration (0, 10, 20, 30, 40 and 50 %) on growth and biomass production of cabbage was conducted under greenhouse condition. The survey has also been conducted for correlating the facts regarding human health. The leachate collected during summer has higher leachate pollution index followed by winter and rainy season. Potentially heavy metals in leachate derived from dumping site have transfer potential till three to four km in soil and ground water and till 5th km in stream water. Cordially high content of heavy metals in the leachate, the groundwater and soil near the dumping site are polluted may be due to redox potential. The enumeration of microbial population in ground water and stream water resulted as increase in population with decrease in distance in summer followed by winter and rainy season. The survey results are also in line with information collected from primary health centre regarding human health and results obtained.

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Provenancial Variation in *Mesua ferrea* L. : A Promising Tree-Borne Oilseed for Biodiesel Production

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Provenance influence on growth, seed quality, oil content, fatty acid profile and biodiesel production of *Mesua ferrea* were evaluated in South Western ghats of Karnataka during 2019-2020. Experiments are undertaken in the already existing trees at four different districts with varying altitudes (114-950.95 m). There was a significant effect of site conditions on various growth and productivity parameters. The seed and kernel parameters were significantly influenced by different locations and sites. Kernel oil yield varied from 63.30 to 79.46 per cent. The GC-MS chromatogram of the oil indicated the presence of 5 to 10 compounds, of which 4 to 5 were identified as the major compounds viz., oleic acid range from 45.25-52.32 per cent, linoleic acid range from 15.54-28.43 per cent, palmitic acid range from 16.29-20.43 per cent, stearic acid range from 7.34-14.9 per cent and arachidic acid range from 0.50-1.32 per cent. The biodiesel having kinematic viscosity of 4.32 mm^2/s (at 40 °C), density as 879.7 (kg/m^3 at 30 °C), caloric value of 39.37 (MJ/kg), acid value was 0.45 (mg KOH/g), Iodine value of 63.33 ($gI_2/100g$), saponification value 242.88 with 96.7 per cent FAME yield was obtained under the optimal condition. The biodiesel parameters fit into the ASTM standards. *Mesua ferrea* has the potential to capture medicinal and biofuel sector, due to its high oil content, oil quality and biodiesel production potential.

Utilization of Medicinal Plant Processing Waste for Electricity Generation through Biomethanation

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The study was undertaken to investigate the generation of biogas from medicinal plant processing waste. In order to know biogas production and methane content, medicinal plant processing waste samples were kept an aerobically for two-months in lab-condition. *Carica papaya* leaf and *Azadirachta indica* yields about 11320 ml and 10610 ml of biogas with 62.98 and 74.12 per cent of methane content which were observed highest. *Garcinia gummi-gutta* and *Cinnamomum verum* were the lowest biogas yielders. An investigation was conducted to know the performance evaluation of 500 m^3 biogas power plant located in Prakruti Products Pvt. Ltd, Ankola. An average biogas generated about 560.37 m^3 per day in the temperature range between 20 to 30 °C. CO_2 and H_2S was removed by water scrubbing method and methane content was measured. It was found that, the methane content after purification was increased up to 22 per cent than before purification. The collected pressurized biogas from the digester was transferred to the generator and produces the electricity of about 645.24 kWh and utilized for various operations in the plant. As per the data assessed from the biogas power plant it summarised that, biogas power plant has economically viable and environmentally sustainable. It was concluded that, instead of dumping or burning of medicinal plant processing waste and causing different types of pollution in the environment, this is the best method of utilization of waste to convert energy in a good manner.

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