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Improvement and production technology of bael *(Aegle marmelos)* in India — a review

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ABSTRACT

Bael [*Aegle marmelos* (L.) Correa ex Roxb.], belongs to family Rutaceae, is one of the oldest known indigenous fruit. Its wide distribution reflecting its adaptation to wide range of edaphoclimatic conditions. Bael has ability to withstand harsh climate and tolerate heat, drought and moisture deficit situations.The efforts have been made to present the current status of bael growing in India, and discuss recent technologies adopted for bael fruit production i.e. improved varieties, propagation techniques, planting systems, canopy management, water and nutrient management, quality management, pest and disease management, physiological disorders, marketing and export scenario.

Key Words: Varieties, Improvement, Cauliflory, Metaxenia, High density planting, Propagation, Production

Bael *(Aegle marmelos)* is a subtropical plant and grows up to an altitude of 1,200 msl and is not damaged by temperature as below as low as-7°C, but under arid conditions of Bikaner, leaves, twigs and fruit are affected by low temperature less than 2°C (Singh *et al.*, 2019a). It grows well in dry forests on hilly and plain areas, and is said to do the best on rich, well-drained soil, but it grows well and fruited even on limestone of southern Florida. It also grows well in swampy, alkaline or stony soils having pH of 5 to 10 (Saroj *et al.*, 2006). This tree requires pronounced dry season to give fruit. It has ability of thriving where other fruit trees can not survive (Singh *et al.*, 2019e).

Different parts (leaves, roots, barks, seeds and fruits) of the plant have been used in the formulation of enthno-medicine to exploit its therapeutic properties (Singh *et al.*, 2019a). Bael *(Aegle marmelos)* is a rich source of bioactive compound, the compounds purified from bael have been proven to be biologically active against several major ailments and it is an impotant ingredient of several traditional formulations against various diseases (Singh *et al.*, 2020d,). Now-a-days world market for functional foods and natural antioxidants are growing rapidly.Bael can pay major role in the form of functional food and fortified value added products (Singh *et al.*, 2020d). A number of value added products such as squash, *murabba*, fruit slab, toffee, powder, jam etc. are prepared from bael (Singh *et al.*, 2013a, 2019a, 2018a).

Bael is a widely distributed plant and found in India, Ceylon, China, Nepal, Sri Lanka, Myanmar, Pakistan, Bangladesh, Nepal, Vietnam, Laos, Cambodia, Thailand, Indonesia, Malaysia, Tibet, Sri Lanka, Java, Philippines and Fiji (Singh *et al.*, 2018d). Though, bael is a fruit crop of subtropical origin, it has wider adaptability and can perform in rainfed hot semi-arid conditions (Singh *et al.* 2019a, 2018a).A little research work is being carried out in Sr Lanka and Bangladesh. At the global level, India ranks first in area and production and productivity of bael.

Generally, its plantations are made as boundary plants, premises of temples or in home gardens. Some seedling plantations are available in natural forest areas. Recently, some progressive farmers of Rajasthan, Chhattishgarh, Madhya Pradesh, Punjab and Gujarat have started planting bael variety Goma Yashi on large

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scale in the form of orchard or as boundry plantation (Singh *et al.* 2018d). About 8000 ha area is under plantation of improved variety of bael in country with approximately 70,000 tonnes of production. Among the varieties, Goma Yashi, NB-5, NB-9 and CISHB-1 have coverd about 90 per cent area in different states of country.

Pollination and fruiting pattern

The stem is short, thick, soft, flaking bark, and spreading, sometimes spiny branches, the lower ones drooping (Singh *et al.* 2014h and 2018d). A wide range of variability with respect to leaf morphology (shape, margin, base and apex) has been observed in different bael germplasm (Singh *et al.*, 2015a 2018b, 2019b). It has also been observed that in place of leaflets (trifoliate), 4-8 leaflets may also be found rarely in bael germplasm (Singh *et al.*, 2015b, 2019e, 2019f). Leaf character and growth pattern in the form of erect, spreading; semi-spreading, spreading and drooping type in different germplasm of bael have been reported by Singh *et al.* (2008a, 2012b, 2014h, 2015a). Considerable variation in thorn orientation, its number, size and shape is found in different genotypes whereas thorn is small and stout, three thorns can be seen at a node (Singh *et al.* 2008b, 2018a, 2018b). Goma Yashi is thornless under rainfed semi-arid conditions (Singh *et al.*, 2010a, 2019e).

The thorn may be seen on primary branches but not at secondary or tertiary branches under dryland conditions, and these may vary in different agroclimatic conditions (Singh *et al.* 2012a, 2015c, 2018c and 2018d). Bael is an ideal cauliflorous example of fruit tree (Singh *et al.*, 2018b). Generally, cauliflorous blossoms are sturdy and well attached and can withstand adverse climatic conditions (Fig. 1). Flowering and fruiting can be seen from current season's shoot to 10-year-old shoots even on main trunk (Singh *et al.*, 2019f). Metaxenia effect (2-5%) on fruit shape and ripening has been observed in differet genotypes of bael (Singh *et al.*, 2019f) (Fig. 2).

The pollination increases fruit setting which varies greatly in different cultivars depending upon amount of functional pollen grains, the relation of pollen grains to setting. Clonal variation in inflorescence and flower morphology was also reported by Singh *et al.* (2014a, 2018b). Fragrant flowers, in clusters of 4 to 7 along the young branchlets, have 4 or 5 curved, fleshy petals, green outside, yellowish inside, and 50 or more greenish-yellow stamens (Singh *et al.* 2019b). No instance of metaxenia phenomenon has ever been described in bael earlier (Singh *et al.*, 2018b). In bael, source of pollen grains exert a direct effect on size, shape and styler end cavity of fruits, seeds and speed of fruit development, and time of ripening of

Fig. 1: Cauliflorus flowering and fruiting pattern in bael under semi-arid conditions

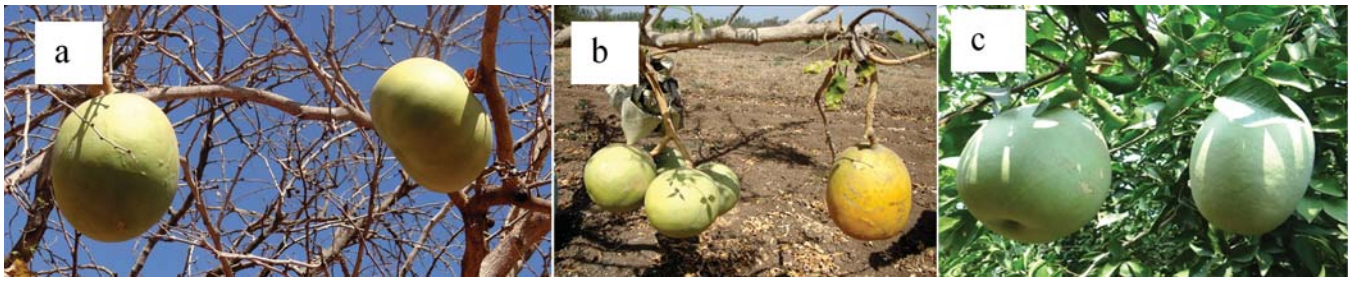

Fig. 2: Metaxenia effect on, (a) fruit shape, (b) shape and ripening (c) styler end shape of fruit

bael fruits (metaxenia) (Singh *et al.* 2018a, 2018b, 2019a, 2021a).

Bud emergence in all varieties started at different times, but lasted from April to late July (Singh *et al.*, 2006a). The varieties which have long flowering period may serve as a long-term resource, whereas flowering and phenology of different cultivar affects reproductive success which allows the presence of a constant population of pollinators (Singh *et al.* 2010b, 2016b). Abnormal number of petals in flower may be observed in almost all genotypes (Singh *et al.*, 2018a, 2019b). During anthesis flowers start loosening their floral organs, some flowers opened all petals at a time while others, one by one which takes 45-60 minutes in complete opening and also vary flower to flower in same genotype (Singh *et al.*, 2019a). In inflorescence, lower side bud opened earlier as compared to rest of buds localized centrally in all varieties, whereas varieties had anthesis vice versa where centrally located buds opened first as compared to lateral buds (Singh *et al.*, 2011c, 2014d). After anthesis within half an hour, the anthers dehiscence started and continued during 5.45- 8.30 A.M. The anthers and floral organs shrunk and turn into brick red after dehiscence as time passed on (Singh *et al.*, 2011b and 2016i). The anthesis clarified that the anthesis and anther dehiscence in bael varieties took place early in the morning (5.30-8.30 A.M.) where low temperature and high humidity prevailed (Singh *et al.*, 2019b).

Fig. 3: Different pollinating agents of bael flowers

In newly opened flowers of all varieties, pollen viability is about 95 % or more in different varieties (Singh *et al.*, 2014c). Stigma receptivity after anthesis was recorded the highest on same day (45.27-68.53%), whereas it was 7.95-15.52% and 3.62-14.37% one day before and after the day of anthesis, respectively, showing considerable difference stigma receptivity (Singh *et al.*, 2014a, 2019b).

Bael is cross pollinated crop, honey bees (*Apis* spp.) and beetles, ants, houseflies and butterflies start visiting the flowers in the forenoon (Singh *et al.* 2019a). Effective pollination occurred through the honeybees (70%), which visit on a flower 5-23 times in one hour and carried the highest number of pollen grains (29.65) than rest of pollinators (Fig. 3) (Singh *et al.* 2014a). Honeybees have been recognized as ultimate and legitimate pollinators in many tropical trees (Singh *et al.*, 2019b) and in bael (Singh *et al.* 2019c, 2019b, 2021a).

Genetic resources and varietal wealth

There is a considerable effort by national groups working on bael diversity to collect, evaluate and conserve bael germplasm from various states of India *viz.*, Uttar Pradesh, Bihar, Gujarat, Rajasthan, Punjab, Haryana, Madhya Pradesh, Jharkhand and West Bengal by NDUAT, Faizabad, ICAR-CIAH and itrs regional Station CHES, Godhra, ICAR-CISH, Lucknow, CCSHAU, Regional Research Station, Bawal, ICAR-CAZRI, Jodhpur (Singh *et al.*, 2019a). The yield and yield-attributing traits of different genotypes, *viz.*, fruit yield (40.50- 69.29 kg), fruit weight (0.43-4.25 kg), length (10.61-19.59 cm), width (9.40-22.00 cm) and fruit girth (29.10-70.00 cm) showed considerable variations. Physical composition of bael fruit exhibited wide variation in their shell weight (115.25- 560.05g), shell thickness (0.16-0.31 cm), number of seed / fruit (90.34-212.25), total fresh seed weight (17.34-43.41 g), number of seed sacs (10.23-19.17), fibre weight (15.91-106.50g) and pulp weight / fruit (0.27-3.67 kg) (Singh *et al.*, 2011d, 2013b, 2014b, 2014e, 2016f, 2019e,). The TSS mucilage, TSS pulp, total sugar, reducing sugar, non reducing sugar, vitamin C, total phenols, acidity and TSS: acidity ratio are 37.00-49.50° Brix, 30.57-37.45° Brix, 16.15-

19.98%, 3.30-4.95%, 12.85-15.13%, 17.13-21.03 mg / 100g, 2.34-2.75%, 0.30-0.49% and 68.88-124.83, respectively (Singh *et al.,* 2014f, 2015e, 2016h, 2016i, Sharma *et al.,* 2013). Singh (2021) repoted 213 clonal and 129 seedling germplasm in the field repository of ICAR-CIAH- RS, CHES, Godhra, Gujarat.

Improved varieties

In recent past, some promising varieties of bael have been developed through selection at ICAR Institutes and Agricultural Universities, cultivated in different parts of India (Table 1). Among them, Goma Yashi is predominant ruling variety in western, southern and central part of India owing to its attracrtive fruit and pulp colour, less seed and mucilage, high TSS, whereas NB-9 and NB-5 in northern India. Other important varieties are Thar Divya, Thar Neelkanth, Thar Srishi, NB-7, NB-9, NB-16, NB-17, CISH-B-1, CISH-B-2, Pant Aparna, Pant Sujata, Pant Urvashi and Pant Shivani. Presently, Goma Yashi is being preferred owing to its dwarf stature, suitability for high-density planting and excellent fruit quality (Singh *et al.,* 2019a, Pandey *et al.,* 2014)).

Quality planting material

Bael seeds belong to recalcitrant category; the seeds cannot be stored for longer period under normal storage conditions (Singh *et al.,* 2018a, 2019a). It has no dormancy; hence fresh seeds can be sown 2-3 cm deep in the nursery within 8-15 days after extraction (Singh *et al*. 2011c). The fresh seeds germinate in 8-15 days after sowing during summer under raifed semi-arid conditions (Singh *et al.* 2019a). Sometimes seeds germinate while fruits are kept on tree for a longer duration after ripening of tree (vivipery) (Singh *et al.,* 2018b). Delayed and poor seed germination and reduced plant growth were observed in response to increased sodicity (Pandey *et al.,* 1988). Salinity caused

Table 1. Improved varieties of bael developed in India

Variety	Characteritics
Goma Yashi	Developed through selection by Central Horticultural Experiment Station (ICAR-CIAH), Godhra, Gujarat.It ripens after March, belongs to mid maturing group, possesses high qualitative attributes like papery shell (1.5 mm), very less fibre, seed and mucilage and attractive pulp colour with an excellent pleasing aroma and flavour. Dwarf stature, suitable for high density planting, accommodating 400 plants/ha, planted at 5mx5m. It is highly suitable for sharbet, RTS, squash, ice cream, candy and Murabba.
Thar Divya	Developed through selection by CHES (ICAR-CIAH), Godhra, Gujarat. It is vigourous and luxuriant growth, heavy yielder (107.24 kg/tree in 10th year) starts ripening after 260 days, earliest among the varieties (first week of February), high TSS (38.90° Brix),dark yellow pulp colour, less affected (40%) by sunscald due dense canopy. It is highly suitable to grow under drland conditions.
Thar Neelkanth	Developed through selection by CHES (ICAR-CIAH), Godhra, Gujarat. It is having compact growth, medium height, less spiny, heavy yield with quality fruits (very sweet in taste, 38.25° Brix TSS) having pleasant flavour and attractive colour of pulp.It is having good flavour and aroma with TSS/acidity ratio (124.83). It is highly suitable in draught prone dry land conditions.
Thar Srishti	Developed by CHES (ICAR-CIAH), Godhra, Gujarat. The distinct qualitative fruit characters of variety is highly centric locule arrangement, rich in fine fibre, less seeds, attractive pulp colour with no off flavor, hence suitable as table as well as processing purpose.it is suitable for RTS, sharbat, ice cream and squash.
NB-5	Developed through selection by NDUAT, Faizabad, Uttar Pradesh.The fruits are of varying size, round with smooth surface and very thin rind (0.16 cm), straw yellow at maturity, less in mucilage, moderately fibrous with light yellow pulp with low seed content. Pulp is soft, good in taste and flavour with TSS 33° Brix.
NB-7	Developed through selection by NDUAT, Faizabad, Uttatr Pradesh. Tree spreading type with large- sized leaf, sparse in bearing with large size fruit (> 2.8kg). The fruits are round and with smooth surface and very thick rind, yellow at maturity, low in mucilage and fiber, attractive yellow pulp with low seed content. It is highly suitable for processing.
NB-9	It is developed through selection by NDUAT, Faizabad, Uttar Pradesh. The plants are spreading growth habit, small leaves and compact canopy. Fruits are medium to large in size, roundish-oblong with smooth surface and thick rind (0.24 cm), light yellow at maturity, moderately fibrous, golden-yellow pulp containing 38.00° Brix total soluble solids in pulp.
NB-16	Developed through selection by NDUAT, Faizabad, Uttar Pradesh. Plants are semi-spreading, precocious and prolific bearing. The fruits are small in size (750-800g), round with rough surface very thick rind (0.35 cm), straw yellow at maturity, high in mucilage, fibrous with yellow pulp. Pulp TSS is 35° Brix and ascorbic acid 17.61 mg/100g of edible portion, suitable for powder making.

Contd.....

NB-17	Developed by NDUAT, Faizabad, Uttar Pradesh. The plants are tall having semi-spreading growth habit. It is sparse in bearing, fruit 1.75-1.9 kg. It can be used for processing (powder). The fruits are large-sized with smooth surface, rind thickness (0.24 cm), straw yellow at maturity, fibrous, attractive yellow pulp, with less seed content.
Pant Aparna	Developed through selection by GBPUAT, Pantnagar, Uttarakhand. Its trees are with drooping foliage, almost thorn-less, precocious and heavy-bearer. The leaves are large, dark green and pear shaped. Fruit has globose shape with small fruits, fruit weight 0.8-1.25 kg, mucilage and seeds are enclosed in separate segments.
Pant Shivani	Developed through selection by GBPUAT, Pantnagar, Uttarakhand. It is an early mid maturing variety. Trees are tall, vigorous, dense, upright growth, sparse fruiting. Fruit shape is ovoid, oblong, fruit weight ranges from 1.78 to 2.4 kg. Rind is medium-thin, lemon-yellow pulp colour with pleasant flavor. Taste is very good having 69% pulp, TSS 36° Brix, acidity 0.47% and ascorbic acid 19.55 mg/100 g of pulp.
Pant Urvashi	It is developed through selection by GBPUAT, Pantnagar, Uttarakhand. It is a mid-season variety. Trees are vigorous, dense, spreading, precocious, sparse bearing habit. Fruit is ovoid-oblong with average size of 14.50 cm x 17.20 cm and fruit weight ranges 1.5-2.50 kg. Fruit is yellow, rind is medium to thin and pulp is light yellow. Fibre content low, TSS 33° Brix, acidity 0.49% and ascorbic acid 17.15 mg/100g pulp.
Pant Sujata	Developed through selection by GBPUAT, Pantnagar, Uttarakhand. Trees are medium-dwarf with drooping and spreading foliage, dense, precocious bearer. Thorns are stout and bigger. Fruit is globose shaped, depressed at both, and fruit weight varied from 1.32 to1.80 kg under rainfed condition. Fruit and pulp are light yellow. Thin rind, and seeds, mucilage and fibre are low. Average yield is 65.57 kg/plant during 8th year in dryland conditions.
CISH-B-1	It is developed through selection by ICAR-CISH, Lucknow Uttar Pradesh. It is early in maturing (March). The plants are semi-tall and having spreading growth habit. The fruits oval-oblong, with smooth surface, yellow at maturity, low in mucilage and fib rous, light yellow pulp with high seed content (170-200). The pulp has 33° Brix TSS in pulp and 43° Brix in mucilage. The fruit weight varies from 0.8 to 1.40 kg with average yield 67.00 kg/plant during 8th year.
CISH-B-2	The plants are tall and spreading and developed through selection by ICAR-CISH, Lucknow, (U.P.). The average fruit yield of 8th year old plant is 56.78 kg. The fruits are medium in size (16.00 cm x 14.00 cm) with smooth surface, yellow at maturity, thick rind, fibrous. Fruits have 31° Brix TSS and acidity (0.41%). The fruit weight 1.7-2.6 kg/fruit. Fruit does not ripe uniformly under natural condition. It is good for processing only.

Source: Singh *et al.*, 2010a, 2012a, 2013c, 2015c, 2016d, 2016e, 2016g, 20172018c, 2019a,

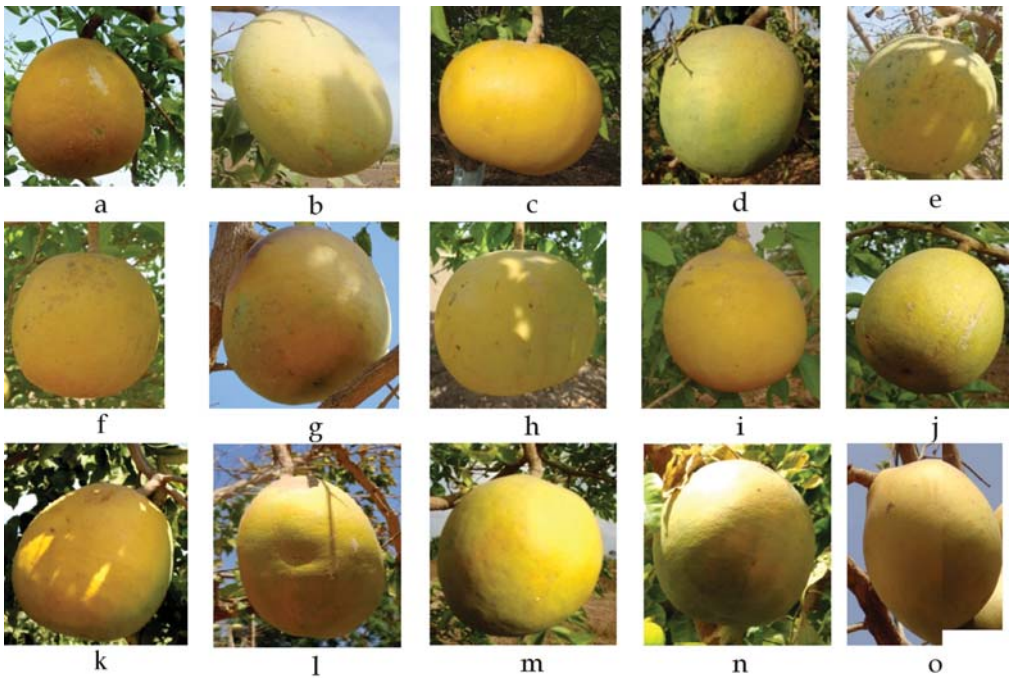

Fig. 4: Variation in fruit shape, size and ripened fruit colour in differet varieties. (a) CISH-B-2, (b) CISH-B-1, (c) Pant Sujata, (d) Pant Urvashi, (e) NB-5, (f) Pant Aparna, (g) NB-17, (h) NB-7, (i) NB-9, (j) NB-16, (k) Pant Shivani, (l)Thar Srishti, (m) Goma Yashi, (n) Thar Divya, (o) Thar Neelkanth

significant increase in leaf Mg, while sodicity decreased it. Leaf Na was at toxic levels in both saline and sodic soils (Shukla and Singh, 1996b).

Young seedlings should be protected from frost during winter under arid ecosystem and from intense radiation in rainfed semi-arid condition (Singh *et al.* 2018d). Forgetting new shoot for budding, thomb size branches should be cut in March. Number of new shoots emerges below the cut portion (Singh *et al.*, 2014g). For accelerated growth of shoot, plants should be irrigated after one week after cutting of branches, whereas for softwood grafting, 4-6 old shoots are used when plant starts putting forth new leaves (Singh *et al.*, 2011f). Under dryland condition, mother plant should be irrigated one day before separation of scion shoots for budding for better success and survival (Singh *et al.* 2011c, 2019a,). The active growth period is indicated by easy and clear separation of the bark from the wood of scion sticks (Singh *et al.*, 2021b).

Bael is commercially propagated through budding and softwood grafting (Singh *et al.*, 2014c). For faster multiplication, seed shown in the month of March (first week) can be used for softwood budding in June (Singh *et al.*, 2019a). This method is very useful for transportation of sapling to distant places (Singh *et al.*, 2018d and 2014g). Patch budding and softwood grafting was found successful when performed in May-June (before onset of rain) under Gujarat conditions, recording 94.14 and 90.82% success, respectively (Singh, 2018). Standardization of grafting technique and identification of suitable rootstock play important role in mitigating abiotic stresses, particularly during drought, salinity and high temperature in arid and semi-arid region (Singh *et al.*, 2019a)). Bael can be multiplied through inarching, cuttings, root suckers, layering and stooling, but success and survival are comparatively very poor than budding and grafting (Singh *et al.*, 2019d). Air layering prepared during second week of August with IBA 1000 ppm in lanolin paste on new shoots emerged after envigoration gave 90% rooting and 77% survival of rooted air layers (Saroj *et al.* 2006).

Micropropagation techniques have been gainfully employed in mass multiplication of various fruit species. Regeneration from explant hypocotyle, nucellus tissues, cotyledons, nucellous callus, leaf, cotyledonary node explants, micro shoots and zygotic embryo has been reported by several workers (Islam *et al.*, 1994, Hossein *et. al.* 1993, Kumar and Seeni, 1998, Islam et al., 1993, Arya *et. al.*, 1986). Simultaneously, biochemical changes particularly the composition of membrane lipids in relation to differentiation in callus culture have been reported.

Planting geometry and high-density planting

The ideal time of planting under rainfed condition is June just after first rain in monsoon. The planting of bael can be done at spacing of 5m-8m depending upon the variety and agroclimatic conditions (Singh *et al.* 2014a, 2011f). Under rainfed condition of hot semi-arid ecosystem, planting of vegetatively propagated plants of dwarf variety, especially Goma Yashi, can be done at 5m × 5m spacing to maximize the productivity. Based on vegetative growth habit, Thar Divya, NB-7, Pant Urvashi,Pant Aparna, Pant Sujata, CISHB-1, CISHB-2 should be planted at 8m × 8m; NB-9, NB-17, NB-16, Thar Neelkanth and Thar Srishti at 8mx6m; and NB-5 at 6mx6m (Singh *et al.*, 2018a 2019a). However, closer spacing, growth regulation by training and pruning, use of mechanical device is required after 8th year of planting for successful adoption of high density planting. At CHES Godhra, work for the evaluation of high density planting (4m × 4m, 6m × 4m, 8m × 6m, 6m × 6m) has been initiated with variety Goma Yashi which has already been recommended for commercial cultivation at the spacing of 5m × 5m under dryland condition (Singh *et al.* 2020a 2020c). At CHES, Godhra, high-density planting of Goma Yashi bael, yield was recorded 237.08q/ha with a net profit Rs. 187,080 purely under rainfed semi-arid conditions (Singh *et al.*, 2020a, 2020e,2020f).

Plant architectural engineering

Training operation starts after 6-8 months to develop structural framework and last up to 2-4 years after planting. The lowest branch is allowed to develop at 50-60 cm above the ground with single stem training or multi stem training. Four or five well spaced branches are allowed to grow in all directions. Single stemmed plant produce less number of branches and its fruiting area goes too high which is difficult to harvest the fruit. Pruning is done twice a year to remove dried twigs, branches and maintain balance between vegetative and reproductive growth. Pruning of 25% annual growth during leafless stage is found to beneficial to encourage the emergence of new shoots to develop dense canopy to avoid sun scald especiallly under dryland conditions (Singh *et al.*, 2018a, 2019a) (Fig. 5).

Nutrient and water management

An annual dose of about 20 kg of FYM during pre-bearing period and 50-80 kg/tree at bearing stage is considered beneficial. It is suggested to apply 10 kg FYM and 50, 25, 50 g N P K, in one-year-old plant, respectively. This dose should be increased every year in the same proportion up to the age of ten years

(a) Patch budding, 13 months old rootstock | (b) Soft wood grafting, one year old root stock | (c) Softwood patch budding, three months old | (d) Softwood grafting, six month old rootstock

Fig. 5: Differet methods of multiplication a, b, c & d under rainfed conditions

(Singh *et al*. 2011 and 2018d and Singh, 1992). Sometimes, in rich soils, trees have a tendency to put on more vegetative growth with the result that the fruiting is delayed. Provision of green manuring has special significant for bael plantation established under degraded lands (Singh *et al.,* 2014f). Three foliar sprays with 0.6% mixture containing zinc sulphate, borax and ferrous sulphate in equal proportion during July, October and November have been found beneficial (Singh *et al.,* 2018a, 2013c).

For commercial production, irrigation is planned as per the requirement of crop growth stage. The irrigation requirement depends on age, season, location and growing practices. Pollination, fruit setting and development are most sensitive phases of a plant growth cycle.Water shortage or excess watering during fruit maturity and ripening stages result in fruit cracking (Singh *et al.*, 2011c). Drip irrigation has great potential due to high water use efficiency and increased yield. Besides water saving (60%), yield can be increased up to 25-30% by drip irrigation. Fertilizers and chemicals can also be applied through drip irrigation. In bearing trees, plant should not be irrigated through flood or heavy irrigation at a time, which may cause severe cracking under dryland condition (Singh *et al.,* 2019a, 2019e). Drip irrigation should be adapted for better growth, fruit and development. Under arid condition plant should be protected from hot desiccating wind and low temperature below 0°C (Saroj *et al.* 2006).

Biotic and abiotic stress management

Bael is not affected by serius diseases, insect and pests, but few pest and diseases are severe threat to bael cultivation (Fig. 6). Major physiological disorders are fruit cracking and sun scalding particulrly in dry areas. Under arid conditions, about 15-30% fruit cracking has been reported at differet stages in bael (Singh *et al.,* 2019a, 2021a). It also varies with variety, season and climate. In fruit cracking, xylem and phloem tissue loss their elasticity. In summer, after dry period (April-June), if water supply is increased, pulp tissues absorb much water, increase in volumeand exert pressure on fruit shell, cause fruit cracking owing to hard shell (Singh *et al.,* 2018a). Fruits split generally when rains come or irrigation is given after a long dry period.For cracking management, application of adequate and regular irrigation at precise interval is required to avoid cracking. Covering of fruits with netting followed by cotton cloth baggging in hot dry period and sufficient calcium, potassium and boron application reduce cracking (Saini *et al.,* 2004).

The extent of fruit drop varied according to genotypes / varieties and locality. Immature fruit drop (marble-sized) has also been observed. Sometimes cricket ball- sized fruits also fall down during August under rainfed semi-arid conditions of Gujarat (Singh *et al.* 2011b, 2011c, 2019a) and mature fruits in January-Febrary in Lucknow conditions. The extent of fruit drop in bael can be reduced effectively by adopting better orchard practices which include mulching with organic materials and proper soil nutrient management (macro-micro) and application of growth hormones like NAA (15-20 ppm / litre) at pea- sized stage during August-September (Singh *et al.,* 2018a). Shweta and Misra (2015) reported that all the growth substances sprayed, proved beneficial in minimizing drop and enhancing quality characters of bael fruits, while

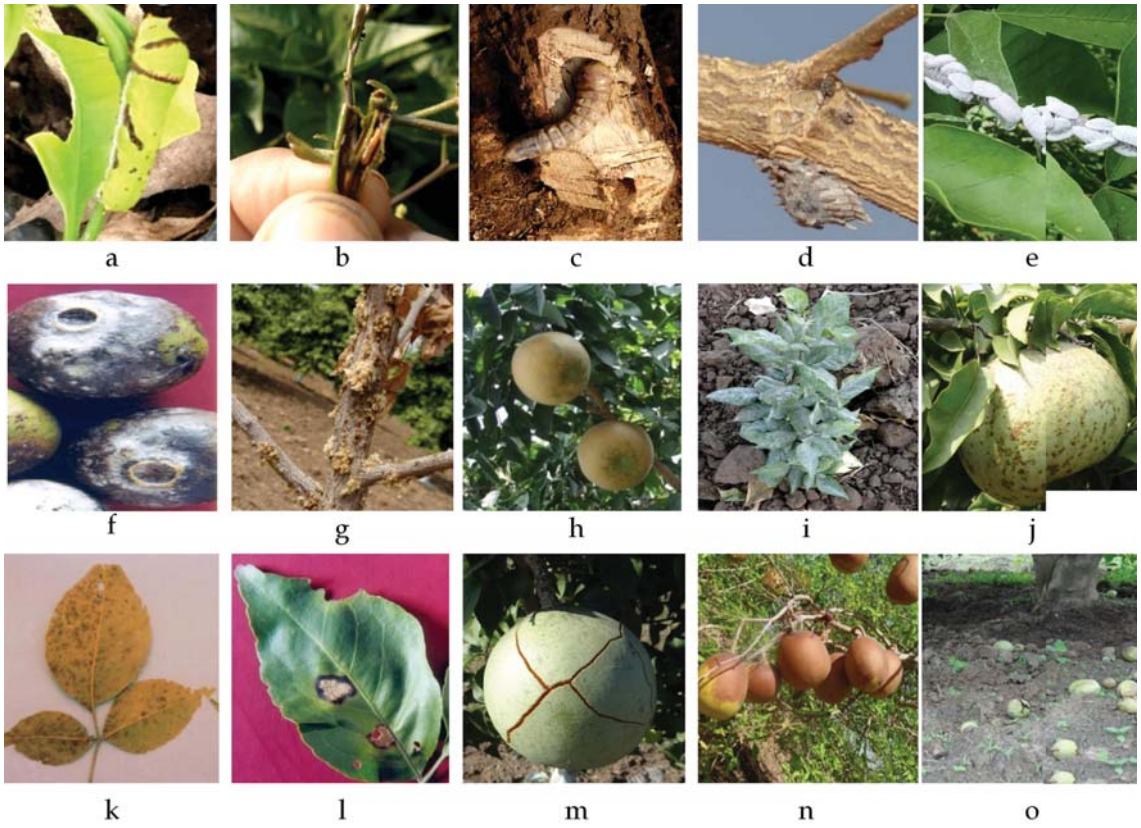

Fig. 6: Abiotic and biotic stresses, (a) lemon butter fly, (b) stem borer, (c) root grub, (d) scale insect, (e) mealy bug, (f) stalk end rot, (g) gummosis, (h) melanose, (i) powdery mildew, (j) canker, (k) black leaf spot, (l) alternaria leaf spot, (m) cracking, (n) sun scald and (o) fruit drop

maximum fruit set (78.48%) was recorded with NAA 30 ppm, and the minimum fruit drop (90.64%) and the maximum fruit retention (9.36%) were recorded with NAA 20 ppm. Maintenance of proper soil moisture regime nearby rhizosphere is useful to reduce the fruit drop (Singh *et al.,* 2019a). Saini *et al.* (2004) suggested that the fruit drop and fruit cracking can be minimized by either spraying of borex 0.1% or application of 100 kg Farm Yard Manure/tree as basal application in monsoon.

Sun scald is manifested by turning of normal green shell into dark brown at the fruit surface where it is expose to hot sun for maximum period during day hours (Singh *et al.,* 2019a). Sometimes, the pulps of fruit beneath the shell also get affected due to moisture loss and irradiation (Singh *et al.* 2017, 2018a). The main reasons of sun scald may be ascribed to intense solar radiation affecting the shell for long time during the day coupled with unavailability of sufficient soil moisture and the temperature of sun scalded portion is increased by 8-10° C as compare to unexposed portion of the fruit, (Singh *et al.,* 2018a, 2019e). Mulching, canopy management and various fruit covers are useful to reduce down this disorder up to some extent. Initial studies revealed that covering of fruits with netting followed by cotton cloth bag is helpful in avoiding the sun scald up to some extent (Singh *et al.,* 2019a).

Canker is caused by Xanthomonas bilvae and it is characterized by minute, circular, brown, water soaked spots on susceptible leaf surface. The pathogen also causes infection on fruit twigs and thorns. Spraying once or twice with streptomycin sulphate 250 ppm or Bordeaux mixture 1% at 12-15 days interval effectively control the disease (Singh *et al.,* 2015d).

During May-June, a severe post-harvest rot caused by *Aspergillus awamori* Nakazawa is observed on bael. The disease is somewhat serious during storage period of fruits. Pre-harvest spray of Carbendazim (0.05%) and avoiding bruises to the pericarp during picking, storage and transport are suggested to manage the disease. It is also suggested to ensure proper ventilation and daily inspection of the storage container (Singh *et al.,* 2018a, 2019a).

Stalk end rot of bael is caused by Fusarium solani (Mart.) Sacc (Bhargava *et al.* 1977). Dropping of immature young fruits is the main symptom. The fungal attack on peduncle ends of the fruit forms a dark brown lesion. Later, fungus weakens the peduncle of

fruits resulting into fruit drop (Pandey and Misra, 2015). For effective control of the disease, two sprays of Thiophanate methyle or Benomyl (0.1%) at fortnightly interval are recommended during early stage of fruit development.

Fusarium rot caused by *Fusarium moniliformae* Shelden is also observed. Cottony growth of fungal mycelium is observed just beneath the hard shell. Later the fungus covers the whole fruit and makes it soft and pulpy. Two sprays of Thiophanate methyl Benomyl (0.1%) at fortnightly interval are recommended to manage the disease (Singh *et al.,* 2019a). Shell soft rot is observed on matured, harvested and fruits which are caused by *Syncephalastrum racemosum*. The affected fruits rot quickly and are not fit for consumption as entire fruit pulp become unpalatable. The affected fruit emits an unpleasant odour typically associated with decay. The fruit ma y be dipped after harvesting in hot water at 52±l°C and then shade dried or it may be dipped in 0.05 per cent Thiophanate Methyl for 2 minutes and dried in shade (Misra, *et al*. 2016). Powdery mildew disease is characterized by appearance of white floury patches on leaflets, especially on younger leaves which increase in size and cover entire lamina soon within 7-10 days (November-December under Godhra condition). Later, colour of colony turns slightly pinkish or grayish. Tender shoots are also found infected with the mildew. Spray with Carbendazim 50 w p (Bavistin 0.1%) or wettable sulphur (0.2%) is found to be useful (Singh *et al.* 2019a, 2018a).

Gummosis is common in bael orchards (Singh *et al.* 2018a). To manage the disease, it is suggested to scrap off the infected portion of bark with the help of a sharp knife, which should be followed by application of Bordeaux paste. Spray with Copper fungicides (Bordeaux mixture 1% or copper oxychloride (0.3%) are also suggested to be applied at monthly interval during and after rainy season. Removal of highly infected twigs and incorporation of *Trichoderma viridae* propagules in soil of rhizosphere of bael were found helpful to control the disease (Singh *et. al.*, 2015d, 2018a, 2019a).

Lemon butterflies, caterpillars feed on foliage and cause economic loss. Others, like Citrus leaf miner (*Phyllocnistis citrella* Stainton), spiralling whitefly (*Aleurodicus Dispersus* Russel), brown scale and root grub is of minor importance, as these are either sporadic in occurrence or confined to certain pockets. In severe infestation, spray with Quinalphos or 0.05% Chlorpyriphos or Phosalone are recommended. *Axinoschymnus puttarudria* and Parasites, *Encarsia haitensis* proved highly effective against spiraling white fly. Scale insect can be controlled by spraying of Diomethoate (0.05%) or Imidachlorpid (0.5ml/l) at fortnightly interval. It is first report of infestation on bael by scale insect under dryland condition (Singh *et al.* 2018a).

Harvesting, fruit quality and marketing

Generally, tree is in leafless condition during harvesting, particularly in late- maturing varieties while early-maturing varieties do not shed their leaves at the time of harvesting under rainfed conditions of semi-arid ecosystem (Singh *et al.*, 2019e).Mature bael fruits are harvested individually from the tree along with the portion of fruit stalk (2-3 cm) to avoid infection and it also helps to judge the ripening (Singh *et al.* 2018a, 2019a. For preserve making, fruit should be harvested from November to December, whereas for fresh consumption, the optimum harvesting time is from second fortnight of February- June in different climatic conditions (Singh *et al.* 2011c). However, harvesting period is influenced by temperature and moisture availability in soil. Singh *et al.* (2018a, 2019a) have reported variation in ripening of bael varieties under dryland conditions.

Under Gujarat condition, a full grown tree gives 80-120 kg under rainfed conditions (10 year onwards). Number of fruit per tree is directly correlated with the size of fruit, a tree having bigger size fruit, the number of fruits is less. However, a seedling tree at the 20-30 years age can yield 500-800 fruits cooperatively smaller size (Saroj *et al.*, 2016f, 2019a). Different types of locule arrangement in different germplasm have been repoted

Fig. 7: Locule arrangement, (a) semi-peripheral, (b) centric, (c) scattered and (d) peripheral

by Singh *et al.* (2018a 2019a).

Yield and quality can be improved by using plant growth regulators (Kundu and Ghosh, 2017) Fruit is berry usually globose, round, flat conical, elliptical, obvate; pericarp (shell) thick to thin, smooth or rough surface, light green to green (immature stage), greenish yellow to yellowish green (mature fruit), whereas fruit surface texture may be smooth or roughor sometimes undulating surface (Singh *et al.*, 2018a, 2019a). The styler end cavity was observed smooth, narrow, depressed, highly depressed and extremely depressed, while stem end cavity was observed smooth, shallow, sunken, depressed and highly depressed (Singh *et al.*, 2011c, 2018a). The seed testa is white with woolly hairs and embryo has large cotyledons and a short superior radicle, while fibre may be thick to thin, colour: white to yellow, fibre content: thin to thick in different germplasm (Singh *et al.*, 2018a). At CHES Godhra, varieties studied for organleptic scaling, Goma Yash recorded maximum organoleptic scoring, exhibited maximum scores in all the parameters (Singh *et al.*, 2013e, 2016c).

About 75% of the farmers sell their produce at the farm level to the village merchants, retailers and factory owners. They cannot afford to transport their produce to distant markets on account of non-availability of transport facilities, expensive transport, malpractices in the market. The demand, supply, price, market outlook, knowledge of the consumer preference, marketing channels are important for marketing of produce, but yet not developed appropriately, which leads to poor price to the growers. Popularization and marketing strategies have been outlined by Singh *et al.*, 2011a. Bael fruit has good storage capacity and it can be transported to distant places easily. Bael fruit powder has immense potential in the global market (Singh *et al.*, 2019a).

CONCLUSION

It can be concluded that for best quality bael production, advanced technologies should be taken into consideration. Improved cultivars, high density planting density, plant growth regulators, drip irrigation, nutrient and canopy management are major horticultural interventions which influence plant health and flowering, and ultimately the yield. Fruit quality should be the major concern for export market, particularly fruit size, pulp colour and aroma with desired minimum residue limit. Bael is a suitable fruit crop for the sustainability of small holdings, as it is well adapted to varied topography and agro-climatic condition. In addition, it provides ample opportunity for nutritional, livelihood and health security particularly in the arid and semi-arid region, as it has high potentials to utilize wastelands and an ideal crop for diversification. Being a medicinal plant, there is dire need of correlating the therapeutic activity with the chemical marker of the plant as well as studying the mode of action of the marker compound and clinical trials against the diseases are essentially required for its commercialization.

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Research Review

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Research status of lasora (*Cordia myxa* L.) in India — a review

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ABSTRACT

Indian cherry (*Cordia myxa* L.), locally called lasora or gonda, is an important multipurpose fruit tree species distributed in arid and semi-arid regions of India. Its versatile adaptability to poor soils, wastelands and tolerance capacity to water stress makes it suitable plant for arid ecosystem. The species is known for its nutritious fruits and diverse uses of other plant parts. It is generally planted as shelter belt on farm boundaries, but now a days, it is grown as planned orchard to fetch premium prices from its fruits in summer season (March-April). In view of its benefits both in tangible and non-tangible terms, the research work on its genetic improvement and production technologies has been attempted at various ICAR institutes and Agricultural Universities. High yielding varieties like Maru Samridhi, Karan Lasora and Thar Bold have been developed by selection from seedling population. The vegetative propagation technique, rootstocks, canopy management and crop regulation by defoliation and irrigation scheduling have been standardized. To review the available information on its germplasm collection, evaluation and improvement as well as production, and post harvest management under-utilized may serve the purpose for benefits of growers, researchers, and policy makers.

Key Words: Genetic improvement, genetic resources, lasora / gonda production management, vegetative propagation

Lasora (*Cordia myxa* L.), 2n=48; Synonym *C. obliqua* Willd; *Cordia dichotoma* Forester f.) belongs to family Boraginaceae. It is known as *gonda or gunda*, lehsua or lasora and by several other vernacular names. It is a medium-sized broad-leaved deciduous tree. Owing to its higher productivity, suitability to adverse soil and climatic conditions and high processing value, it is now popularly grown as planned orchard in arid and semi-arid regions (Saroj, 2018). It is distributed throughout the country especially in warmer regions of North West and central India (Rai and Gupta, 1996, Samadia 2005; Nagar and Fageria, 2006). It is suitable for planting in non-cultivable or wastelands, backyards, on road sides and around farm boundaries (Singh *et al.*, 2019; Hanelt and IPK 2001; Samadia 2005). Almost all parts of lasora are used for different purposes (Yadav and Goel, 2006). The unripe fruits are used as vegetable, pickled with raw mango and can be dehydrated for use in off season.

The special adaptive features like deep tap root systems, waxy and leathery leaves, sunken and covered stomata in leaves and leaf shedding under water stress conditions, water binding mechanism and tolerance to salinity and alkalinity make it preferred species for arid and semi-arid region as potential underutilized crop (Chandra and Pareek, 1992). Wide variability in its natural population was found in north-western region of India (Samadia 2005, 2007; Kaushik and Dwivedi, 2004; Nagar and Fageria, 2006). Though, importance and usage are known, its commercial potential has not yet been fully exploited. The lack of ideal genotypes / varieties for cultivation and value-added products for consumer preference are the reasons for its non-commercialization (Yadav and Goel, 2006). Germplasm collection, conservation and evaluation of genetic diversity for desired traits are primary requirements for identification of superior genotypes for its exploitation.

Genetic resource

The research work on collection and improvement have been attempted at few locations in agricultural universities (CCSHAU, Regional Research Station, Haryana and SKNAU, Jobner) and ICAR institutes. (ICAR-Central Arid Zone Research Institute, Jodhpur, and ICAR-Central Institute for Arid Horticulture,

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Bikaner). The research work conducted at ICAR-CAZRI, Jodhpur resulted in development of variety Maru Samridhi and some high yielding accessions such as CZCM-2011, CZCM-2021, CZCM-2012 and CZCM-2062. ICAR-CIAH Bikaner has released one variety *i.e.* Thar Bold and one high yielding selection CIAH Sel-2. SKNAU, Jobner has also released one variety of lasora, i.e. Karan Lasora. Large number of germplasm accessions are being maintained at Jodhpur, Jobner, Bikaner and at CCSHAU, regional centre, Bawal in Haryana.

Crop improvement

In lasora, regular bearing, big fruit size, cluster bearing, high pulp: stone ratio and high yield potential may be considered prime objectives for improvement. Samadia (2007) opined that an ideal genotype of *lasora* may be one having oval round shaped fruits, green to dark green at unripe mature stage, big fruit size (9-12 g), besides higher yield and extended harvesting period. There is also need to explore the possibility to use its exudates gum and mucilage in coating, encapsulation, confectionaries, processing and pharma industries.

Genetic diversity of *Cordia* species especially *C. myxa* has been collected by National Bureau of Plant Genetic Resources (NBPGR) from Rajasthan, Haryana, Gujarat, Madhya Pradesh, Himachal Pradesh and Uttar Pradesh. The germplasm represented the sizable diversity in fruit weight, shape, size, surface feature, pulp content, seed size, weight and shape. Forty-five accessions of elite germplasm have been collected by NBPGR in collaboration with Choudhary Charan Singh Haryana Agricultural University (CCSHAU) Regional Research Station, Bawal from Rewari, Mahendergarh and Bhiwani districts of Haryana and germplasm was established at field gene bank at CCSHAU, Regional Research Station, Bawal and Jodhpur. Saini *et al.* (2002) conducted a field survey in Haryana and Rajasthan, during 1996 to identify and select promising genotypes that are suitable for commercial cultivation. A total of 27 promising genotypes were collected and planted in an orchard in Haryana. Kaushik and Dwivedi (2004) recorded variability in fruit length (1.34-2.96 cm) fruit breadth (1.84-3.34), fruit weight (1-16.25g), TSS (8.5-28%) and seed weight (0.22-0.85 g). Samadia (2007) collected *lasora* germplasm from wide range of agroclimatic conditions in 18 districts covering 95 sites from Rajasthan. He recorded rich variability in germplasm from Pushkar valley of Ajmer, Sadri area of Pali, parts of Jodhpur, Barmer, Jalore, Jaipur, Bhilwara and Nagaur. One promising accession with bold fruits, shining surface and prolific bearing has been identified by local farmers near Kotputli, Rajasthan. Nagar *et al.* (2013) reported variability in 15 provenances of lasora and the characters such as fruits per cluster, fruit weight, fruit diameter, and TSS had high heritability which implied these characters to be more under genetic control and that such variability can be exploited for genetic improvement of lasora.

The NBPGR Regional Station, Jodhpur and Central Institute for Arid Horticulture, Bikaner have identified some bold fruited types with high productivity (Krishna *et al.*, 2015). At CIAH, Bikaner under *ex-situ* conservation, 65 germplasm of lasoda have been collected and planted under field conditions to identify suitable genotypes. Kaushik and Dwivedi (2004) reported wide range of biodiversity in morphological and quality characters in 45 collections of lasoda from Haryana. Bold fruited variety Thar Bold has been released by CIAH, Bikaner (Saroj *et al.*, 2018).

Since improved varieties are generally not available, it is commonly propagated by freshly extracted seeds from ripened fruits by nursery men. Owing to cross pollination, great deal of variability is found in its population derived from seed propagation or sexual propagation. Therefore, selection of high yielding genotypes along with other desirable characters associated with fruit yield from seedling population and perpetuation of the same by clonal propagation is the best strategy for improvement of this crop. Clonal propagation through budding has been standardized (Meghwal, 2007, Singh *et al.* 2003). Eighteen germplasm accessions from different parts of Rajasthan were collected during 2000-2015 which are being conserved in field gene bank (Meghwal *et al.* 2018). These accessions showed vide variation in fruit weight, bunch weight, number of fruits per bunch and pulp: stone ratio. Based on fruit yield and other desirable attributes, two elite genotypes *i.e.* CAZRI-G2021 and CAZRI-G2025 were identified as high yielding accessions. The accession CAZRI-G2025 was later released as Maru Samridhi during 2018 which is very heavy yielder with long term average fruit yield of 85 kg per plant (Meghwal and Singh, 2019). The diversity in fruit characteristics of 14 accessions of lasora revealed high coefficient of variation, mean, range and standard deviation in bunch weight, number of fruits per bunch, fruit weight and pulp:stone ratio (Meghwal *et al.*, 2014a). Morphological characterization of 10-year-old trees for 17 traits indicated wide variation with accession AHCM-22 to be the superior germplasm line for most of the horticulturally useful traits as it had highest per cent fruit set, pulp:stone ratio and fruit weight (Sivalingam *et al.*, 2012).

Clonal propagation

Lasora can be propagated by seeds and vegetative method such as budding. Although propagation by seeds is easy but not recommended since it results in

variable plant population. However, for preparing rootstock, it is most common practice. The seeds should be extracted from fully ripened fruits which are available during May-June. The fruits turn yellowish cream in colour at full ripening. Such fruits can be collected for extracting the seeds. The seeds of lasora lose viability upon storage under ordinary conditions, hence, they should be sown immediately after extraction. The ripened fruits are first cleared off mucilaginous pulp, washed in water and surface dried under shade. Seed treatment with GA_3 (250 ppm for 2 hours) improved germination to 50% as compared to only 10% in control. However, the highest germination was recorded when this treatment was preceded by mechanical scarification (Meghwal, 2007). The seeds should be sown in polythene bags of size (25 × 10 cm) filled with a mixture of compost, clay and sand (1:1:6) during first week of June. The seeds are placed vertically 1.5 inch-deep and covered with soil and watered immediately. Germination completes in about 15-30 days of sowing. The seedlings become ready for transplanting or for budding after about 75 days of sowing. The buddable thickness of rootstock seedling is about 5-8 mm diameter.

Vegetative propagation is the desired method to propagate true to type plants and budding is the easiest method. About 75 days old seedling rootstock of wild types lasora seedlings or commercial big fruited lasora seedlings can be used as rootstock. The maximum bud take was observed when budded on 15th August but it could be done up to 15th September with almost equal success rate (Meghwal, 2007). The compatibility of different rootstock indicated that it can be budded on seedling rootstock of lasora, small fruited lasora and also on goondi (*Cordia* gharaf) (Meghwal, 2007). However, long term performance of lasora on these rootstocks revealed that scion / stock ratio at bud union was one or slightly more on large fruited gonda or small fruited gonda but it was significantly higher (1.32-1.42) on goondi rootstock as compared to other two rootstocks which were at par with each other (Meghwal *et al.*, 2014b). Considering vegetative growth, fruit yield, extent of gummosis, drying of terminal branches, it emerged that goondi rootstock shows the symptoms of delayed incompatibility with gonda (Meghwal, 2008). Though, the scion stock union was intact even after 20 years of budding, but it showed gradual decrease in fruit yield and increased incidence of gummosis and drying of terminal branches. Therefore, small fruited gonda was considered better rootstock for commercial gonda. Cuttings of dried up branches and application of Bordeaux paint at cut ends and gum oozing sites may be effective to control die back of branches caused by gummosis. The superiority of small fruited gonda as rootstock was reconfirmed during evaluation of different gonda genotypes on different rootstocks (Meghwal *et al.*, 2014b). Effect of time of budding for propagation of lasoda has been studied Singh *et al.* (2003) and Cchovatia and Singh (1996).

At ICAR-CIAH, Bikaner, work was undertaken to develop a micropropagation protocol for lasoda and protocol for the same using nodal segments of lasoda has been standardized (Krishna and Singh, 2013). Single node cuttings, prepared from the new growth of a clonal selection of lasoda, CIAH-1, were cultured on MS medium supplemented with 2.0, 4.0 and 6.0 mg / l kinetin and BAP alone or their combination with 0.01 mg / l NAA. The best response was observed with 4.0 mg / l kinetin. The regenerated shoots from shoot buds were separated aseptically and thereafter, transferred to the rooting medium containing NAA and IBA along with 750 mg / l charcoal. Of the different combinations, medium supplemented with 2.0 mg / l each of IBA and NAA in combination with charcoal was found superior over the other hormonal combinations with regard to rooting response. Inoculation of Arbuscular mycorrhizal fungi during *ex vitro* hardening resulted in higher survival and improved growth of micropropagated lasoda plants (Krishna *et al.*, 2015).

Package of cultivation practices

Meghwal and Roy, (2011) reported square or rectangular system of planting at 5-7 m spacing.

No information based on experimental finding is available for lasora on recommendation of manures and fertilizers. However, about 20 kg FYM per pit is mixed with soil at the time of pit filling. In second year 10 kg of FYM / plant is again added during July-August (Meghwal and Roy, 2011). At the age of 5 years and above about 40 kg FYM or 30 kg compost / plant / year should be applied (Meghwal and Singh, 2019). The FYM / compost should be applied in two equal split doses once in July and again in February before fruiting.

Canopy management is important operation to regulate crop and enhance yield and quality of fruits. The budded plants need to be managed low headed to facilitate easy fruit harvesting. The upright growing shoots are retained and the rests are pruned. In due course of time, 3-4 well spaced upright growing limbs are allowed to develop as main scaffold. The plants require leaf defoliation for early and uniform fruiting. Roy and Meghwal, (2012) suggested defoliation time and methods to be done in the end of December to beginning of January. The leaves start yellowing and falling naturally after withholding irrigation during November-December. Leaves can be removed either manually or by chemical spray. A foliar spray of ethrel

@1000 ppm (laboratory grade) during first week of January enhances easy leaf fall. Defoliation of gonda leaves during first week of January resulted in early and uniform fruiting which could avoid the adverse effect of high temperature late in the season besides fetching premium price of early fruit harvesting (Roy and Meghwal, 2012).

Lasora plants require regular irrigation during first three years for establishment. The irrigation should rather be with held from October to January to facilitate easy leaf defoliation during December-January. The defoliated leaves must be spread in tree basins which serve dual purpose of keeping the weeds away and conserving soil moisture. The leaves decompose with time and contribute towards the build-up of soil organic matter with increase in soil fertility. The use of lasoda leaves as mulch material have been found very effective in reducing soil temperature and conserving moisture during summer months under arid conditions of Bikaner (Awasthi *et al.,* 2003). Singh *et al.* (2020) also reported that use of organic mulches is found beneficial in several fruit crops in improving soil physical and biological properties with enhanced moisture holding ability leading to better growth and yield of plants. First irrigation should be started in the beginning of February. There after regular irrigation at 7-10 days intervals (about 400 L / plant / irrigation based on open pan evaporation) should be applied up to last week of April depending upon the weather condition. The fruit harvesting is completed by the end of April after which irrigation is stopped to save precious water. As an adaptive mechanism leaves may drop off during May-June if not irrigated but the plants remain alive and restart growth with the monsoon rain.

Off-season flowering and fruiting occur during September to November. The assessment of extent of off-season fruiting in lasora was made on budded plants on three types of rootstocks as well as on seedling plants (Meghwal *et al.,* 2018). Although, the climate change might be the major factor but the role of rootstocks and different genotypes cannot be ruled out as there was lot of variation in fruit yield owing to genotypes and rootstocks.

Flowering, fruit setting, harvesting and value addition

Flowering starts in middle of February and fruiting in March. The fruits are ready for harvest after about 30-40 days of fruit set. The fruits are harvested at mature green stage before ripening for culinary purposes.The fruits should be harvested in clusters along with stalk to enhance shelf life after harvest. The fruit harvesting has to be done in staggered manner as all fruits do not mature at a time and should be completed by first week of May. Fruits start ripening during first week of May. Fruits turn yellowish upon ripening and are very sweet but they are highly viscous at this stage and not good for culinary puposes. However, such fruits can be sold to nurserymen at very high rate for seed purpose. Yield of lasoda varies with the age of the tree, climate and management practices. Young plants produce 5-10 kg green fruit plant-1 while a developed plant yields nearly 50 kg fruits, which can be increased by adopting, improved orchard management techniques up to 100 kg tree^{-1}. However, Chandra and Pareek (1992) reported 32.4 kg yield tree^{-1} from *Cordia myxa* when the plant age was 8-year-old in arid areas of Jaisalmer. In normal rainfall conditions, it gives 100-150 kg fruits / tree which also depend upon the genetic potential of genotype and prevailing weather conditions at the time of flowering and fruit set.

The mature fruits cannot be stored for longer period at room temperature. After harvesting, bruised or injured fruits are sorted out. Healthy fruits are packed in bamboo baskets or gunny bags and marketed. For distant transportation, it is always better to pack them in bamboo baskets. The tender fruits also cannot be stored for longer period at room temperature as they turn yellow and hence become unsuitable for use as vegetable and pickle purpose (Chandra *et al.,* 1994). Off-season utilization of dehydrated green fruits of gonda is very common among local people. For dehydration fruit bunches with stalk intact are dipped in boiling water till they become soft. After draining the water fruits are surface dried under the fan. It is then cooled to room temperature to separate stones from fruits carefully by pressing the fruits. To get better quality of dried fruits without discoloration, the destoned fruits are fumigated with sulphur powder (3 g / kg fruits) for 43h. Fruits are then dried under the Sun or in mechanical drier at 50-60°C temperature till they dry completely and produce cracking sound on pressing (4-5% moisture). Dehydrated fruits can be stored in air tight containers for about one year at ambient temperature.

CONCLUSIONS

The improvement in lasora depends on selection of genotypes having bold size, high yield potential, good quality fruits and tolerance to abiotic stresses. Trait specific varieties having, economically feasible production technologies and popularization of value added products may be researchable issues. Systematic research work on its improvement, standardization of production technology, management of diseases and pests and post harvest management technology may provide a commercial opportunity for this crop in arid and semi-arid areas of India.

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Research Review

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Emergence of new insect pests on vegetables during the last decade: a case study

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ABSTRACT

With the changes in cropping system, climate and introduction of highly input-intensive high-yielding varieties/hybrids are the root cause for a shift in insect pest status in time and space, resulting in enhanced damage caused by them in the world. Many of them also act as vectors for several viral and mycoplasma diseases, aggravating the problem further. In India, yield loss due to major insect pests is varying from 30-40%. In addition to the regular pests, recently, many exotic and invasive insect pests have invaded in many parts of the countries. South American pin worm (*Tuta absoluta* Meyrick), solenopsis mealy bug (*Phenacoccus solenopsis* Tinsley) are few such insects. Similarly, mirid bugs (*Nesidiocoris cruentatus* (Ballard) and *Metacanthus pulchellus* Dallas), melon weevil [*Acythopius curvovistris citrulli* (Marshall)], white plume moth [*Sphenarches caffer* (Zeller)], cucumber moth *(Diaphania indica)* and moringa fruit borer (*Noorda blitealis* Walker), tortoise beetle (*Cassida circumdata* Herbst) are the insects which have come up in bigger way in current decade either by expanding their host horizon or increase their severity. Therefore, these emerging insect pests in vegetable ecosystem in current decade, their suitable control measures and some issues/challenges in their ecofriendly management are discussed.

Key Words: Biotic stresses, Invasive insect pests, host horizon, ecofriendly management

Insect pests are major biotic constraints to vegetables production in India. Apart from causing direct damage either by feeding or sucking the plant sap, most of them also act as vectors for several viral diseases. The crop losses of 30 - 40 per cent have been reported in vegetable crops (Rai *et al.*, 2014b). Most of the plant protection recommendations in vegetables so far indicated the calendar-based scheduled application of insecticides and acaricides. This has become a common practice over the years by most of the farmers, growing vegetables in the country (Roy *et al.*, 2017). Establishment of new/invasive pests in India is also a matter of concern. Many such new emerging pests have occurred in India during last decade. Apart from these invasive pests, many regular insects are also expanding its host horizon in the last decade. Such new emerging pests in vegetables during lust decade in India have been given in Table 1.

MATERIALS AND METHODS

The data were recorded at Varanasi, Mirzapur and Deoria districts of Uttar Pradesh during 2009 - 2019 on vegetables. To record the damage severity, fruits and shoots of sponge and ridge gourds were sampled and healthy and infested/damaged shoots and fruits were separated and damage (%) were computed. For its management, talc-based formulations of promising entomopathogenic fungus, *viz. Beauveria bassiana, Metarhizium anisopliae* and *Lecanicillium (=Verticillium) lecanii* were tested alone and in combination (1:1 ratio) with neem oil (1%). Twenty insecticides including conventional and newer molecules of different groups and mode of actions, as per IRAC 2014, were evaluated for their relative efficacy against the adult weevil at their recommended doses (Halder *et al.*, 2007; Kodandaram *et al.*, 2010).

Similarly, in case of bottle gourd, mirid bugs, mirid bugs were collected by sweeping from bottle gourd plants and species composition was calculated and expressed in per cent. For damage severity, bottle gourd fruits were harvested and healthy and infested/damaged fruits were separated and damage (%) was computed. To know the preference, olfactometer study (Halder and Rai, 2016) was conducted with different

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Table 1. Yield losses due to major insect pests in vegetable crops in India

Crop/pest	Damage* (%)	Crop/pest	Damage* (%)
Brinjal		**Tomato**	
Shoot and fruit borer, *Leucinodes orbonalis*	8 - 37% shoot damage 17 - 93% fruit damage	Tomato fruit borer, *Spodoptera litura, Helicoverpa armigera*	7 - 68% fruit damage
Cabbage		**Cucurbits**	
Diamond back moth, *Plutella xylostella*	21-100% curd damage	Cucumber moth, *Diaphania indica* Fruit fly, *Bactrocera cucurbitae*	Up to 23% fruit damage
Cow pea		Muskmelon	28 - 100% fruit damage
Spotted pod borer, *Maruca vitrata*	Up to 42% pod damage	Pumpkin	8 - 67% fruit damage
Hadda beetle, *Epilachna vigintioctopunctata*	13 - 88% leaf damage	Bottle gourd	13 - 29% fruit damage
Okra		Bitter gourd	16 - 74% fruit damage
Shoot and fruit borer, *Earias vittella, E. insulana*	21 - 54% fruit damage	Sponge gourd	11 - 24% fruit damage
Red spider mite, *Tetranychus* spp.	Up to 100% plant damage	Ridge gourd	7 - 16% fruit damage

* Damages by these major insect pests also depend on crop variety, season, geographical area, cultural practices and fertility status of soil.

plant parts, viz. apical buds, young leaves, tender fruits, male flowers and female flowers. Bio-efficacy study was conducted with above mentioned entomo-pathogens and insecticides under field and laboratory conditions.

Studies on different biological parameters of invasive *Tuta absoluta* was conducted by keeping *T. absoluta* adult male and female (2:1 ratio) in a transparent perforated plastic jars (15 cm diameter, 19.2 cm height) with four-leaf staged tomato seedlings (cv. Kashi Aman) under laboratory conditions at 26 ± 2ºC temperature, 70-80% relative humidity and a photoperiod of 13:11 (L:D) h. Bioassay with different entomopathogens alone and in combinations with neem oil (1:1 ratio) was conducted by leaf residue method (Halder *et al.,* 2019).

Seasonal incidence of white plume moth, *Sphenarches caffer* was studied by recording periodical observation at weekly intervals on bottle gourd and Indian bean throughout their growing periods. Field collected *S. caffer* larvae were collected and brought to the biocontrol laboratory and reared on bottle gourd twigs under caged conditions. The parasitoid emerged from these larvae were collected and taxonomically identified.

Similarly, incidence of exotic mealy bug, *Phenacoccus solenopsis* was recorded round the year in almost all the vegetables growing both in open and protected conditions. Toxicological data on different biopesticides including *Beauveria bassiana*, *Metarhizium anisopliae* and *Lecanicillium (=Verticillium) lecanii* and neem oil alone and their 1:1 combination were generated by direct spray method under Potter's tower.

Biology and damage symptoms of moringa seed borer, *Noorda blitealis* was studied under biocontrol laboratory at 28±2ºC temperature, 70-80% relative humidity and a photoperiod of 13:11 (L:D) h as per the methodology developed by Halder and Rai, 2014.

Severity of cucumber moth, *Diaphania indica* on cucumber was recorded by taking periodical data on its harvesting. Seasonal incidence of this oligophagous pest was recorded at weekly intervals.

RESULTS AND DISCUSSION

During the decade (2009-2019), following insect pests, *viz.* melon weevil [*Acythopius curvovistris citrulli* (Marshall)], mirid bugs [(*Nesidiocoris cruentatus* (Ballard) and *Metacanthus pulchellus* Dallas)], South American pin worm (*Tuta absoluta* Meyrick), white plume moth [(*Sphenarches caffer* (Zeller)], solenopsis mealy bug (*Phenacoccus solenopsis* Tinsley), moringa fruit borer (*Noorda blitealis* Walker), cucumber moth [*Diaphania indica* (Saunders)] and tortoise beetle (*Cassida circumdata* Herbst) are few such insects were observed as emerging in the vegetable ecosystem.

Melon weevil: Melon weevil [*Acythopeus curvirostris citrulli* (Marshall) (Coleoptera: Curculionidae)] is an emerging serious borer pests of gourd crops, especially on sponge and ridge gourds. The pest was first recorded from Varanasi, India on sponge gourd. About 70 - 80 per cent fruits and 30 per cent shoots were damaged by this weevil (Halder *et al.*,

2016). The tender fruits had several brown puncture spots with initial yellowish white secretions followed by brown gummy encrustations causing drying and rotting. Weevils also punctured on vines leading to gradual drying of sponge gourd vines bearing flowers and fruits also accentuated the problem further.

Gravid females lay eggs in small batches on tender fruits just beneath the rind and on hatching, grubs start feeding on soft, tender fruit pulp and continue till pupation. Due to its feeding, affected fruits rot and there was no seed formation. Pupation occurs inside the fruits. Cocoons are hard blackish in colour made up of fibrous materials of the fruits and larval excreta. Adults emerge from the dry fruits by making small emerging holes. Affected fruits exhibited characteristic brown gummy encrustations on the fruits which significantly reduce its market value (Halder *et al.*, 2016).

Challenges

- Being an internal feeder it is difficult to control with insecticides
- Over lapping generations and short life-cycle
- Long hibernation during winter season
- Lack of information about its available biocontrol agents including entomopathogens

Control measures: Amongst the duo gourd crops, sponge gourd was most preferred by the *A. c. citrulli* than the ridge gourd. The summer sponge and ridge gourd crops suffered less damage than the rainy season crops. Similarly early sowing crops had lower infestation than the late sown. Halder *et al.,* (2016) observed that significantly lowest fruit damage (43.48%) was recorded in the sponge gourd grown in raised bed system than the trailing system (80.73%). Among the biopesticides, *Lecanicillium lecanii* at recommended dose was found most effective (LT_{50}= 87.84 h), followed by *Metarhizium anisopliae* (LT_{50}= 101.08 h) and they were also found compatible and synergistic in nature with neem oil (1%) (Halder *et al.*, 2016). Amongst insecticides tested, Quinalphos, Deltamethrin and Thiodicarb were found promising and caused 100% mortality within 24 hours under laboratory conditions.

Bottle gourd mirid bugs: Two mirid bugs species, *viz*. *Nesidiocoris cruentatus* (Ballard) and *Metacanthus pulchellus* Dallas (Hemiptera: Miridae) were recorded as serious and emerging sucking pests of bottle gourd from Varanasi, Uttar Pradesh, India. Studies indicated that about 70 - 80 per cent fruits and 30 per cent shoots were damaged by these bugs. Infested leaves showed numerous minute puncture spots with yellow hallow. While damage was more prominent on young fruits with typical brown puncture spots often in the form of irregular lines on the rind with sap oozing out from the tender fruits formed the characteristic symptoms of these sucking pests (Halder *et al.,* 2017b). Affected fruits therefore had significantly reduced market value. Studies on species composition of duo mirid bugs revealed that *N. cruentatus* was dominant species contributing overall 68.63% of the mirid bug population infesting bottle gourd followed by *M. pulchellus* (31.37%).

Challenges

- Round the year bottle gourd cultivation helps them quick multiplication
- Lack of knowledge about duo the species as phytophagous
- Early monitoring of the pest is generally ignored
- Farmers often confused with initial damage symptoms with fruit fly damage

Control measures: Amongst the different plant parts, highest number of *N. cruentatus* (26.39%) was oriented towards apical buds followed by young leaves (16.67%) and tender fruits (15.28%) so selective spraying should be done on these following plant parts. Trailing (*i.e.*, bower) system of cultivation harbored significantly the highest number of bugs per tender shoot (7.2) than the raised bed system (1.35). Amongst the biopesticides tested, neem oil (1%) was found most promising with lowest median lethal time (LT_{50}) (50.31 h) followed by entomopathogenic fungi, *B. bassiana* (52.26 h) and *L. lecanii* (56.59 h) whereas Flonicamid 50% WG and Spiromesifen 22.9% SC were most promising chemicals under field and laboratory conditions.

South American tomato pinworm: South American tomato pinworm, *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) is a key oligophagous pest of tomato originating from South America and recently introduced to India. It causes reductions in yield and fruit quality, to a tune of 50-100% loss in either greenhouses or fields. Plants are damaged by direct feeding on leaves, stems, buds, calyces, young and ripe fruits by caterpillars and the invasion of secondary pathogens which enter through the wounds made by the pest (EPPO, 2005).

In India, its infestation was first recorded from Pune, Maharashtra and subsequently spread to other tomato growing states *viz.*, Karnataka, Tamil Nadu, Andhra Pradesh, Chhattisgarh, Himachal Pradesh, Gujarat, Uttar Pradesh and Kerala (Kalleshwaraswamy *et al.*, 2015; Ballal *et al.*, 2016; Swathi *et al.*, 2017; Rasheed *et al.*, 2017; Sidhu *et al.*, 2017). Larvae feed on the mesophyll tissues of the leaves, leaving only the epidermis intact. They often cause conspicuous irregular leaf blotches which later turned to necrotic. Tomato plants, from seedlings to mature stage, attacked

by this pest. On fruits, small minute pin sized hole is often visible. Damaged fruits with frassy galleries accompanied by an open areas acts as entry paths for invasion by secondary pathogens, leading to fruit rot is the common symptom of this pest (Halder *et al.*, 2019).

Challenges

- Wide host range and oligophagy nature made it difficult to control
- Damage symptoms on leaves often resembles with serpentine leaf miner
- Lack of awareness and knowledge about this exotic pest to the farmers

Control measures: *Tuta absoluta* has a strong affinity towards solanaceous plants. Apart from tomato *(Solanum lycopersicum)*, it can also attack potato *(Solanum tuberosum)*, Chillies *(Capsicum annuum)*, eggplant *(Solanum melongena)* and black nightshade *(S. nigrum)*. Amongst the different biopesticides, *Bacillus thuringiensis* var *Kurstaki* was found most promising causing 66.7 and 73.37% mortalities at 48 and 72 h after the treatment followed by *Bacillus subtilis*-2 and the corresponding values were 53.36 and 66.70%, respectively, under laboratory conditions (Halder *et al.*, 2019). The egg parasitoid, *Trichogramma achaeae* Nagaraja and Nagarkatti (Hymenoptera: Trichogrammatidae) has been recommended for the control of new invasive pest, South American pinworm *Tuta absoluta* in tomato in Azores Islands (Oliveira *et al.*, 2017).

White plume moth: White plume moth, *Sphenarches caffer* (Zeller) (Lepidoptera: Pterophoridae), is a serious pest of lablab, beans etc. (Nair, 1995; Sujithra *et al.*, 2010). Recently, it attained its pest status as an apical bud and foliage feeder in bottle gourd as they damaged the leaves and buds of bottle gourd by scrapping the chlorophyll portion thereby reducing the photosynthetic activity of the plants in and around Varanasi region. However, damage was more severe when they feed on the emerging buds resulting in restricted growth of the buds with characteristic black excreta inside it (Halder *et al.*, 2014). During the peak summer months of May-June when atmospheric temperature was around 45°C in Varanasi its incidence was also observed. From mid-October onwards when *rabi* season bottle gourd was in its vegetative stage there was no incidence of this plume moth. Sujithra *et al.*, 2010 from Tirupati, Andhra Pradesh reported *S. caffer* as one of the major pod borer of field bean. However, in Varanasi region incidence of this plume moth is restricted to summer and *kharif* bottle gourds only.

Challenges

- Round the year bottle gourd cultivation makes it available almost throughout the year
- Larvae feed inside the buds, difficult to identify at early stage.
- Lack of knowledge about conservation of its potential endoparasitoid, *Apanteles paludicole*

Control measures: Hand collection and destruction of the larvae is beneficial. Conservation of solitary, larval, endoparasitoid *Apanteles paludicole* (Hymenoptera: Braconidae) (maximum parasitization 40.91%) (Halder *et al.* 2014) and chalcid pupal parasitoid, *Tropimeris monodon* are beneficial. Need based application of *Bacillus thuringiensis* @ 1 kg / ha is able to control this pest.

Solenopsis Mealy bug: In recent years, solenopsis mealy bug, *Phenacoccus solenopsis* (Tinsley) (Hemiptera: Pseudococcidae), an invasive, emerging, polyphagous pest has been observed in serious proportion on number of solanaceous, malvaceous and cucurbitaceous vegetables and other crops including many weeds (Halder *et al.*, 2013). Polyphagous, soft bodied this insect previously known as a minor pest in vegetables but now possess a new threat to most of the cultivated crop plants. Presently, they feed more than 400 host plants covering cereals, pulses, oil seeds, fruits, vegetables, ornamental crops as well as many weeds including *Parthenium*. Amongst the vegetable crops, they found to attack on variety of plants belonging to malvaceae (ladies finger), solanaceae (tomato, brinjal, potato, chilli, Capsicum), leguminoceae (cow pea, filed bean), cucurbitaceae (pointed gourd, cucumber, pumpkins and gourds) (Halder *et al.*, 2015). Besides sucking the sap, they also secret the copious amounts of honey dew which deposited on the plants and create black sooty mould and there by reducing the photosynthetic activity of the plants (Saini *et al.*, 2009; Sankar *et al.*, 2011). Problems are more severe in poly and net-house conditions.

Challenges

- Protective waxy coating over the body make it difficult to control as insecticides are not much effective in this pest and they also cause residue problem
- Honey dew attracts the ants which give them protection against natural enemies
- Ants also held responsible for physical movement of this pest
- Lack of knowledge about potential bioagents *viz.*, Australian lady bird beetle, *Cryptolaemus montrouzeiri* and biopesticides like *Lecanicillium (=Verticillium) lecanii* and *Beauveria bassiana* amongst the farmers.

Control measures: Hence, it is a polyphagous pest so proper management practices should be taken. Removal of alternate hosts and weeds like *Parthenium hysterophorus* from and around the field will help to reduce the pest incidence. Ants help in transmitting the mealybug beside they give protection to mealybugs against its natural enemies (Kumar *et al.,* 2008). So, selective destruction of the ants' colonies during land preparation is advisable. Uprooting and burning the affected plants reduce the pests load from the field. Spraying of fish oil resin soap (FORS) @ 20 g/lit of water (Kumar *et al.,* 2012) or entomopathogenic fungi *Lecanicillium lecanii* (2×10^8 cfu/ml) @ 5 g/lit of water give better control. Combination of *Lecanicillium lecanii* (2×10^8 cfu/ml) @ 2.5 g/lit of water and Neem oil (0.5%) at 1:1 ratio was found compatible and synergistic activity against many vegetable sucking pests including mealybugs (Halder *et al.,* 2017; 2018). Recently, Patel *et al.,* (2010) reported that Buprofezin @ 625 g ai/ha is effective in controlling this pest.

Moringa fruit borer: Apart from regular feeding on leaves, recently, a lepidopteran borer pest, *Noorda blitealis* Walker (Lepidoptera: Pyralidae) was observed in infesting in significant proportion of moringa fruits in and around Varanasi. The characteristic symptoms included brown gummy secretions on freshly infested pendulous fruits and gradual drying of the fruits in the later stages. Critical observations of infested samples revealed that fully developed green pods had small circular exit hole(s) (1.5 ± 0.08 mm) indicating the occurrence of the borer. A maximum of three to four such holes were recorded from a single fruit. A clear larval gallery filled up with frassy excreta was also evident when fruits were cut open. The brownish white larva was found feeding on the cotyledon portion of the seeds. Full grown larvae of *N. blitealis* were 15.65 ± 1.07 mm long and had typical bands with alternate white and brown stripes arranged dorso-laterally across the body. Damaged seeds showed direct feeding symptoms and were completely filled with frassy excreta. A maximum 30.06% fruits were damaged by this pest (Halder and Rai, 2014).

Challenges

- Being internal feeder difficult to control
- Early infestations often not visible and there by ignored which further make it difficult to control
- Inadequate knowledge about its suitable biocontrol agents

Control measures: Collection and destruction of affected fruits are advisable to minimize the pest incidence. Similarly, installations of light trap @ 1/acre are recommended. Spraying of *Bacillus thuringiensis* var Kurstaki @ 2 g/lit during evening hour may be followed.

Cucumber moth: This oligophagous pest, *Diaphania indica* (Saunders) (Lepidoptera: Pyralidae) earlier was known to be a minor pest of cucurbits like cucumber, bitter gourd, pointed gourd, snake gourd, gherkin and sponge gourd. But in last several years, its seriousness as fruit borer on bitter gourd and cucumber were observed in many parts of India. Apart from fruits, its infestation was also observed on tender leaves, flowers and apical buds in crops like cucumber and bitter gourd (Jana, 2014; Rai *et al.,* 2014b). Light green larvae, with two prominent longitudinal dorsal whitish lines, feed chlorophyll portion of the leaves by webbing them together (Halder *et al.,* 2017a). The larvae make characteristic holes on the fruits and feed inside it. The bored fruits become unfit for human consumption. In cucumber up to 78% fruits and 36% shoots were observed to be devoured by this pest. Recently, Nagaraju *et al.,* (2018) reported that the damage by larvae to leaves of pointed gourd was ranged from 25-30%. Damage was more severe during August and September coinciding with receding monsoon in the Varanasi region. The maximum, minimum and mean temperature, growing degree day, heliothermal unit and evaporation rate showed significant positive correlations with this sporadic pest where as a negative correlation was established with relative humidity, rainfall and wind velocity (Halder *et al.,* 2017a).

Challenges

- Wide host range and oligophagy nature make it difficult to control
- Short life-cycle and overlapping generations help it quick multiplication.
- As the pest is sporadic in nature so regular/early monitoring helps its easy and timely control

Control measures: Collection and destruction of the larva from the plants followed by spraying of NSKE 4% or *Bacillus thuringiensis* var Kurstaki @ 2 g/lit during evening hour would be advantageous. Four natural enemies *viz, Trichogramma chilonis, Dolichogenidea stantoni,* larval pupal parasitoid *Xanthopimpla punctata* and the entomopathogen *Nomuraea rileyi* were recorded from the eggs and larval stages of the pest in pickling cucumber (*Cucumis anguria* L.) from Karnataka, India (Visalakshy, 2005). Need based application of Chlorantranilprole 18.5% SC @ 0.2 ml/lit is recommended.

Tortoise beetle: Tortoise beetle [*Cassida circumdata* Herbst (Coleoptera: Chrysomelidae: Cassidinae)] is becoming an emerging problem in water spinach (*Ipomoea aquatica* Forsk), (family Convolvulaceae), an aquatic/semi-aquatic vegetable occurs both wild and cultivated forms in many parts of India. GreSSitt (1952) reported that *C. circumdata* fed on a number

of Convolvulaceae plants including *Ipomoea palmata, I. batatas, I. aquatica, I. cairica, I. digitata*. Critical observation revealed that its early instar grubs scrap the chlorophyll part of the leaves resulting skeletalization of the leaves of water spinach. Later instars make small irregular shot holes and notches on the leaves. Numerous such small holes (2 to 39 with an average 11.37) occurred on a single leaf. Black excreta were often visible on the upper surface of the leaves. Affected leaves had lower photosynthetic activity and also fetch lower market values (Halder and Rai, 2020). Maximum fifty percent leaves were recorded to be infested by this leaf feeder.

Challenges

- Aquatic / semi aquatic nature of the host, i.e. water spinach rendered difficulty in its management
- Color mimicry of tortoise beetle with its host helps in its hiding
- Lack of information about its available biocontrol agents including entomopathogens

Control measures: Collection and destruction of the grubs, adults and severely infested plant parts is advisable. Since, the pest new in the region other management practices have yet to be developed.

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Research Article

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Exploring microbial community diversity of mango leaf compost

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ABSTRACT

A microbial consortium of 6 bacterial (*Lactobacillus* sp., *Acetobacter* sp., *Saccharomyces* sp., *Bacillus* sp., *Pseudomonas* sp. and *Microascus* sp.) and 5 fungal isolates (*Aspergillus niger, A. oryzae, Fusarium solani, Trichoderma viridae* and *Penicillium citrinum*), isolated from degrading organic substrates and having high degradative enzyme activities, was used for composting of mango leaves. It took one month for complete composting. The ready compost was subjected to physico-chemical, microbial and metagenomic analyses. The culturable bacterial and fungal isolates were purified and maintained on nutrient agar and potato dextrose agar slants and identified using 16S rDNA and ITS region sequencing. Molecular identification of cultured bacteria reflected the dominance of *Bacillus subtilis* along with *Bacillus* sp. and *Microbacterium* sp. The fungal isolates included *Trichoderma* sp,. *Aspergillus niger*, *Acremonium sclerotigenum*, *Alternaria* sp., *Trichoderma* sp. and Geotrichum candidum. Metagenomic analysis of mango (Mangifera indica) leaf compost resulted in 22842 number of total operational taxonomic units (OTU). At phylum level, 35% and 24% of OTUs were assigned with Ascomycota and Basidiomycota respectively. Rest belonged to unidentified phyla. At class level, 25% and 24% of OTUs were assigned with Sordariomycetes and Agaricomycetes, respectively. At genus level, 12% and 10% of OTUs were assigned with Coprinus and Zopfiella, respectively. The study indicated that despite the addition of microbial consortium, during the process of composting, microbes are coming from the environment which are helping in composting process.

Key Words: Mango leaf, Compost, Metagenome, Bacteria, Fungi, Operational taxonomic units

Composting is a biological process resulting into conversion of complex organic matter into humus like substance which can enhance the soil physical-chemical and biological properties. The process depends upon the type, amount and physico-chemical composition of organic solids, environmental factors including temperature, pH, aeration, water content. There are continuous changes in microbial abundance, composition during the composting process. Numerous microbial communities compete as well as succeed each other in a composting ecosystem where microbial flora utilizes the available material in the substrate as well as the cellular components of its predecessors for growth (Vargas-Garcia *et al.*, 2010). Thus compost involves multitude of microbial diversity.

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Mango leaves are rich source of calcium, magnesium, nitrogen, phosphorous and some other traceelements (Faria *et al.*, 2016). The common management practices for dealing with leaf litter problem is burning of leaves, which causes environmental pollution as well as reduce soil fertility. Mango leaves composting is beneficial from environmental and soil fertility point of view. However, it takes 120-150 days for composting due to complex lignocellulosic nature of mango leaves. Das *et al.* (2013) reported that mango leaves contained 22.5, 46.8 and 16.2% (w/w) of cellulose, hemicellulose, and lignin, respectively. Lignin is resistant to decomposing, hence, microbes take time to get selected and further to build the inoculums. After initial breakdown of simple sugar, complex sugars are degraded by a succession of microbes selected during the process.

A number of reports are available stating that microbial inculcations can enhance the organic decomposition during composting. Xi *et al.*, (2005) used *B. azotofixams, B. megaterium, B. mucilaginosus,* cellulolytic

strains and white-rot fungi, while Vargas-García *et al.*, (2007) used *Bacillus shackletonni, Streptomyces thermovulgaris* and *Ureibacillus thermosphaericus* as seeding and concluded that the benefits of inoculation depended on the properties of the applied raw materials and microorganisms. Inoculation with thermo-tolerant lipolytic microbes has been shown to enhance decomposition of food waste and shorten the maturation time in vessel composting (Ke *et al.*, 2010). The objective of this study was microbial community fingerprinting of mango leaf compost matagenome which was inoculated with specific microorganism having degradative properties.

MATERIALS AND METHODS

Mango leaves were collected from mango orchards and a heap was made. The dimensions of composting pile was 1.50 × 0.90 × 0.80 m (Faria *et al.*, 2016). Bacterial cultures were obtained from the culture collection of microbiology lab of ICAR-CISH. These were *Lactobacillus* sp., *Acetobacter* sp., *Saccharomyces* sp., *Bacillus* sp., *Pseudomonas* sp. and *Microascus* sp. The fungal cultures used were *Aspergillus niger, Aspergillus oryzae, Fusarium solani, Trichoderma viridae* and *Penicillium citrinum.*

Inoculums of 6 bacterial and 5 fungal cultures having known high enzyme activities were multiplied in jaggary solution (10%) for 3 days to produce a population of $4.0*10^8$ CFU / ml bacteria and 2.3×10^6 CFU / ml fungi, well shaken and sprayed (5 litre each) over the leaves. Contents were mixed thoroughly, covered with a black polythene sheet and turned at weekly intervals. The control leaves were just heaped. The water content in both treatments was maintained around 60% during the process. In microbe inoculated treatment, the composting process was complete 30 days after initiation of composting as indicated by humification of organic mass and no gas emission. In this case, samples were withdrawn for physicochemical and microbial analysis of compost and DNA extraction, counting, isolation and molecular characterization of the culturable microflora.

The different physico-chemical parameters for proximate analysis of mango leaf *viz.* cellulose, hemicelluloses, lignin and mango leaf compost *viz.* pH, E C, moisture, total C, N, P (%) as well as micronutrients *viz.* Zn, Fe, Mn, Cu, Pb, Cd, Ni and Co were determined as per protocols described by AOAC (2005). Counting of total microbial population in ready compost was carried out by method of Benson, 2002. The dilution series ranging from 10^{-1} to 10^{-5} was prepared in triplicate using 1 g of compost in 9 ml of saline solution and 1ml aliquot of each dilution was pour plated on nutrient agar (NA) and Rose Bengal Chloramphenicol agar plates. The isolation plates were incubated at room temperature and enumerated after 5 days for total microbial counts expressed as colony forming unit per gram (CFU / g). The bacterial and fungal isolates were purified and maintained on nutrient agar and Potato dextrose agar slants.

DNA was isolated from the bacterial culture and quality was evaluated on 1.2% Agarose Gel, a single band of high-molecular weight DNA has been observed. Isolated DNA was amplified with *16S rRNA* Specific Primer using Veriti® 99 well Thermal Cycler (Model No. 9902). A single discrete PCR amplicon band of about 1500 bp was observed. The PCR amplicon was enzymatically purified and further subjected to Sanger Sequencing. I-directional DNA sequencing reaction of PCR amplicon was carried out with forward and reverse primers using BDT v3.1 Cycle sequencing kit on ABI 3730×l Genetic Analyzer. Consensus sequence of about 1500 bp*16S rDNA* was generated from forward and reverse sequence data using aligner software. The *16S rDNA* sequence was used to carry out BLAST alignment search tool of NCBI Genbank database. Based on maximum identity score first fifteen sequences were selected and aligned using multiple alignment software program ClustalW. Distance matrix was generated using RDP data.

DNA was isolated from the fungal culture and quality was evaluated on 1.2% Agarose Gel, a single band of high-molecular weight DNA has been observed. Isolated DNA was amplified with ITS region Specific Primers using Veriti® 99 well Thermal Cycler (Model No. 9902). A single discrete PCR amplicon band of approx. 700 bp was observed. The PCR amplicon was enzymatically purified and further subjected to Sanger Sequencing. Bi-directional DNA sequencing reaction of PCR amplicon was carried out with forward and reverse primers using BDT v3.1 Cycle sequencing kit on ABI 3730×l Genetic Analyzer. Consensus sequence of approx 600 bp of ITS region was generated from forward and reverse sequence data using aligner software. The ITS region sequence was used to carry out BLAST alignment search tool of NCBI Genbank database. Based on maximum identity score first fifteen sequences were selected and aligned using multiple alignment software program ClustalW. Distance matrix was generated using RDP database and the Phylogenetic tree was constructed using MEGA6 (Tamura *et al.*, 2011).

Carbohydrate utilization broth with 1% pectin / starch / carboxymethyl cellulose was inoculated with bacterial and fungal isolates and incubated at 28°C for 72 hours. For bacterial enzyme estimation, culture broth was centrifuged at 10,000 rpm for 10 minutes and the supernatant was used for enzyme analysis and for

fungus enzyme estimation, broth was filtered through G-1 glass crucible to remove the fungus growth and filtrate was used for enzyme precipitation. One volume of sample (culture filtrate from bacteria/fungus) was added in 4 volume (1:4) of cold acetone mixture, kept at -20°C for 20 minutes, centrifuged at 10,000 rpm for 15 minutes at 4°C. The supernatant was discarded and the pellet was suspended in acetate buffer solution (0.2mM). The mixture was used for enzymatic analysis for cellulase, pectinase and amylase using carboxy methyl cellulose, pectin and starch as substrate as per method described by Miller, (1972); Garg and Ashfaque (2010); Wood and Bhat (1988), respectively. The enzyme activity was expressed as Unit of sugar released per ml per min of incubation

DNA for metagenomic analysis was extracted from mango leaf compost (30 days after initiation of composting) using genomic DNA isolation research kit according to the manufacturer protocol (Chromos Biotech Pvt. Ltd., India). Twenty five ng DNA was used to amplify 16S rRNA hyper variable region V3-V4. The reaction includes KAPA HiFi HotStart Ready Mix and 10 M final concentration of modified 341 F and 785 R primers (Klindworth *et al.,* 2012). The PCR program involved an initial denaturation of 95°C for 5 min followed by 25 cycles of 95°C for 30s, 55°C for 45s and 72°C for 30s and a final extension at 72°C for 7 min using primers *viz.*, forward primer (V3V4F:5'-CCTACGGGNGGCWGCAG-3') and reverse primer (V3V4R:5'-ACTACHVGGGTATCTAATCC-3'). The amplicons were purified using Ampure beads to remove unused primers and this was followed by 8 cycles of PCR using Illumina barcoded adapters to prepare the sequencing libraries.

The library was further sequenced on Illumina MiSeq platform using 2×250 Paired- end (PE) chemistry by targeting 0.5 million reads per sample. The quality check of raw reads was carried out by Fast QC (v0.11.7) (Andrews, 2017), trimmed, processed to remove gaps and overhangs (UCHIME algorithm) (Edgar et al., 2011) filtered using GREENGENES v.13.8-99 (DeSantis *et al.*, 2006). The contigs were then clustered into OTUs. After the classification, OTU abundance was estimated. PICRUSt (Langille *et al.,* 2013) was used to predict gene family abundance. Metagenomes were predicted using predict metagenomes py script and used for further downstream analysis using QIIME (v.1.9.0). Paired end data were given as input in QIIME and OTU were assigned to similar sequences, UCLUST algorithm was used at sequence similarity threshold of 97% against Greengenes as the reference database for picking up OTUs. The output files from the QIIME are analyzed for the taxonomic classification using micro biome analyst, which is an online comprehensive statistical, visual and meta-analysis of microbiome data available at https://www.microbiomeanalyst.ca/faces/home.xhtml. Alpha Diversity, OTUs were identified and statistical analysis was carried out

For library preparations, about 25 ng of DNA was used to amplify ITS2 hyper variable regions of fungi using 100 nm final concentrations of ITS3 mix forward primer (ITS3mixF: 5'CAHCGATGAAGAACGYRG-3') and ITS4ngs reverse primer (ITS4R5'CCTSCGC TTATTGATATGC-3') harboring partial Illumina sequencing adapters as overhangs and KAPA HiFi Hot Start Ready Mix (Tedersoo *et al.,* 2015). The PCR reaction was performed using the following steps which include an initial denaturation of 95°C for 5 min followed by 30 cycles of 95°C for 30s, 55°C for 45s and 72°C for 30s and a final elongation at 72°C for 7 min. The amplicons of 300bp size were purified using Ampure beads and unused primers were removed. Libraries were quantitated using Qubit dsDNA High Sensitivity assay kit. QC passed libraries were sequenced using Illumina Miseq 200 with 2×300PE V3 sequencing kit.

Sequence obtained from NGS platform were assessed for their quality using FastQC (Andrews, 2017) and MultiQC (Ewels *et al.,* 2016) softwares. Quality read with QC threshold (R20 > 90%) were trimmed (20bp) from 5' end to remove the degenerate primers, further processed to remove adapter sequences and low quality bases using Trimgalore (DeSantis *et al.*, 2006). The final QC passed reads were imported into USEARCH (Edgar, 2010) and the paired ends were aligned to form contigs with penalty of maximum 10 mismatches. The contigs were screened for errors and high quality contigs were analyzed to generate unique sequences. These unique sequences were then clustered at 97% sequence similarity into OTUs (Operational Taxonomical Unit) by detecting and removing chimeric contigs in parallel pipeline. OTUs with only one representative sequence named singletons were discarded. OTU clustering and chimera removal was carried out by the UNOISE algorithm (Edgar, 2016). OTUs were populated by mapping back all the filter passed contigs onto the representative sequence from which the abundance in each BD preparations were calculated and further OTUs were classified based on UNITE ITS fungal database version 7.2 (Kõljalg *et al.*, 2013).

Sequence information generated was submitted in the NCBI database.

RESULTS AND DISCUSSION

Mango leaves contain cellulose (36.3%), hemi-celluloses (41.5%) and lignin (23.5%), respectively (Das *et al.,* 2013), hence, their degradation under natural

conditions (without addition of inoculum) is a slow process and took more than 150 days. At 30 days the leaf structure was more or less intact indicating the slow pace of degradation, hence this treatment was not further investigated. Studies have revealed that major bacterial groups in the beginning of the composting process are mesophilic organic acid producing bacteria such as *Lactobacillus* spp. and *Acetobacter* spp (Antunes *et al.*, 2016). Both bacteria and fungi are present and active in a typical composting process. Later, at the thermophilic stage, Gram-positive bacteria such as *Bacillus* spp. and Actinobacteria, become dominant (Antunes *et al.*, 2016). However, it has been observed that the most efficient composting process is achieved by mixed microbial communities. Therefore, a consortium of cellulolytic, pectinolytic and amylolytic mesophilic bacteria and fungi were added to mango leaves to help in fast initiation of the process. Inoculation of enzymatically potential microbial inoculums completed the composting process in 30 days. The pH of ready compost was found to be 7.3 while the E.C. was 13 mV and moisture content was 47%. The chemical composition of ready mango leaf compost was as follows: The total C, N and P (%) were 32.5, 1.079 and 0.787 respectively. The micro-nutrients *viz.* Zn, Fe, Mn, Cu, Pb, were 1.14, 141.5, 3.23, 0.49, 0.80 ppm while Cd, Ni and Co content were 9.4, 191 and 407 ppb respectively. The bacterial and fungal population per gm sample was more than 10^6 and 10^4 CFU.

The culturable bacterial and fungal isolates from compost samples have been listed in Table 1 and the NCBI SRA submission hyperlink for bacterial and fungal sequence information is available at https://submit.ncbi.nlm.nih.gov/subs/sra/SUB6628258/overview.

Molecular identification of cultured Bacteria reflected the dominance of Bacillus subtilis along with Bacillus sp. and Microbacterium sp. (Table 1). The fungal isolates included *Trichoderma* sp,. *Aspergillus niger, Acremonium sclerotigenum, Alternaria* sp., *Trichoderma* sp. and *Geotrichum candidum* (Table 2). The bacterial and fungal isolates were observed to possess high degradative enzymatic activities (Table 1 & 2), suggesting their potential usefulness inbiodegradation of organic components of soil further making nutrients available to plants, when the compost is added to soil.

Since, bacteria that can grow in pure culture under laboratory conditions represent a small fraction (up to 1%) of the total microbial diversity found in nature, hence these are not representative of the total phylogenetic diversity (Pham and Kim., 2012). Many bacteria having specific nutrient or chemical requirements are naturally present in various eco systems but difficult to isolate using culturable techniques. In addition, syntrophic relationship in complex microbial communities becomes a limiting factor in culturing many microbes. Hence, 16S rRNA and ITS based metagenomic approach were followed to study the microbial communities in mango leaf compost.

Amplicon sequencing of V3-V4 region of 16S rRNA revealed that in mango leaf compost sample, the number of representative sequences clustered were 0.113262 million. QIIME analysis of the sequenced data resulted in identification of 22882 no. OTUs. Zhou *et al.*, (2017) reported presence of 99.7% of bacteria and very few archaea, eukarya, and uncharacterized

Table 1. Molecular identification and enzyme production potential of culturable bacterial isolates from mango leaf compost

Identified bacteria	Accession no.	NCBI link	Potential Enzymatic Property	µmol/ ml/minutes
Bacillus subtilis strain NG106	MN493056	https://www.ncbi.nlm.nih.gov/nuccore/MN493056.1	Pectinase	265.6
Bacillus subtilis strain NG105	MN493055	https://www.ncbi.nlm.nih.gov/nuccore/MN493055.1	Pectinase	309.9
Lysinibacillus parviboronicapiens strain NG 30	MN372105	https://www.ncbi.nlm.nih.gov/nuccore/MN372105.1	Cellulase	569.2
Bacillus sp. strain NG8	MN264266	https://www.ncbi.nlm.nih.gov/nuccore/MN264266.1	Amylase	305.3
Bacillus circulans strain NG114	MN818667	https://www.ncbi.nlm.nih.gov/nuccore/MN818667.1	Cellulase	569.2
Microbacterium sp. strain NG113	MN818658	https://www.ncbi.nlm.nih.gov/nuccore/MN818658.1	Pectinase	253.8

Table 2. Molecular identification and enzyme production potential of culturable fungal isolates from mango leaf compost

Identified bacteria	Accession no.	NCBI link	Potential Enzymatic Property	µmol/ ml/minutes
Trichoderma sp. isolate NG110	MN636774	https://www.ncbi.nlm.nih.gov/nuccore/MN636774.1	Pectinase	802.3
Aspergillus niger strain NG109	MN636772	https://www.ncbi.nlm.nih.gov/nuccore/MN636772.1	Pectinase	601.7
Acremonium sclerotigenum strain ng107	MN636771	https://www.ncbi.nlm.nih.gov/nuccore/MN636771.1	Amylase	224.8
Alternaria sp. strain NG102	MN473278	https://www.ncbi.nlm.nih.gov/nuccore/MN473278.1	Amylase	200.0
Trichoderma sp. strain str. NG17	MN332239	https://www.ncbi.nlm.nih.gov/nuccore/MN332239.1	Amylase	294.6
Geotrichum candidum strain NG15	MN306309	https://www.ncbi.nlm.nih.gov/nuccore/MN306309.1	Amylase	266.2

organisms in apple pomace-adapted compost. The analysis of metagenomic datasets showed that Mango leaf compost was predominately composed of bacterial members (81%), unassigned organisms (16%) along with very few archaea (3%). Presence of large number of unassigned microorganism suggests uniqueness of the compost ecosystem.

The OTUs were used to classify the bacterial population present in the samples at phylum, class, family, order, genus and species levels. Alpha diversity indices *viz*. Chaos1 and ACE (abundance based estimator indices of species richness) were 24409.68013 and 26331.71385 while community composition based estimator *viz*. Shannon-Weaver and Simpson were 8.638596 and 0.001256, respectively. These indices are widely used to characterize microbial communities in any ecosystem (Schloss and Handelsman, 2006). The results are in consensus with Mello *et al.*, 2016 reported that microbial consortia obtained from nutrient limited minimal medium had greater diversity and proliferation of lignocellulose-degrading micro-organisms as compared with microbial communitities grown in nutrient rich medium. Rarefaction plot (Fig. 1a, b) indicated bacterial diversity in the mango leaf compost sample. Heat map of phyla as shown in Fig. 2 illustrates the diverse phyla present in the mango leaf compost sample.

The four most abundant phyla in mango leaf compost are Proteobacteria (23%), Planctomycetes (16%), Bacteroidetes (13%) and 7% of Actinobacteria (Fig. 3a). Sixteen percent of OTUs were corresponding to unassigned phyla suggesting the novel nature of them or the lack of the sequence information about these bacteria in the public domain databases. Wang

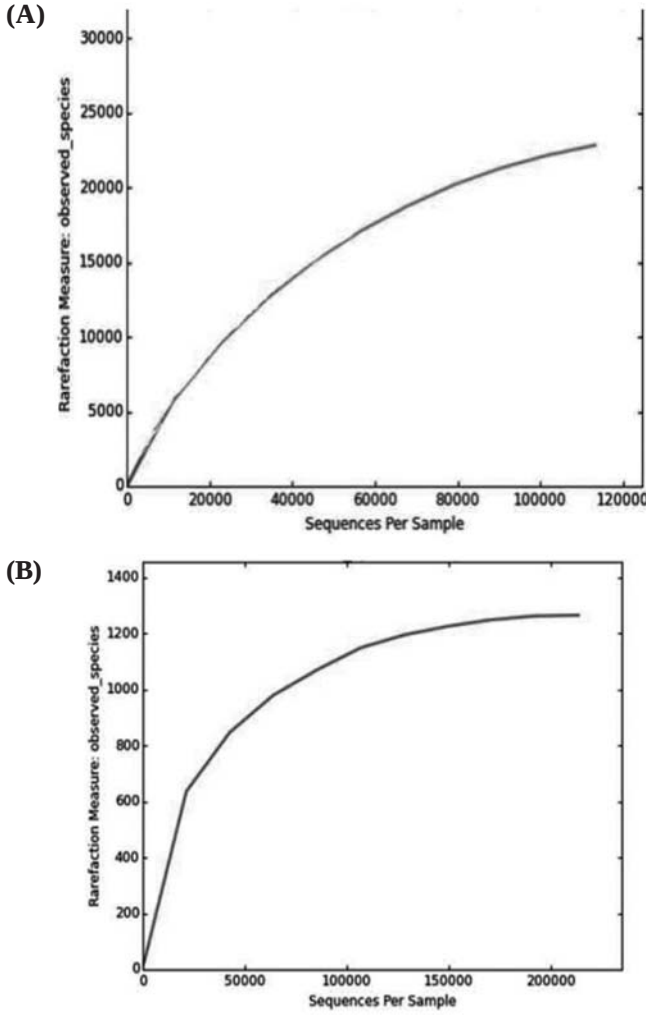

Fig. 1: Rarefaction plot reflecting bacterial (A) and fungal (B) diversity in the mango leaf compost

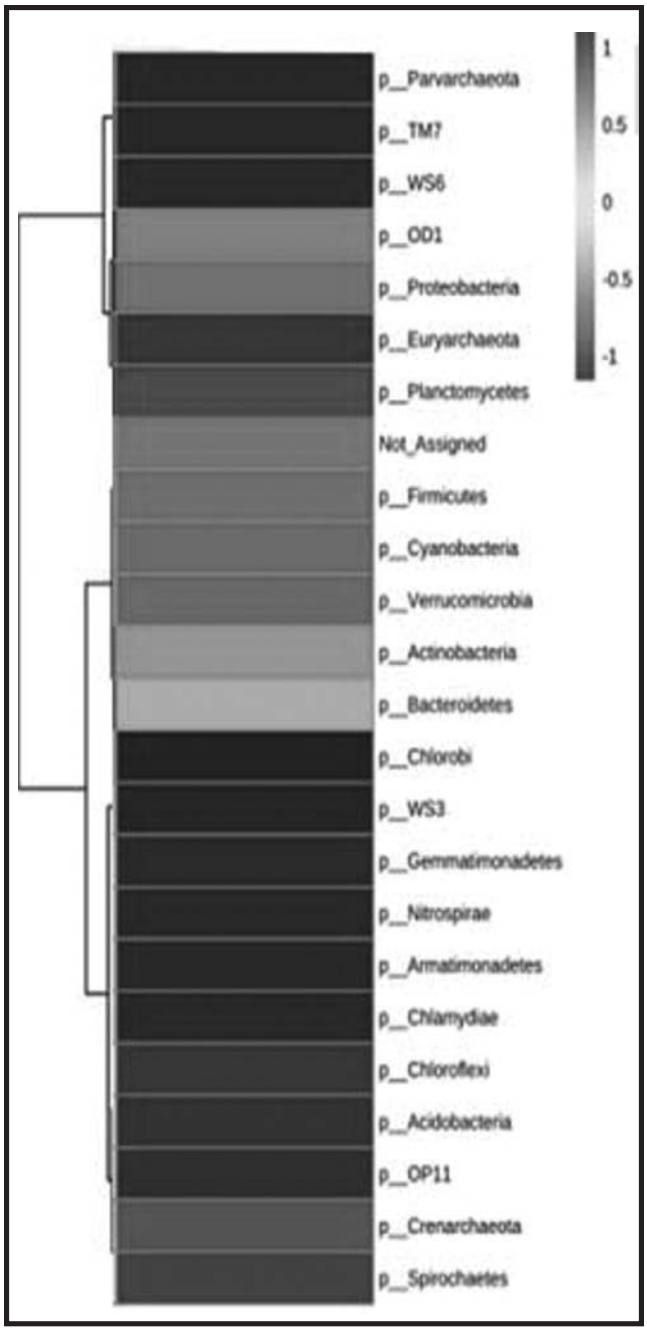

Fig. 2: Heat map plot depicting abundance of bacterial phyla in mango leaf compost

et al., (2016) emphasized the role of thermophilic Actinobacteria in lignocellulose biodegradation processes in the compost habitat. Antunes *et al.*, (2016) also reported Firmicutes, Proteobacteria, Bacteroidetes and Actinobacteria as the most abundant phyla of a thermophilic composting operation and accounted for at least 85% of all classified reads in all samples. Zhou *et al.*, (2017) reported dominance of phyla Proteobacteria, Bacteroidetes, Actinobacteria, and Firmicutes

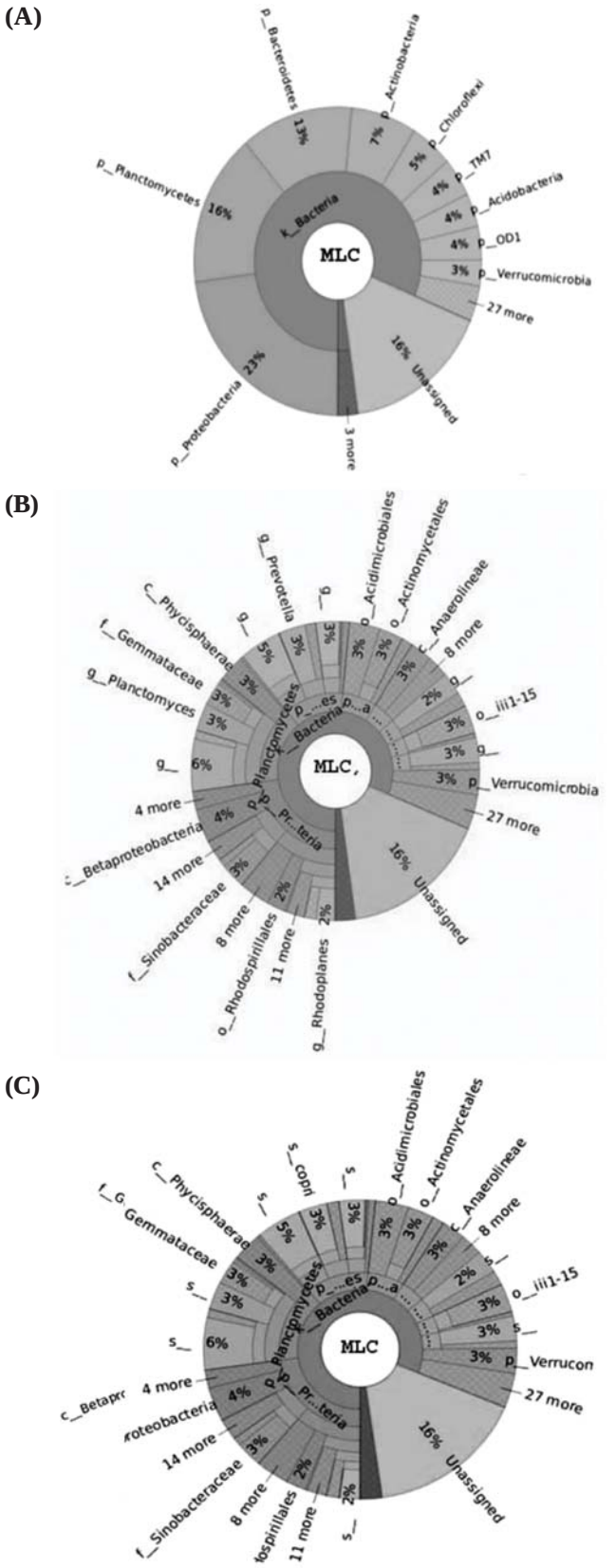

Fig. 3: Bacterial diversity in mango leaf compost at phylum (A) genus (B) species (C) level

in apple pomace-adapted compost. Wang *et al.,* (2016) reported phylum Actinobacteria as the predominant group among the Bacteria, followed by Proteobacteria, Firmicutes, Chloroflexi, and Bacteroidetes. Taxonomic analysis of wheat straw compost showed dominance by phyla Proteobacteria, Actinobacteria, Firmicutes, Bacteroidetes, Streptophyta, and Ascomycota (Yang *et al.,* (2019) All these observations suggest that the final microflora of the compost varies with the type of starting raw material.

At class level Planctomycetia and Alphaproteobacteria were dominant (13 and 11%, respectively) followed by Gammaproteobacteria (6%) and Cytophagia (5%). OTUs representing other classes were Betaproteobacteria and Bacteroidia (4% each). Acidobacteria, Actinobacteria, Anaerolineae, Saprospirae, Verrucomicrobia and Phycisphaerae each represented 3%,while Deltaproteobacteria and TM7-1 and 3 were 2% each (Table 3).

At the order level, relative high abundance of order Pirellulales (7%) and Rhizobiales (6%) was observed. Cytophagales and Xanthomonadales were 5 and 4%, respectively. Antunes *et al.,* (2016) observed high abundance of orders Clostridiales, Bacillales, and Actinomycetales in large composting operation in the São Paulo Zoo Park. Martin *et al.,* (2013) suggested important role of bacteria belonging tothe orders Clostridiales and Actinomycetales in lignocellulosic degradation process during composting. However, our observations suggest that bacteria belonging to Pirellulales and Rhizobiales, Cytophagales and Xanthomonadales play important role in composting of mango leaf. Londhe *et al.,* (2019) reported significant presence of bacteria belonging to orders Pirellulales, Planctomycetales, Pelagiococcales, Saprospirales and Bacteriodales in mature samples of organic kitchen waste . Table 3 depicts bacterial diversity at class, and family level in mango leaf compost sample. Fig. 3b, c reflects diversity at genus and species level.

During ITS metagenome sequencing, the total number of OTUs assigned were 1266, out of these 71% were assigned to kingdom fungi and 29% were Unassigned. At phylum level, 35% and 24% of OTUs were assigned with Ascomycota and Basidiomycota, respectively, while 7% were unassigned. At Class level, 25% and 24% of OTUs were assigned with Sordariomycetes and Agaricomycetes, respectively. At Order level, 12% and 11% of OTUs were assigned with Agaricales and Sordariales, respectively. At Family level, 12% and 11% of OTUs were assigned with Coprinaceae and Lasiosphaeriaceae, respectively. At Genus level, 12% and 10% of OTUs were assigned with Coprinus and Zopfiella, respectively. At Species level, 11% of OTUs were assigned with *Coprinus cordisporus*. Seven percent of the fungi were either unidentifiable or un culturable. Neher *et al.,* (2013) reported fungal communities of compost from a mixture of dairy manure and silage-based bedding were distinguished by a greater relative abundance of Pezizomycetes and Microascales. Abundance of

Table 3. Relative abundance of Operational taxonomic units at class and family level in mango leaf compost

Class	Percent abundance	Family	Percent abundance
c_Alphaproteobacteria	11%	f_Hyphomicrobiaceae and 11 more	3%
c_Gammaproteobacteria	6%	f_Rhodospirillaceae and 8 more	2%
c_Betaproteobacteria	4%	f_Sinobacteraceae and 14 more	3%
c_Deltaproteobacteria	2%	c_Betaproteobacteria and 4 more	3%
c_Planctomycetia	13%	f_Pirellulaceae	7%
c_Phycisphaerae	3%	f_Planctomycetaceae	3%
c_Cytophagia	5%	f_Gemmataceae	3%
c_Bacteroidia	4%	c_Phycisphaerae	3%
c_Saprospirae	3%	f_Cytophagaceae	5%
c_Acidimicrobiia	3%	f_Prevotellaceae	3%
c_Actinobacteria	3%	f_Chitinophagaceae	3%
c_Anaerolineae and 8 more	3%	o_Acidimicrobiales	3%
c_TM7-1 and 3 more	2%	o_Actinomycetales	3%
c_Acidobacteria-6	3%	c_Anaerolineae and 8 more	3%
c_ZB2	3%	f_	2%
p_Verrucomicrobia and 27 more	3%	o_iii1-15	3%
Unassigned and 3 more	16%	f_	3%
		p_Verrucomicrobia and 27 more	3%
		Unassigned	16%

Epicoccum, Thermomyces, Eurotium, Arthrobotrys, and Myriococcum was observed in hay based composting system while the hardwood based system contained relatively abundant Sordariomycetes and Agaricomycetes. Rarefaction plot (Fig. 1b) indicated fungal diversity in the mango leaf compost sample.

Production potential of cellulase, pectinases and amylase by the culturable bacteria and fungi (Table 1,2) highlights their importance in the degradation of complex organic substrate in the compost ecosystem. Hankin *et al.,* (1975) reported diversity of the extra-cellular degradative enzymes including cellulase, pectinase and amylase, produced by bacteria and fungi from a compost pile. Nakamura *et al.,* (2004) isolated *Cerasibacillus quisquiliarum* strain BL×^{T} and *Bacillus thermoamylovorans* strain BTa from compost and their gelatinase and amylase production roles in the decomposition of biopolymers. *Cytophaga, Polyangium,* Sorangium, *Pseudomonas* & related genera of bacteria and *Chaetomium, Fusarium,* and *Aspergillus* are the fungi having cellulolytic property. Few Actinobacteria are known to degrade cellulose in compost. These microbes in compost bring about bio-transformations and result in compost stability.

CONCLUSION

The study indicated that mango leaf compost is a rich source of macro and micronutrients along with unique microbial population and culturable microflora having high degradative enzymatic potential. The study also explored the diversity of unculturable bacterial and fungal communities in mango leaf compost. The results indicate that mango leaf compost can improve the soil physico-chemical properties as well as microbial diversity. To our knowledge this work is the first report of a whole microbial community study of mango leaf metagenome.

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Conflict of interest

The authors declare that they have no conflict of interest.

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Effect of growth regulators and micronutrients spray on physico-chemical properties of litchi *(Litchi chinensis)*

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ABSTRACT

The experiment was conducted to find out the effect of plant growth regulator and micronutrients on physico-chemical properties of litchi (*Litchi chinensis* Sonn.) at the Regional Horticulture Research and Training Station, Dhaulakuan, Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan, dring 2014-15. The experiment consisted of 19 treatments with three replications laid out in Randomized Block Design. The growth regulators and micronutrients applied were GA_3 (T_1 = 25 ppm, T_2 = 50 ppm, T_3 = 75 ppm), CPPU (T_4 = 5 ppm, T_5 = 10 ppm, T_6 = 15 ppm), $ZnSO_4$ (T_7 = 0.25%, T_8 = 0.50%, T_9 = 0.75%), boric acid (T_{10} = 0.25%, T_{11} = 0.50%, T_{12} = 0.75%), GA_3 + CPPU (T_{13} = 25+5 ppm, T_{14} = 50+5 ppm, T_{15} = 75+5 ppm), Boric acid + $ZnSO_4$ (T_{16} = 0.25+0.50%, T_{17} = 0.50+0.50%, T_{18} = 0.75+0.50%) and T_{19} the control. The growth regulators and micronutrients significantly improved all physico-chemical properties (fruit size, fruit weight, fruit volume, fruit pulp content, pulp percentage, minimum peel percentage, pulp: peel ratio, pulp: stone ratio, peel colour and juice percentage) of fruit. Of which T_2 (GA_3 50 ppm) increased fruit size, fruit weight and volumes, Minimum peel percentage, pulp: peel ratio and peel colour were highly affected by boric acid alone or in combination with $ZnSO_4$.

Key Words: Boric acid, CPPU, Growth regulators, Micronutrient, $ZnSO_4$

Litchi (*Litchi chinensis* Sonn.) responds well to growth ingredients like gibberellic acid, NAA and CPPU. Hota *et al.* (2017 a, b, c, d, e & f) and Hota *et al.* (2018) piloted an examination in 26-year-old apricot cv. New Castle by consuming CPPU and NATCA during 2015 and 2016. He established that CPPU at petal fall phase upsurges the vegetative growth, yield-attributing characters, physico-chemical properties.

Micronutrients perform explicit protagonist in refining the growth, yield and quality of litchi even though these essentials are desirable in trivial magnitudes. Boron and zinc are fundamentally prerequisite for growth and development in litchi and intricate in sundry range of enzyme system. Bearing in mind the prominence of plant growth regulators and micronutrients in fruit production, contemporary analysis was conceded on cv. Calcuttia to perceive the consequence of gibberellic acid (GA_3), CPPU (N-(2-Chloro-4-pyridyl)-N-phenylurea), boric acid and zinc sulphate on physico-chemical properties of litchi. Hence, an experiment was conducted.

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MATERIALS AND METHODS

The experiment was conducted on 12-year-old trees of litchi cultivar Calcuttia, at Regional Horticulture Research and Training Centre, Dhaulakuan, Dr Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan (Himachal Pradesh), during 2014-15. Fifty-seven identical yielding trees with undeviating vigor and size, ingrained at a layout of 8m × 8m were selected for examination. The required amount of each plant growth regulators was taken and final volume was made to one liter with water to serve as stock solution. Two to three drops of surfactant (teepol) per liter of solution was added to reduce surface tension and to facilitate the absorption of solution.

The experiment consisted of 19 treatments [GA_3 (25, 50 and 75 ppm), CPPU (5,10 and 15 ppm), $ZnSO_4$ (0.25 %, 0.50% and 0.75%), boric acid (0.25%, 0.50% and 0.75%), GA_3 + CPPU (25+5, 50+5 and 75+5 ppm), boric acid+ $ZnSO_4$ (0.25+0.50, 0.50+0.50 and 0.75+0.50) and the control] and 3 replications with randomized block design. The data generated were appropriately computed, tabulated and analyzed. The level of

significance was tested for different variables at 5 per cent level of significance.

Ten fruits were collected randomly from marked panicle and size, weight and volume was measured. The volume of fruits was measured by water displacement method. Then these fruits were peeled and pulp was collected after removal of seed and weighed separately.

$$\text{Pulp / peel / stone (\%)} = \frac{\text{Total weight of fruit pulp / peel / stone taken}}{\text{Total weight of fruits taken}} \times 100$$

The pulp : peel ratio was worked out by dividing the weight of pulp by weight of peel. The pulp to stone ratio was worked out by dividing the weight of fruit pulp (pulp weight = fruit weight – stone weight) by weight of stone. Pericarp colour was examined visually and red colour development on the fruit skin was determined as per 4 points scale (< 25% surface colour = 1; 25-49% surface colour = 2; 50-74% surface colour = 3 and > 75% surface colour = 4). Using the unitary method, the juice content was calculated and expressed in per cent.

RESULTS AND DISCUSSION

The fruit weight varied from 11.30 to 16.60 g. The data indicates that fruit weight differs significantly with different concentrations of growth regulators and micronutrients. The pooled data showed that maximum fruit weight (16.60 g) was recorded in plants treated with T_2 (GA 350 ppm), which was statistically at par with T_1, T_5, T_{14} and T_{16}, whereas all other treatments T_3, T_4, T_6, T_7, T_9, T_{12}, T_{13} and T_{18} increased the fruit weight over control and were statistically at par with each other (Table 1). The minimum fruit weight (11.30 g) was recorded in T_{19} (control).

Various treatments had significant effect on fruit volume compared to the control. The maximum fruit volume (14.00 cc) was recorded by T_2 (GA_3 50 ppm), which was statistically at par with T_{10} (boric acid 0.25%) (12.20 cc) and superior than all other treatments, whereas minimum fruit volume (8.00 cc) was observed in T_{19} (control). Treatments (T_5, T_6, T_7, T_8, T_9, T_{12}, T_{13} and T_{16}) were statistically at par with each other and had similar effect on fruit volume. The trend was found to be similar during both the years except that during 2014-15 minimum fruit volume (8.20 cc) was observed in fruits treated with CPPU 5 ppm.

The treatments had significant effect on fruit length than the control. The maximum fruit length (2.70 cm) was recorded by T_2 (GA_3 50 ppm) which was statistically at par with T_1, T_{10}, T_{11}, T_{14}, T_{16} and T_{18}, whereas, all other treatments recorded increase in fruit length over the control, while minimum fruit length (1.20 cm) was observed in T_{19} (control). The pooled analysis of data indicates that all treatments recorded significantly higher fruit diameter than T_4 (CPPU 5 ppm), which recorded minimum fruit diameter. The plants treated with T_2 (GA_3 50 ppm) treatment recorded maximum fruit diameter (1.90 cm), which was statistically at par with T_1, T_5, T_6, T_{11}, T_{14}, T_{16}, T_{17} and

Table 1. Effect of growth regulators and micronutrients spray on fruit traits in litchi cv. Calcuttia

Treatment	Fruit weight	Fruit volume	Fruit length (cm)	Fruit diameter (cm)	Pulp (%)
T_1 GA_3 (25 ppm)	14.60	11.60	2.41	1.83	70.40(57.14)
T_2 GA_3 (50 ppm)	16.60	14.00	2.70	1.90	72.70(58.48)
T_3 GA_3 (75 ppm)	12.20	11.20	2.10	1.72	68.60(55.93)
T_4 CPPU (5 ppm)	12.30	9.30	2.20	1.50	73.00(58.97)
T_5 CPPU (10 ppm)	14.90	10.20	2.20	1.86	60.60(51.07)
T_6 CPPU (15 ppm)	12.20	10.15	2.10	1.80	71.00(57.49)
T_7 $ZnSO_4$ (0.25%)	12.70	10.90	2.20	1.60	63.40(52.76)
T_8 $ZnSO_4$ (0.50%)	13.40	10.65	2.30	1.65	74.00(59.34)
T_9 $ZnSO_4$ (0.75%)	12.80	10.30	2.10	1.60	62.80(52.42)
T_{10} Boric acid (0.25%)	13.50	12.20	2.40	1.70	67.20(55.02)
T_{11} Boric acid (0.50%)	11.80	9.80	2.40	1.81	80.60(63.86)
T_{12} Boric acid (0.75%)	12.60	10.15	2.20	1.65	73.70(59.10)
T_{13} GA_3 (25 ppm) + CPPU (5ppm)	12.20	10.20	2.10	1.70	73.20(58.79)
T_{14} GA_3 (50 ppm) + CPPU (5 ppm)	15.20	11.65	2.69	1.82	67.50(55.23)
T_{15} GA_3 (75 ppm) + CPPU (5 ppm)	13.30	11.25	2.20	1.70	72.30(58.27)
T_{16} Boric acid (0.25%) + $ZnSO_4$ (0.50%)	15.00	10.85	2.40	1.81	65.90(54.36)
T_{17} Boric acid (0.50%) + $ZnSO_4$ (0.50%)	13.80	11.35	2.10	1.77	79.40(63.03)
T_{18} Boric acid (0.75%) + $ZnSO_4$ (0.50%)	12.60	9.10	2.40	1.84	70.90(57.32)
T_{19} Control (water spray)	11.30	8.00	1.20	1.66	51.40(45.66)
CD 0.05	2.33	1.85	0.37	0.14	6.90

Figures in parentheses are arc sine transformed value

T_{18} and the minimum fruit diameter (1.50 cm) was observed in CPPU 5 ppm (Table 1).

The treatments had significant effect on fruit pulp compared to the control. The maximum fruit pulp (80.60%) was obtained with T_{11} (boric acid 0.50%) which was statistically at par with T_8, T_{12} and T_{17} and all other treatments registered a significant increase in pulp per cent over the control, whereas minimum pulp (51.40%) was observed in T_{19} (control). The trend was found to be similar during both the years (2013-14 and 2014-15).

The treatments exerted significant effect on the peel compared to control (Table 2). The minimum peel (11.10%) was observed in plants treated with T_8 ($ZnSO_4$ 0.50%), which was statistically at par with T_{12} and T_{14}. The maximum peel (19.10%) was recorded by T_{13} (GA_3 25 ppm + CPPU 5 ppm), followed by T_5 (CPPU 10 ppm) (17.50%). The minimum per cent stone (13.10%) was observed in T_5 (CPPU 10 ppm) treated plants, followed by T_8 and T_{17}, whereas all other treatments resulted increase in stone percentage over minimum value. The T_1, T_2, T_3, T_4, T_7 and T_{18} were statistically similar to each other and recorded higher stone content. The maximum fruit stone (23.00%) was obtained in T_{19} (control).

The maximum pulp: peel ratio (7.20) was recorded with T_{17} (boric acid 0.50% + $ZnSO_4$ 0.50%), followed by T_8 ($ZnSO_4$ 0.50%) (6.70), and was statistically at par with T_8, T_{12} and T_{15} (Table 2). The minimum pulp: peel ratio (3.10) was observed in T_{16} (boric acid 0.25% + $ZnSO_4$ 0.25%) treated plants. All other treatments recorded higher pulp: peel ratio over T_{16} and the trend was found to be similar during both the years.All the treatments significantlyimprovedpulp: stone ratio compared to the control. The maximum pulp: stone ratio (6.50) was recorded by T_6 (CPPU 15 ppm) which was statistically at par with T_8, T_{12}, T_{15}, T_{16} and T_{17}, whereas, minimum pulp: stone ratio (3.00) was observed in T_{19} (control), which was statistically at par with T_2, T_3, T_9, T_{10}, T_{13} and T_{18}. The trend was found to be similar during both the years (Table 2).

The growth regulators and micronutrients improved peel colour. The peel colour intensity varied from 1.20 to 3.80. The peel colour intensity was higher (3.80) in T_{16} (boric acid 0.25% + zinc sulphate 0.50%) and was statistically at par with treatment T_7, T_{10}, T_{11} and T_{12}, while all other treatments developed higher colour intensity over control. The least intensity in peel colour was observed in T_{19} (control).

The maximum juice content (64.70%) was recorded by T_{14} (GA_3 50 ppm + CPPU 5 ppm) which was statistically at par with T_{12}, T_{13} and T_{15}, where as rest of the treatments recorded significantly higher fruit juice content than the control. The minimum juice content (43.60%) was observed in T_{19} (control). The trend was similar during both the years except during 2013-14 where minimum juice (43.48%) was observed in CPPU 15 ppm treated plants.

The increase in fruit size and weight following

Table 2. Effect of growth regulators and micronutrients spray on peel (%), stone (%), pulp: peel ratio, pulp: stone ratio and juice content in litchi

Treatment		Peel (%)	Stone (%)	Pulp : peel ratio	Pulp: stone ratio	Peel colour	Juice content (%)
T_1	GA_3 (25 ppm)	14.00(3.86)	16.10(4.07)	5.10	4.40	2.30	50.70(45.38)
T_2	GA_3 (50 ppm)	12.30(3.64)	16.20(4.14)	5.60	4.00	2.50	52.00(46.12)
T_3	GA_3 (75 ppm)	14.60(3.93)	16.60(4.19)	4.80	4.20	1.50	50.30(45.14)
T_4	CPPU (5 ppm)	15.60(4.06)	16.85(2.76)	4.70	4.33	2.20	47.90(43.77)
T_5	CPPU (10 ppm)	17.50(4.30)	21.90(4.78)	3.40	4.70	1.50	44.70(41.92)
T_6	CPPU (15 ppm)	14.80(3.97)	13.10(3.75)	4.90	6.50	1.70	45.70(42.50)
T_7	$ZnSO_4$ (0.25%)	13.50(3.81)	16.80(4.21)	4.70	4.90	3.60	50.50(45.27)
T_8	$ZnSO_4$ (0.50%)	11.10(3.48)	14.40(3.90)	6.70	5.50	2.50	51.30(45.72)
T_9	$ZnSO_4$ (0.75%)	16.20(4.14)	19.30(4.50)	3.80	3.10	1.60	48.40(44.05)
T_{10}	Boric acid (0.25%)	17.10(4.24)	15.80(4.08)	4.00	4.20	3.30	60.50(51.02)
T_{11}	Boric acid (0.50%)	13.80(3.84)	15.57(2.55)	5.80	5.17	3.60	61.10(51.40)
T_{12}	Boric acid (0.75%)	11.12(3.48)	15.00(3.99)	6.70	5.30	3.20	60.70(51.17)
T_{13}	GA_3 (25 ppm)+CPPU (5ppm)	19.10(4.48)	19.08(3.88)	3.10	3.83	1.70	63.50(52.84)
T_{14}	GA_3 (50 ppm)+CPPU (5 ppm)	11.11(3.47)	15.60(4.06)	4.10	4.60	2.50	64.70(53.55)
T_{15}	GA_3 (75 ppm)+CPPU (5 ppm)	12.50(3.67)	15.80(4.08)	6.30	5.80	2.80	63.30(52.70)
T_{16}	Boric acid (0.25%)+$ZnSO_4$ (0.50%)	15.20(4.02)	21.00(4.66)	4.90	5.50	3.80	54.40(47.52)
T_{17}	Boric acid (0.50%)+$ZnSO_4$ (0.50%)	16.60(4.19)	14.66(3.25)	7.20	5.41	1.50	56.50(48.69)
T_{18}	Boric acid (0.75%)+$ZnSO_4$ (0.50%)	11.80(3.58)	16.30(4.15)	5.60	4.20	2.20	53.90(47.24)
T_{19}	Control (Water spray)	13.62(3.82)	23.00(4.89)	5.30	3.00	1.20	43.60(41.23)
CD 0.05		0.28	0.66	1.16	1.21	0.83	3.26

Figures in parentheses are arc sine transformed value

application of T_2 (GA 50 ppm) are in conformity with those of Rani and Brahmachari (2002), Chang and Shyan (2006), Kumar (2014). The increment in fruit size and weight might be due to stimulation of cell division and elongation by gibberellic acid, which further increased number and size of small cells in outer and inner pericarp and increase cell number in the core. The maximum pulp content was recorded with foliar application of T_{11} (boric acid 0.50%), followed by T_{17} (boric acid 0.50% + zinc sulphate 0.50%) and T_4 (CPPU 5 ppm) treatments. The findings are in agreement with those of Haq *et al.*, (2013). The increase in fruit pulp may be due to increase in volume of intercellular spaces in the mesocarpic cells. Availability of boron may lead to regulated cell-wall permeability, consequentlyhigher mobilization of food and minerals from other parts of plants towards developing fruits (Mishra *et al.*, 2017).

The reduction in peel content in cv. Calcuttia was recorded with the application of T_8 ($ZnSO_4$ 0.50%). The reduction in peel content by zinc may be due to increase in plasticity of cell wall which caused cell enlargement, thus stretched the peel and made it thinner (Arie *et al.*, 1997 and Priyadarshi *et al.* (2017, 2018 a&b).

The intensity of peel colour inlitchi was more in fruits treated with micronutrients, T_{16} (boric acid 0.25% + $ZnSO_4$ 0.50%). The present findings are in conformity with those of Haq and Rab (2012) in litchi, Bhalerao *et al.*, (2014) and Patil *et al.*, (2017) in banana. The effect of boric acid may be due to its effect on carbohydrate synthesis. Thus, it is concluded that GA_3 @ 50 ppm increased the fruit size, fruit weight, and fruit volume. On the other hand, boric acid alone or with zinc sulphate increasedfruit pulp content, pulp percentage, minimum peel percentage, pulp: peel ratio and peel colour.

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Effect of weed control on growth, dry-matter production and partitioning in elephant-foot yam [*Amorphophallus paeoniifolius* (Dennst.) Nicolson]

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ABSTRACT

A field experiment was conducted to find out the effect of weed control on growth, dry-matter production and partitioning in elephant-foot yam [*Amorphophallus paeoniifolius* (Dennst.) Nicolson] during 2016 and 2017 at the Regional Centre, ICAR-CTCRI, Bhubaneswar, Odisha. The treatments consisted of combinations of herbicides (pre- and post-emergence), hand-weeding and weed control ground cover (WCGC) along with the control (weedy check). The treatments WCGC, 4 hand-weeding at 30, 60, 90 and 120 DAP and 2 hand-weeding at 30 and 60 DAP+glyphosate (at 90 DAP) resulted in higher plant height, canopy spread, pseudostem diameter, dry-matter accumulation in shoot, corm, root and total. Higher corm length, corm diameter and corm yield were noticed in treatments WCGC, 4 hand-weeding at 30, 60, 90 and 120 DAP and 2 hand-weeding at 30 and 60 DAP+glyphosate (at 90 DAP). The treatment control (weedy check) resulted in lower growth attributes, yield attributes and corm yield. The treatments WCGC, 4 hand-weeding at 30, 60, 90 and 120 DAP and 2 hand-weeding at 30 and 60 DAP+glyphosate (at 90 DAP) resulted in higher dry-matter and starch, and lower calcium oxalate content in corms. The treatment control (weedy check) resulted in lower dry-matter and starch, and higher calcium oxalate content in corms.

Key Words: Elephant-foot yam, Growth, Dry-matter production and partitioning, Quality, Yield

Elephant-foot yam [*Amorphophallus paeoniifolius* Dennst. Nicolson] is cultivated in Andhra Pradesh, West Bengal, Bihar, Uttar Pradesh, Tamil Nadu, Kerala, Maharashtra, Odisha and Karnataka (Nedunchezhiyan and Byju, 2005). Recently, interest has been increasing as a commercial cash crop in India due to its high productivity and profit (Nedunchezhiyan *et al.*, 2010). It is planted at wider spacing to prevent overlapping of canopy from neighbouring plants. It is propagated through corm sets, which takes long time (20-30 days) to sprout. Weeds often germinate and grow earlier than elephant-foot-yam and smother the crop. Ravindran *et al.* (2010) reported that elephant-foot yam is susceptible to weed growth, especially during initial growth phases due to the time gap between planting and sprouting, and slower canopy spread in first few months. Weeds in elephant-foot yam compete below ground for water and nutrients, and above the ground for light and space, and inhibit growth and development of crop (Rao and Nagamani, 2010; Rao *et al.*, 2015). Application of herbicides for weed control at pre- or post-emergence can reduce dependency on hand-weeding and reduce cost per weeding. Herbicides are likely to become an inevitable method of weed control in elephant-foot yam especially where labour is scarce, or expensive, or farm size is large. However, time of herbicides application is important in determining the effectiveness and length of weed control duration (Carter *et al.*, 2007; James *et al.*, 2007). Information on effect of weed control on growth and development in elephant-foot yam is very negligible. Hence, experiment was undertaken to find out the effect of weed control on growth, dry-matter production and partitioning in elephant-foot yam.

MATERIALS AND METHODS

A field experiment was conducted during 2016 and 2017 at the Regional Centre, ICAR-CTCRI (20º 14' 50" N and 85º 47' 06" E), Bhubaneswar, Odisha. The climate of the experimental site was warm and humid

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in summer and cool and dry in winter. The soil of the experimental site was sandy clay loam with pH 6.67. The soil was low in organic carbon (0.36%) with available N, P and K content 172.4, 25.1 and 178.2 kg/ha, respectively. The experiment was laid out in a randomized block design (RBD) with three replications. The treatments consisted of combinations of herbicides, hand-weeding and weed control ground cover (WCGC): T_1 - Pendimethalin @ 1000 g/ha [1 day after planting (DAP)] + Glyphosate @ 2000 g/ha (at 90 DAP); T_2 - Metribuzin @ 525 g/ha (at 1 DAP) + Glyphosate @ 2000 g/ha (at 90 DAP), T_3 - Pendimethalin @ 1000 g/ha (at 1 DAP) + tank mix of Pyrithiobac sodium @ 62.5 g/ha and Propiquizafop @ 62.5 g/ha (at 90 DAP), T_4 - Metribuzin @ 525 g/ha (at 1 DAP) + tank mix of Pyrithiobac sodium @ 62.5 g/ha and Propiquizafop @ 62.5 g/ha (at 90 DAP), T_5 - Pendimethalin @ 1000 g/ha (at 1 DAP) + 2 hand-weedings (at 60 and 90 DAP), T_6 - Metribuzin @ 525 g/ha (at 1 DAP) + 2 hand-weedings (at 60 and 90 DAP), T_7 - 2 hand-weedings (at 30 and 60 DAP) + Glyphosate @ 2000 g/ha (at 90 DAP), T_8 - 2 hand-weedings (at 30 and 60 DAP) + tank mix Pyrithiobac sodium @ 62.5 g/ha and Propiquizafop @ 62.5 g/ha (at 90 DAP), T_9 - WCGC, T_{10} - 4 hand-weedings (at 30, 60, 90 and 120 DAP), and T_{11} - control (weedy check). Farmyard manure @ 10 t/ha was uniformly incorporated before levelling in all the treatments and ridges were formed at the spacing of 90 cm.

In elephant-foot yam variety Gajendra, whole corm of weighing 400 g, treated with cow dung slurry (10 kg of fresh cow dung dissolved in 10 L of water and mixed with 50 g *Trichoderma*) one day before were planted at a 90 cm × 90 cm spacing on ridges. The pre-emergence herbicides (pendimethalin and metribuzin) were applied one day after planting corms. The post-emergence herbicides (glyphosate, and a tank mix of pyrithiobac sodium and propiquizafop) were applied directly on weeds. Using a spray volume of 500 L/ha of water, herbicides were applied without drift on plants with a manually operated knapsack sprayer with a flat-fan nozzle attached to a hood. The WCGC is a polypropylene woven fabric (100 g m^{-2}) which allows air and water to pass through to the soil, but suppresses weed emergence and growth was spread on the ridge and furrows and the ends were covered with soils. Holes were made, and corms were planted using a 10 cm diameter pipe. The recommended dose of water soluble fertilizers @ 120-60-120 kg/ha of N-P_2O_5-K_2O was applied through drip irrigation. The crop was planted 1 May and harvested 31 December during both the years.

The plant height, canopy spread and pseudostem girth at collar region were recorded from the first pseudostem at 3 MAP and the second pseudostem at 5 MAP in randomly selected three plants in each treatment (Nedunchezhiyan, 2014). As elephant-foot yam plant withered/dried at 8 MAP, no growth observations were recorded. However, observations on dry-matter partitioning were taken from consecutive two whole plants/hills in each treatment at 3, 5 and 8 MAP (harvest).

The data collected were subjected to analysis of variance (ANOVA) for RCBD using SAS (ver. 11.0, SAS Inc., Cary, NC). The homogeneity of error variance was tested using Bartlett's χ^2-test. As the error variance was homogeneous, pooled analysis was done. Comparison of treatment means for significance at P=0.05 was done using critical difference (CD) (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

The treatment WCGC (T_9) resulted in maximum plant height at 3 and 5 MAP and it was statistically at par with treatments 4 hand-weeding at 30, 60, 90 and 120 DAP (T_{10}) and 2 hand-weeding at 30 and 60 DAP + glyphosate (at 90 DAP) (T_7) (Table 1). Greater canopy spread at 3 and 5 MAP was noticed in treatment WCGC (T_9) and it was statistically comparable with 4 hand-weeding at 30, 60, 90 and 120 DAP (T_{10}), 2 hand-weeding at 30 and 60 DAP + glyphosate (at 90 DAP) (T_7), 2 hand-weedings (at 30 and 60 DAP) + tank mix Pyrithiobac sodium @ 62.5 g/ha and Propiquizafop @ 62.5 g/ha (at 90 DAP) (T_8), Pendimethalin @ 1000 g/ha (at 1 DAP) + 2 hand-weedings (at 60 and 90 DAP) (T_5) and Metribuzin @ 525 g/ha (at 1 DAP) + 2 hand-weedings (at 60 and 90 DAP) (T_6). The treatment WCGC (T_9) resulted in greater pseudostem girth at 3 and 5 MAP and it was statistically at par with treatments 4 hand-weedings at 30, 60, 90 and 120 DAP (T_{10}) and 2 hand-weedings at 30 and 60 DAP + glyphosate (at 90 DAP) (T_7), 2 hand-weedingss (at 30 and 60 DAP) + tank mix Pyrithiobac sodium @ 62.5 g/ha and Propiquizafop @ 62.5 g/ha (at 90 DAP) (T_8) and Pendimethalin @ 1000 g/ha (at 1 DAP) + 2 hand-weedingss (at 60 and 90 DAP) (T_5) at 3 and 5 MAP, and Metribuzin @ 525 g/ha(at 1 DAP) + 2 hand-weedingss (at 60 and 90 DAP) (T_6) at 5 MAP only. Kumar *et al.* (2019) reported that pre-emergence herbicides tembotrion was very effective in controlling weeds at early crop stage up to two months after planting and thereby promoted the growth of the crop and resulted in higher pseudo stem height, pseudo stem girth, leaf area and leaf area index in elephant-foot yam. The treatment control (weedy check) (T_{11}) recorded significantly lower plant height, canopy spread and pseudostem girth at 3 and 5 MAP (Table 1).

Table 1. Effect of weed control method on plant height, canopy spread and pseudostem girth of elephant-foot yam

Treatment	Plant height (cm)		Canopy spread (cm)		Pseudo stem girth (cm)	
	3 MAP	5 MAP	3 MAP	5 MAP	3 MAP	5 MAP
T_1	65	88	86	102	14.8	18.2
T_2	62	84	82	100	14.3	18.0
T_3	71	96	94	113	15.3	18.6
T_4	68	92	88	106	15.1	18.4
T_5	76	98	96	115	15.6	18.8
T_6	73	97	95	114	15.5	18.7
T_7	80	102	99	120	16.0	19.2
T_8	69	93	96	118	15.8	19.0
T_9	86	108	102	124	16.3	19.6
T_{10}	84	107	100	123	16.3	19.4
T_{11}	58	72	68	83	10.6	12.8
CD (0.05)	6	8	7	10	0.7	0.9

The dry-matter production of elephant-foot yam was partitioned into shoot, corm and root at 3, 5 and 8 MAP, and was presented in the Fig. 1. The dry-matter accumulation in corm was higher than shoot and root at 3, 5 and 8 MAP. At 3 MAP, the dry-matter accumulation in shoot, corm, root and total was higher in the treatment WCGC (T_9) and it was followed by 4 hand-weedings at 30, 60, 90 and 120 DAP (T_{10}) and 2 hand-weedings at 30 and 60 DAP + glyphosate (at 90 DAP) (T_7). This was due to higher growth attributes. The treatments T_9, T_{10} and T_7 registered 144.9, 141.5 and 136.5% higher total, 131.7, 130.2 and 127.0% higher shoot, 170.1, 165.4 and 158.1% higher corm, and 66.7, 64.8 and 64.8% higher root dry-matter production, respectively over T_{11}. Lower dry-matter accumulation in shoot, corm, root and total in control (weedy check) (T_{11}) was due to lower growth attributes like plant height, canopy spread and girth of pseudostem. At 5 MAP, the treatment WCGC (T_9) resulted in higher dry-matter accumulation in shoot, corm, root and total. The treatment T_9 recorded 62.4, 182.4, 84.8 and 150.8% higher root, corm, shoot and total dry-matter production over T_{11}.

The treatment control (weedy check) (T_{11}) resulted in lower dry-matter accumulation in shoot, corm, root and total. At 8 MAP, the treatment WCGC (T_9) resulted in higher dry-matter accumulation in shoot, corm, root and total. It was followed by 4 hand-weedings at 30, 60, 90 and 120 DAP (T_{10}) and 2 hand-weedings at 30 and 60 DAP + glyphosate (at 90 DAP) (T_7). The treatments T_9, T_{10} and T_7 registered 208.9, 200.0 and 186.4% higher total, 58.0, 50.8 and 49.2% higher shoot, 283.2, 273.1 and 253.5% higher corm, and 47.8, 46.0 and 45.1% higher root dry-matter production, respectively over T_{11}. The treatment control (weedy check) (T_{11}) resulted

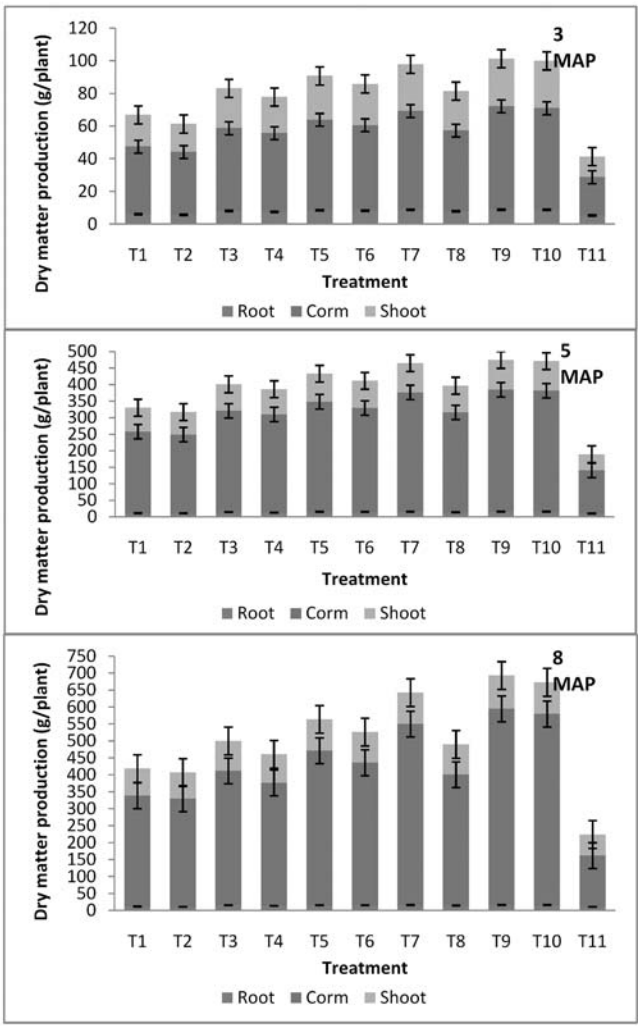

Fig. 1: Effect of weed control method on dry-matter production and partitioning in elephant-foot yam (means ± SE)

in lower dry-matter accumulation in shoot, corm and root. This indicated that in control (weedy check) treatment (T_{11}), the production and partitioning of photosynthates was less owing to poor growth and development which was caused by presence of more weeds.

Marked variation in yield attributes and yield was observed due to weed control methods (Table 2). The WCGC treatment (T_9) resulted in significantly higher corm length and corm diameter than other treatments, however it was statistically at par with 4 hand-weeding at 30, 60, 90 and 120 DAP (T_{10}). Significantly higher corm yield per plant was also noticed with WCGC treatment (T_9), however it was statistically at par with 4 hand-weeding at 30, 60, 90 and 120 DAP (T_{10}) and 2 hand-weeding at 30 and 60 DAP + glyphosate (at 90 DAP) (T_7). Significantly lower corm length, corm diameter and corm yield per plant were noticed with control (weedy check) (T_{11}). Weed control method significantly influenced elephant-foot yam corm yield (Fig. 2). The WCGC treatment (T_9) resulted in higher corm yield which was 253% higher than control (weedy check) (T_{11}). The treatments 4 hand-weedings at 30, 60, 90 and 120 DAP (T_{10}) and 2 hand-weeding at 30 and 60 DAP + glyphosate (at 90 DAP) (T_7) were the next best and resulted in 244 and 229% higher than control (weedy check) (T_{11}). Higher corm yield in these treatments indicated keeping weed free for longer periods increased elephant-foot yam growth attributes like plant height, canopy spread and pseudostem girth, and yield attributes like corm length, corm diameter and corm yield per plant. Keeping plots weed free as long as through either hand-weedings or herbicides caused significant reduction in growth and competition of weeds with crop and resulted in better fresh weight of elephant-foot yam corm (Nedunchezhiyan *et al.*, 2018; Kumar *et al.*, 2019) and cassava (*Manihot esculenta* Crantz) tubers (Nedunchezhiyan *et al.*, 2017). The treatment control (weedy check) (T_{11}) resulted in lower corm yield owing to season long crop-weed competition, which was indicated by growth and yield attributes (Table 1 and 2). Kumar *et al.* (2019) also reported that weed interference in un-weeded plots resulted in slow growth and lower leaf area, which might have affected the production of necessary assimilates for tuber bulking and resulted in poor yield.

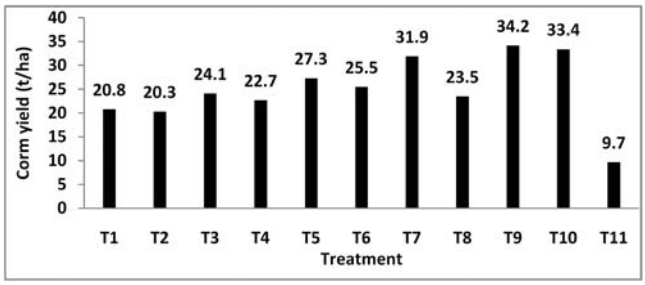

Fig. 2: Effect of weed control method on dry-matter production and partitioning in elephant-foot yam [CD (0.05): 4.3]

The corm dry-matter was ranged from 19.1 to 20.8% and starch was ranged from 15.2 to 16.5% (Table 2). High dry-matter and starch gives good consistency after cooking of the corm. Among all the methods of weed control, WCGC treatment (T_9) resulted in higher dry-matter and starch. The next best treatments were 4 hand-weedings at 30, 60, 90 and 120 DAP (T_{10}) and 2 hand-weedings at 30 and 60 DAP + glyphosate (at 90 DAP) (T_7). The treatment control (weedy check) (T_{11}) resulted in lower dry-matter and starch content in corm. Calcium oxalate (raphite) is an anti-nutrition factor present in elephant-foot yam and causes irritation in the throat when corms are eaten. The treatment control (weedy check) (T_{11}) resulted in higher calcium

Table 2. Effect of weed control method on dry-matter, starch and calcium oxalate content in elephant-foot yam corm

Treatment	Corm length (cm)	Corm diameter (cm)	Corm yield (g/plant)	Dry-matter content (%)	Starch content (%)	Calcium oxalate (mg/100 g)
T_1	13.4	15.2	1690	19.3	15.4	74.6
T_2	13.0	14.8	1650	19.3	15.4	74.8
T_3	14.9	16.8	1960	20.2	16.2	73.8
T_4	14.2	16.3	1850	19.6	15.4	74.2
T_5	16.8	18.7	2220	20.5	16.2	70.2
T_6	15.2	17.3	2070	20.3	16.1	71.4
T_7	19.3	21.8	2590	20.6	16.3	69.6
T_8	14.6	16.7	1910	20.2	16.1	72.4
T_9	21.4	23.4	2780	20.8	16.5	68.2
T_{10}	21.0	23.1	2720	20.7	16.5	68.4
T_{11}	10.2	11.4	790	19.1	15.2	75.2
CD (0.05)	0.9	1.1	350	0.8	0.6	6.1

oxalate content. The treatments WCGC (T_9), 4 hand-weedings at 30, 60, 90 and 120 DAP (T_{10}), and 2 hand-weedings at 30 and 60 DAP + glyphosate (at 90 DAP) (T_7) resulted in lower calcium content. This may be due to dilution effect. A decrease in calcium oxalate content at higher corm yield has been reported by Suja *et al*. (2012).

Thus, treatments WCGC, 4 hand-weedings at 30, 60, 90 and 120 DAP, and 2 hand-weedings at 30 and 60 DAP + glyphosate could be recommended for higher growth, dry-matter production and partitioning, yield and quality in elephant-foot yam.

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Evaluation of phenotypic and biochemical diversity in peach (*Prunus persica* (L.) Batsch) and nectarine (*Prunus persica* (L) var *nucipersica*) cultivars in the subtropical region of Punjab

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ABSTRACT

The experiment was conducted to find out phenotypic variability in cultural and biochemical fruit quality traits in peach [*Prunus persica* (L.) Batsch] and nectarine [*Prunus persica* (L.) var. *nucipersica*] during 2017 and 2018. The fruit length, fruit breadth and fruit weight; and fruit quality parameters, *viz*. flesh firmness, TSS, TA and ripening index were determined. Biochemical fruit quality traits such as ascorbic acid, total phenols, anthocyanins and relative antioxidant capacity were evaluated. Maximum fruit length (50.68 mm), total phenols (30.17 mg/100g FW) and relative antioxidant capacity (83.28%) was noted in Flordaglo, whereas, Tropic Beauty recorded maximum fruit breadth (55.17 mm), fruit weight (85.04 g), flesh firmness (14.74 lbf), ripening index (15.92) and ascorbic acid content (5.15 mg/100g FW). Maximum TSS (12.57°Brix) was noted in Florda Grand, while, minimum TA (0.78%) was recorded in Punjab nectarine. Cultivar Punjab Nectarine and Suncoast nectarine have maximum anthocyanin content (10.57 mg/100g FW). The cultivars exhibited wide phenotypic variation in cultural as well as biochemical traits. Such findings would be helpful in the future breeding programs for selecting cultivars having more health enhancing properties and good postharvest efficiency.

Key Words: Antioxidant, Fruit weight, Phenotypic value, Flesh firmness, TSS, Phenol

Peach [*Prunus persica* (L.) Batsch] and Nectarine [*Prunus persica* (L.) var. *nucipersica*] belong to Rosaceae family (sub family *Prunoideae*). Nowadays there are approximately more than 3000 peach and nectarine cultivars worldwide, which can be differently classified as having melting, non-melting and stony hard flesh; hairy (peach) and smooth (nectarine) skin; clingstone and freestone, *etc.* (Zhao *et al.*, 2015). Peach and Nectarines were considered as one of the most genetically characterized species in the Rosaceae family, which makes them a model genome species for the genus *Prunus* as well as for the other genus in the Rosaceae family (Abbot 2002). Qualitative traits such as flavour, sweetness and juiciness vary from cultivar to cultivar in peaches and nectarines (Cano-Salazar *et al.*, 2013). For that individual fruits must be inspected for the changes during ripening period, because ripening pattern in one cultivar may not be similar to other cultivar in the same species (Goulao and Oliveira, 2008). The biochemical properties of fruits have gained more importance because of their potential health benefits (Prior and Cao, 2000). It is quite challenging for the peach and nectarine growers for selection of the ideal scion cultivar which fulfills the market demand and also boost their profits (Yue *et al.*, 2014). Breeding of new cultivars can be achieved through phenotypic and genetic characterization based on desirable fruit quality traits. Therefore, an experiment was conducted to characterize four peach and two nectarine cultivars on the basis of phenotypic and phytochemical fruit quality traits.

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MATERIALS AND METHODS

Four peach and two nectarine cultivars were evaluated and characterized according to the peach descriptor (IBPGR Rome Italy, 1984). All cultivars were budded on 'Flordaguard' peach rootstock and established in New Fruit Orchard, Department of Fruit Science, PAU, Ludhiana, Punjab (Table 1). Three plants for genotype were evaluated for two successive years, *i.e.*, 2017 and 2018. Most of the peach and nectarine accessions were non-melting, clingstone and yellow fleshed. Trees were grown under standard cultural practices of fertilizer application, irrigation, pest and disease management, thinning and winter pruning.

Fruits were hand-picked at commercial maturity by assessing fruit peel colour and flesh firmness. For the evaluation of quality parameters of fruit, a representative sample of ten fruits per tree was selected. Fruit length and breadth were determined by digital vernier caliper and expressed in mm, while, fruit weight was measured by using digital weighing balance and average was expressed in grams. Flesh firmness was determined with the help of penetrometer fitted with 8-mm diameter probe. The total soluble solids (TSS) of the juice was measured with a digital hand refracto-meter and expressed as ºBrix. The titratable acidity (TA) was determined by titrating 5 ml of juice with 0.1N NaOH (AOAC, 1984). The ripening index (RI) was calculated as the ratio of TSS: TA. Then, 5 g of flesh samples were taken from each tree and stored in liquid nitrogen at -20ºC for further analyses of biochemical properties.

The procedure described by Law *et al.* (1983) and adapted from Okamura *et al.* (1980) was used for the estimation of ascorbic acid content in fruits. For the determination of ascorbic acid, samples were kept in 5 mL of 5 % metaphosphoric acid in liquid nitrogen at -20 ºC for the preservation of ascorbic acid. The samples were mixed evenly with the help of shaker and centrifuged at 16000 rpm for 20 minutes at 4 ºC. The sample was then filtered using muslin cloth and the supernatant was used for the analysis. The absorbance was measured at 525 nm using a spectrophotometer using ascorbic acid solution as standard. The ascorbic acid was expressed as mg per 100 g fresh weight (FW).

The total phenolic content in the fruits was evaluated according to the method suggested by Swain and Hills (1959). The assay consists of a colorimetric method based on the chemical reduction of Folin-Ciocalteau reagent. The absorbance was measured at 725 nm using a spectrophotometer. The phenolic content was expressed in milligrams of gallic acid equivalents (GAE) per 100 g fresh weight (FW).

The fruit pulp was crushed and anthocyanin was extracted with 10 ml of 1% HCl (w / v) in 80% methanol (Rabino *et al.*, 1977). The sample was kept in the dark at 4°C overnight. The absorbance of extract which was clarified by filtration was measured at 530 nm and 657 nm. The anthocyanin content of the extracts was calculated as A530- 0.33 A657 and expressed as mg per 100g fresh weight (FW).

where, A 530 = Absorbance at 530 nm
A 657 = Absorbance at 657 nm

Antioxidant capacity of peach extracts was measured using 1, 1-diphenyl-2-picrylhydrazyl (DPPH), as described by Brand-Williams *et al.* (1995). The absorbance of samples was measured at 515 nm after 10 min of reaction. The antioxidant activity was expressed in percentage (%).

The data were analyzed according to completely randomized design in factorials with three replications, using SAS v9.0.0 software and separation of mean was done using Least Significant Difference (Fisher's LSD) test at $\leq$0.05 level of significance.

RESULTS AND DISCUSSION

There was high variability among the cultivars for phenotypic characters and fruit traits. The maximum mean fruit length (50.68 mm) was recorded in Flordaglo, followed by Tropic Beauty (49.26 mm), Florda Grand (48.20 mm) and Punjab Nectarine (44.86 mm), while, minimum (39.51 mm) was observed in Suncoast Nectarine, followed by Tropic sweet (42.32 mm) (Table 2). Maximum mean fruit breadth (55.17 mm) was reported in Tropic Beauty, followed by Flordaglo (52.83 mm) that was at par with Florda Grand (51.56 mm). Minimum mean fruit breadth (39.38 mm)

Table 1. Fruit shape, flesh colour and flesh adhesion to stone of the evaluated peach and nectarine cultivars

Cultivar	Fruit shape	Flesh colour	Flesh adhesion to stone
Florda Grand	Medium oblate	Orange Yellow	Freestone
Tropic Beauty	Round (Circular)	Yellow	Freestone
Flordaglo	Round (Circular)	Greenish white	Freestone
Tropic Sweet	Round (Circular)	White	Freestone
Suncoast Nectarine	Elliptic	Orange yellow	Freestone
Punjab Nectarine	Elliptic	Greenish yellow	Freestone

Table 2. Fruit length, breadth, weight and flesh firmness of peach and nectarine cultivars

Cultivars	Fruit length (mm)			Fruit breadth (mm)			Fruit weight (g)			Flesh firmness (lbf)		
	2017	2018	Mean	2017	2018	Mean	2017	2018	Mean	2017	2018	Mean
Florda Grand	47.97	48.43	48.20	51.46	51.65	51.56	80.60	79.04	79.82	8.83	9.53	9.18
Tropic Beauty	48.87	49.66	49.26	54.89	55.45	55.17	85.94	84.14	85.04	14.50	14.98	14.74
Flordaglo	50.45	50.92	50.68	51.64	54.01	52.83	75.06	73.18	74.12	14.43	14.82	14.63
Tropic Sweet	42.11	42.52	42.32	44.72	45.16	44.94	41.10	37.24	39.17	14.00	14.44	14.22
Suncoast Nectarine	39.31	39.70	39.51	39.64	39.12	39.38	73.62	73.21	73.42	13.77	14.08	13.92
Punjab Nectarine	44.59	45.13	44.86	39.43	40.21	39.82	75.51	74.80	75.16	13.70	14.03	13.87
$LSD_{0.05}$	3.37	2.82	1.67	2.75	2.18	1.34	4.16	3.02	1.79	1.17	1.03	0.78

was noted in Suncoast Nectarine which was non-significantly different from Punjab Nectarine (39.82 mm). Among the cultivars, Tropic Beauty has maximum mean fruit weight (85.04 g), while, Tropic Sweet have minimum mean fruit weight (39.17 g). The variation in fruit related traits among the different genotypes might be due to the inherent genetic nature of plants (Thirugnanavel *et al.*, 2018) and crop load that appear to be responsible for difference in fruit length, breadth and weight. Rouse and Sherman (1989) reported that the variation in fruit weight may be due to varied fruit size (length and breadth) and differences in crop load. Dirlewanger *et al.*, (1999) concluded that fruit weight is a major quantitative inherited trait that determines fruit yield, quality and consumer acceptability.

The maximum mean fruit firmness (14.74 lbf) were noted in Tropic Beauty (Table 2), followed by Flordaglo (14.63 lbf). Cultivars Suncoast Nectarine (13.92 lbf) and Punjab Nectarine (13.87 lbf) were non-significantly different from each other. Minimum mean fruit firmness (9.18 lbf) was recorded in Florda Grand. These variations in the fruit firmness may be due to the difference in cell pore density per unit area in the different genotypes. The higher firmness in some genotypes may be due to high level of pectin, starch or other biochemical constituent (Chanana *et al.*, 1992).

The maximum TSS (12.57 °Brix) was observed in Florda Grand which was non-significantly different from Tropic Beauty (12.56 °Brix), while, minimum TSS (11.41 °Brix) was noted in Suncoast Nectarine which was at par with Punjab Nectarine (11.47 °Brix) (Table 3). The acidity was minimum (0.78%) in Punjab Nectarine, while, maximum acidity (0.90%) was observed in Suncoast Nectarine. The maximum mean ripening index (15.92) was calculated in Tropic Beauty, whereas, minimum mean ripening index (12.70) was in Suncoast Nectarine. The variation in the TSS might be due to the varietal character and period interval available from fruit setting till maturity, resulting in breakdown of more starch to simple ones in peach (Cantin *et al.*, 2010). The varying levels of acid content among genotypes might be due to the different rate of conversion of organic acids into soluble sugars. Agro-ecological and nutritional factors could also have an influence on TSS, acidity and ripening index of fruits. In peaches, ripening index is a major organoleptic quality trait which is most commonly used as a quality index. The relationship between TSS and TA has an important role in the consumer acceptance of peach and nectarine cultivars.

The biochemical fruit quality traits showed a high variability among cultivars (Table 4). The ascorbic acid content ranged from 3.28 to 5.15 mg/100g of FW.

Table 3. Total soluble solids (TSS), titratable acidity (TA) and ripening index (RI) of peach and nectarine cultivars

Cultivars	Total Soluble Solids (°Brix)			Titratable Acidity (%)			Ripening Index		
	2017	2018	Mean	2017	2018	Mean	2017	2018	Mean
Florda Grand	12.47	12.67	12.57	0.83	0.81	0.82	15.03	15.84	15.43
Tropic Beauty	12.50	12.62	12.56	0.80	0.79	0.79	15.71	16.13	15.92
Flordaglo	11.73	11.87	11.80	0.84	0.82	0.83	14.03	14.54	14.29
Tropic Sweet	11.77	11.98	11.87	0.81	0.79	0.80	14.59	15.17	14.88
Suncoast Nectarine	11.37	11.44	11.41	0.91	0.89	0.90	12.49	12.91	12.70
Punjab Nectarine	11.43	11.51	11.47	0.79	0.77	0.78	14.54	14.95	14.75
$LSD_{0.05}$	0.74	0.47	0.31	0.04	0.05	0.03	1.46	1.29	0.88

Table 4. Ascorbic acid, total phenols, anthocyanin content and relative antioxidant capacity of peach and nectarine cultivars

Cultivars	Ascorbic acid (mg/ 100g FW)			Total Phenols (mg/ 100g FW)			Anthocyanin content (mg/ 100g FW)			Relative Antioxidant Capacity (%)		
	2017	2018	Mean	2017	2018	Mean	2017	2018	Mean	2017	2018	Mean
Florda Grand	4.60	4.67	4.64	26.04	26.17	26.11	5.76	5.79	5.78	70.53	70.58	70.56
Tropic Beauty	5.12	5.18	5.15	10.50	10.81	10.66	5.61	5.68	5.65	65.00	65.04	65.02
Flordaglo	4.88	4.92	4.90	30.13	30.21	30.17	3.07	3.12	3.09	83.26	83.30	83.28
Tropic Sweet	4.57	4.60	4.59	20.18	20.22	20.20	4.23	4.25	4.24	67.65	67.69	67.67
Suncoast Nectarine	3.26	3.29	3.28	22.75	22.97	22.86	10.55	10.58	10.57	77.46	77.53	77.50
Punjab Nectarine	4.18	4.20	4.19	23.80	23.86	23.83	10.55	10.59	10.57	76.74	76.83	76.78
$LSD_{0.05}$	0.99	0.71	0.49	3.28	3.25	1.66	0.31	0.31	0.17	2.38	2.38	1.01

Maximum ascorbic content (5.15 mg/100g) was in Tropic Beauty, while, the minimum (3.28 mg/100g) was in Suncoast nectarine. The results indicated that peach is a good source of ascorbic acid. There were significant differences observed among cultivars regarding total phenolic content. The amount of total phenolics in cultivars ranged from 10.66 to 30.17 mg/ 100g with maximum numerical value (30.17 mg/100g) in Flordaglo and minimum (10.66 mg/100g) in Tropic Beauty. The anthocyanins content ranged from 3.09 to 10.57 mg/100g of FW, showing high variability among the cultivars. The maximum total anthocyanin content (10.57 mg/100g) has been recorded in Suncoast and Punjab Nectarine, while, minimum total anthocyanin content (3.09 mg/100g) was observed in Flordaglo followed by Tropic sweet (4.24 mg/100g). The data clearly indicate wide variability with respect to total anthocyanin content among different peach and nectarine hybrids and cultivars. This variation might be due to genetic makeup of genotypes and further their interaction with the environment. Cantin *et al.*, (2010) reported that total anthocyanin content greatly varied among different peach genotypes that ranged between 0.1 to 26.7 mg of C3Geq/ kg of FW depending upon the red pigmentation in the flesh. Abidi et al., (2018) observed anthocyanin content in the range of 1.2 to 6.3 mg C3Geq/ kg of FW, showing high variability among genotypes which is in accordance with the present study. The relative antioxidant capacity (RAC) ranged from 65.02 to 83.28% showing greater variation among genotypes. The maximum relative antioxidant capacity (83.28%) was obtained in Flordaglo, while, minimum (65.02%) was noted in Tropic Beauty. These variations might be due to genetic make-up of genotypes and further their interaction with the environment. The variations regarding antioxidant capacity could be explained by the fact that the antioxidant capacity of fruits varies in relation to antioxidant molecules present in different species (Gil *et al.*, 2002). Cantin *et al.* (2009) observed significant variations among different peach genotypes with respect to ascorbic acid content, total phenols, anthocyanin content and relative antioxidant capacity. Phenotypic and biochemical diversity has been reported in jackfruit (Gaithoiliu and Pereira, 2016), aonla (Kumar *et al.*, 2016),tamarind (Sharma *et al.*, 2015) and Bauhinia (Makwana *et al.*, 2014).

Thus, it was concluded that relative antioxidant capacity of peach and nectarine is characterized by vast levels of variations, though explained by genotype but interaction between genotype and environment may also be significant factor. There is an important genetic potential for selecting new peach cultivars having greater fruit quality traits.

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Induction of flowering and increasing fruit yield and quality in pomegranate (*Punica granatum* L.) cv. 'Bhagwa' by application of certain chemicals

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ABSTRACT

The field trail was conducted at ICAR- IIHR, Bengaluru to assess the effect of different chemicals (Nitrobenzene @ 1.0 ml, 1.5 ml and 2.0 ml/litre, Cycocel @ 500 ppm, 1000 ppm and 1500 ppm, Uracil @ 25 ppm and 50 ppm, Cycocel @ 1000 ppm + Uracil @ 25 ppm and Cycocel @ 1500 ppm + Uracil @ 50 ppm) on flower induction, fruiting and yield parameters in tissue cultured plant propagules of pomegranate (*Punica granatum* L.) cv. 'Bhagwa' during 2016-17 at ICAR-IIHR, Bengaluru. The foliar application of Cycocel @ 1500 ppm gave a significantly increased number of hermaphrodite flowers (287.84) and intermediate flowers (254.14) per plant, thereby increasing the percentage of fruit setting (86.10 %) and number of fruits (156.66) per plant. Thus fruit yield (54.53 kg/plant and 21.81 tonnes/ha), fruit weight (348.32 g), fruit length (8.53 cm) and fruit volume (333.93 ml) increased significantly. Consequently, foliar application of Cycocel @ 1500 ppm led to a significant reduction in number of male flowers (219.70) produced per plant. However, fruit width was non-significant among treatments.

Key Words: Flowering, Fruit yield, Cycocel, Fruiting, Uracil, Fruit width

Pomegranate (*Punica granatum* L.) is flourishing well, gaining impetus in the arid and semi-arid ecosystems in India (Jalikop, 2003). Morphological modifications possessed by the plant, given a promising potential for promoting its plantation in the poor and marginal soils as well as in the mismanaged areas (Bankar and Prasad, 1992). There are three distinct seasons of flowering in pomegranate, i.e. ambe bahar (January-February), mrig bahar (June-July) and hastha bahar (September-October). The inflorescence is a dichasial cyme. The flowering habit is influenced by prevailing climatic condition (Pareek and Sharma, 1993). Flowering and fruit setting are most critical, occurring after establishment of plants (Sonawane *et al.*, 2016). In tropical climates, it flowers almost throughout the year, whereas, under subtropical conditions it flowers once in a year. In areas, where temperature is lower during winter season, plant behaves as a deciduous, but under tropical conditions, its plant is evergreen (Sankaran *et al.*, 2006).

'Bhagwa' is most widely cultivated pomegranate variety, occupying major area due to its attractive red skin, deep red arils, soft seeds (mellowness), gaining huge export demand (Babu *et al.*, 2017). Keeping in view, field trial was conducted to induce flowering, fruit setting and fruit yield in pomegranate cv. Bhagwa by foliar application of nitrobenzene, uracil and cycocel, individually as well as in combinations.

MATERIALS AND METHODS

The trial was conducted on healthy and uniformly grown tissue-cultured plant propagules of pomegranate cv. Bhagwa procured from M/s Jain Irrigation Pvt. Ltd, Jalgoan (Maharashtra) at the ICAR-IIHR, Hesaraghatta, Bengaluru during Hastha bahar (September-October) season of 2016-17. Average maximum and minimum temperatures recorded during the experimentation were 33.08°C and 20.43°C and relative humidity and rainfall recorded were 75.04% and 74.95 mm respectively. Initially (prior to imposition of treatments) all the plants were subjected to stress by means of withholding irrigation for a period of one month and defoliation was done by foliar application of ethrel @ 2 ml litre, followed by pruning of twigs. The experiment consisted of eleven treatments

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which were replicated thrice and statistical design used was randomized block design. The treatments were: T_1 - nitrobenzene 1.0 ml/litre, T_2 - nitrobenzene 1.5 ml/litre, T_3 - nitrobenzene 2.0 ml/litre, T_4 - cycocel 500 ppm, T_5 - cycocel 1000 ppm, T_6 - cycocel 1500 ppm, T_7 - uracil 25 ppm, T_8 - uracil 50 ppm, T_9 - cycocel 1000 ppm + uracil 25 ppm, T_{10} - cycocel 1500 ppm + uracil 50 ppm and T_{11} - control (water spray). Standard cultural practices such as de-suckering wasdone prior to and during the investigation.

Observation on flower types was recorded 15 days after treatment. Number of male, hermaphrodite and intermediate flowers/plant was recorded by selecting one quarter of tree and counting of flower number under each quadrant and multiplying the number with four. The fruit setting was determined by counting the lemon sized fruits present on entire tree. Individual fruit weight was recorded by randomly selecting nine fruits under each treatment and the mean value was expressed in g/fruit. The percentage of fruit setting was calculated by using the following formula:

Percentage of fruit setting =

$$\frac{\text{Number of fruits harvested}}{\text{Number of hermaphrodite flowers}} \times 100$$

Number of fruits/plant was counted at every harvesting and the cumulative mean value was expressed as number of fruits/tree. Fruit yield was recorded by recording weight of fruits harvested at maturity and expressed as kg/tree. The data were analyzed as per the method of variance outlined by (Panse and Sukhatme, 1985). Statistical significance was tested by F- value at 5% level of significance. Least significant difference at 0.05 levels was worked out for the effects which were significant.

RESULTS AND DISCUSSION

The foliar application of cycocel @ 1500 ppm recorded significantly highest number of hermaphrodite flowers/plant (287.84), followed by foliar application of cycocel @ 1000 ppm (261.19) and cycocel 500 ppm (256.69) without any significant differences among the treatments. Similarly highest number of intermediate flowers (254.14) were observed by foliar application of cycocel @ 1500 ppm in combination with uracil at 50 ppm followed by application of cycocel at 1500 ppm (250.53) and cycocel 1000 ppm + uracil 25 ppm (250.08) without any significant differences among the treatments (Table 1). It is evident that exposure of plants to stress in pomegranate promoted accumulation of proline which acted as an endogenous signal to induce flowering (Neale, 1990). Further, a positive correlation was observed between leaf proline content and the number of hermaphrodite flowers produced (Powerwanto and Inoue, 1990). Application of ethrel at high concentration (2 ml/litre) to defoliate pomegranate also regulates flowering (Saroj *et al.*, 2017). Foliar application of ethrel causes activated gene expression of cell-wall degrading enzymes such as cellulase and polygalacturonase. Ethrel perception was found involved in the arrest of stamen development through induction of DNA damage which promotes hermaphrodite flower production in some plant species (Xie *et al.*, 2015). The foliar application of cycocel @ 1500 ppm, 1000 ppm and 500 ppm induced higher number of hermaphrodite flowers/plant. Such a trend could be attributed to role of cycocel which reduces endogenous GA levels and increased auxin and cytokinin levels through t-ZR and DHZR contents. An increase in ribosyl derived cytokinins is reported to act

Table 1. Flowering in pomegranate 'Bhagwa' as influenced by different chemicals

Treatments	Number of male flowers	Number of hermaphrodite flowers	Number of intermediate flowers
Nitrobenzene 1.0 ml / litre	277.40	195.05	215.43
Nitrobenzene 1.5 ml / litre	283.42	203.66	231.23
Nitrobenzene 2.0 ml / litre	252.27	241.02	234.57
Cycocel 500 ppm	243.79	256.69	238.52
Cycocel 1000 ppm	232.63	261.19	245.02
Cycocel 1500 ppm	219.70	287.84	250.53
Uracil 25 ppm	252.13	220.73	230.50
Uracil 50 ppm	241.69	222.66	236.40
Cycocel 1000 ppm + uracil 25 ppm	234.75	239.99	250.08
Cycocel 1500 ppm + uracil 50 ppm	234.99	243.43	254.14
Control (water spray)	286.14	181.85	204.06
LSD (0.05)	14.68	11.51	11.22
SEm±	4.94	3.87	3.77

positively in inducing flower bud formation (Murti *et al.*, 2001). Blockage of GA synthesis due to application of cycocel might have resulted in induction of flowering. Similar kind of observation was reported earlier by (Khader, 1991) which is in consonance with that of application of cycocel at optimum levels can block GA synthesis and enhance the percentage of bisexual flowers in mango.

There was highest fruit size weight (348.32 g), length (8.53 cm), width (8.96 cm) and volume (333. 93 ml) with foliar application of cycocel @ 1500 ppm (Table 2). Cycocel being growth retardant acts as an antagonist by blocking the synthesis of gibberellins by inhibiting the conversion of geranyl geranyl pyrophosphate to ent-kaurene. An increase in fruit size with foliar spray of cycocel might have been attributed to retardation of vegetative growth due to reallocation of assimilates, mineral elements and soluble proteins synthesized in leaves, stems and roots were diverted towards the growth and development of fruit (Wang *et al.*, 1995). Enhancement in fruit size by foliar application of cycocel could also be explained due to its involvement in stimulation of cell division and cell expansion due to synthesis of auxins and cytokinins (Vidya *et al.*, 2016) thus resulting in larger fruit size. These results were found in close agreement with the earlier report published by (Bikramjit *et al.*, 2012) while working with litchi cv. Calcutta. It may also be attributed to better physiology of the developing fruits in terms of better supply of water, nutrients and other essential compounds vital for proper growth and development of fruits which resulted in improved size. On the other

Table 2. Effect of different chemicals on fruiting behaviour in pomegranate 'Bhagwa'

Treatments	Fruit weight (g)	Fruit length (cm)	Fruit width (cm)	Fruit volume (ml)
Nitrobenzene 1.0 ml / litre	276.61	7.65	7.83	267.37
Nitrobenzene 1.5 ml / litre	280.13	7.82	7.98	276.86
Nitrobenzene 2.0 ml / litre	281.24	7.86	8.06	267.17
Cycocel 500 ppm	315.86	8.33	8.28	300.60
Cycocel 1000 ppm	325.05	8.49	8.36	310.60
Cycocel 1500 ppm	348.32	8.53	8.96	333.93
Uracil 25 ppm	299.93	8.04	8.12	263.80
Uracil 50 ppm	303.91	8.11	7.96	287.06
Cycocel 1000 ppm + uracil 25 ppm ppm	280.82	8.34	8.06	239.41
Cycocel 1500 ppm + uracil 50 ppm	290.75	8.00	8.14	203.87
Control (water spray)	270.41	7.71	7.66	263.74
LSD (0.05)	23.62	0.58	N.S.	37.53
SEm±	7.95	0.19	0.35	12.63

Table 3. Yield and yield contributing characters in pomegranate 'Bhagwa' as influenced by different chemicals

Treatments	Percentage of fruit setting (%)	Number of fruits / plant	Fruit yield (kg / tree)	Fruit yield (tonnes / ha)
Nitrobenzene 1.0 ml / litre	37.52	96.33	26.66	10.66
Nitrobenzene 1.5 ml / litre	40.63	106.00	29.68	11.87
Nitrobenzene 2.0 ml / litre	48.01	115.66	32.52	13.01
Cycocel 500 ppm	70.01	142.66	45.12	18.04
Cycocel 1000 ppm	75.50	147.33	47.93	19.17
Cycocel 1500 ppm	86.10	156.66	54.53	21.81
Uracil 25 ppm	39.26	94.33	28.38	11.35
Uracil 50 ppm	40.36	98.33	29.90	11.96
Cycocel 1000 ppm + uracil 25 ppm	46.72	104.00	29.21	11.68
Cycocel 1500 ppm + uracil 50 ppm	51.02	112.66	32.80	13.12
Control (water spray)	31.49	90.66	24.52	9.80
LSD (0.05)	4.18	12.42	5.78	2.31
SEm±	1.41	4.18	1.94	0.77

hand, flower quality may potentially be a factor influencing fruit size in pomegranate. Production of larger size fruit requires flowers with adequate numbers of both functional ovules and a source of viable pollen (Wetzstein *et al.*, 2001). Pomegranate is characterized by having hermaphrodite and functional male flowers, a condition called andromonoecy (Wetzstein *et al.*, 2011) helped in improving the fruit size.

The data on fruit yield and yield contributing characters exhibited significant differences among different treatments and treatment combinations. Foliar application of cycocel 1500 ppm implicated in registering high fruit setting (86.10 %), number of fruits per plant (156.66) and fruit yield (54.53 kg / plant and 21.81 tonnes / ha) (Table 3). Fruit setting percentage in pomegranate generally relies on number of hermaphrodite flowers present on plant (Chaudari and Desai, 1993) and relative availability of functional male flowers determine the fruit setting capacity. An increase in number of fruits / plant could be ascribed to more number of hermaphrodite flowers as fruits develop exclusively from them in pomegranate and thus high fruit setting percentage (Wetzstein *et al.*, 2015 a) observed due to presence of sufficient availability of functional male flowers. Fruit yield is a culmination of many series of events like fruit size (weight, length, width and volume) and fruit number. The foliar application of cycocel @ 1500 ppm increased fruit size and number of fruits / plant, thus, their improvement complemented fruit yield.

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Effect of foliar spray of water- soluble fertilizer on growth and yield of chilli *(Capsicum annuum)*

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ABSTRACT

The experiment was conducted to find out the effect of foliar application of water soluble fertilizers on growth and yield of chilli (*Capsicum annuum* L.) during 2015-16, 2016-17 and 2017-18 at Bharatpur, Rajasthan. The application of recommended dose of fertilizers-NPK @ 70:48:50) + water-soluble fertilizers (polyfeed NPK-19:19:19) @1% at 45 and 75 days after transplanting recorded higher yield of green chilli (93 q / ha) as compared to the control (84 q / ha). There was 10.71% increase in yield over the control .The technology gap in productivity (7 q / ha) was computed. The technology index value (7.53%) was recorded. The results indicated the gap existed in the potential yield and demonstration yield is due to soil fertility and weather conditions. By conducting on-farm testing of proven technology of nutrient management, yield potential of chilli can be increased. This will substantially increase the income as well as the livelihood of farming community.

Key Words: On- farm testing, Control, Polyfeed NPK-19:19:19, Technology, Yield

Chilli (*Capsicum annuum* L.) is an important vegetable crop grown all over the country in summer and *kharif* season. There are a number of factors that are responsible for transaction of assimilates and metabolites. Of which, nutrient play an important role in rapid translocation. Soil application of fertilizers is a general method practised by the farmers in which the fertilizers are placed near the root zone, but efficiency of soil applied nutrients is poor due to various losses like volatilization, immobilization and fixation in soil. The uptake of necessary nutrient elements becomes difficult for the plant, when application of fertilizers to the soil leads to formation of certain soil complexes and applied fertilizers are not fully utilized by plants. Thus, foliar nutrition using water-soluble fertilizer can eliminate such problems. Foliar feeding has been widely used and accepted the essential part of crop production, especially in horticultural crops (Kumar, 2013). The NPK fertilizers play a significant role in successful chilli production. Application of N,P and K in different ratio through foliar spray is a modern method of fertilization in vegetable crops due to nature of heavy feeder of nutrients. Foliar nutrients usually penetrate the cuticle of leaf or stomata, enter the cells rapidly and fulfil the nutrient demand of growing plants, thus ameliorating nutrient deficiencies rapidly. Hence, an experiment was conducted.

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MATERIALS AND METHODS

An on -farm testing was conducted in Bharatpur district to see the effect of foliar feeding of water-soluble fertilizer on the yield of chilli during 2015-16, 2016-17 and 2017-18 at farmers' fields. Soils of the experimental fields were sandy loam in texture, medium in nitrogen, phosphorus and potash with saline reaction. Seeds were sown in first week of July in nursery. The 30-35 days old seedlings were transplanted in the first week of August. The two treatment consisted of control (farmers practice) and recommended dose of fertilizers-NPK @ 70:48:50) + water soluble fertilizers (NPK-19:19:19) @ 1% 45 and 75 days after transplanting (DAT). The inorganic fertilizers were applied in the form of urea, diammonium phosphate and muriate of potash. Nitrogen was applied in 4 equal split doses as basal application, and 30, 60 and 90 days after transplanting.

The full dose of phosphorus and potassium were applied as basal application at the time of transplanting. Weed management, need-based plant protection chemicals were applied.

The data on cost of cultivation, production, productivity, total return and net return were collected in both treatments as per schedule from all selected farmers. An average of cost of cultivation, yield, net returns of different farmers was analyzed by the formula.

Average = [F_1 + F_2 + F_3.....Fn] / N

F_1 = Farmer

N = Nnmber of farmers

The technology index was operationally defined as the technical feasibility obtained due to implementation of demonstration (on-farm testing) in chilli. To estimate the technology gap, extension gap and technology index, following formula used by Samui *et al.* (2000), Sagar and Chandra (2004) were used.

Technology gap = Pi (potential yield) – Di (demonstration yield)

Extension gap = Di (demonstration yield) – Fi (farmers yield)

Technology index – [(potential yield – demonstration yield / potential yield) × 100]

RESULTS AND DISCUSSION

Performance of on-farm testing

The application of RDF (NPK @ 70:48:50) + spray of water-soluble fertilizers (NPK-19:19:19) @ 1% 45 and 75 days after transplanting recorded the higher yield (93q / ha) than farmers practice (84 q / ha). The Percentage increase in the yield (10.71%) over farmer's practice was recorded. The recommended dose of inorganic fertilizers and spraying of water-soluble fertilizers exhibited significant influence on yield. This might be due to the solubility and uniform distribution of nutrients would have increased the growth and yield. This could be due to increased uptake of primary nutrients (NPK) and fast movement of photosynthates within the plant system. The utilization of applied nitrogen in protein synthesis stimulates all enzymatic reaction, and to cell division and cell enlargement and increased the plant growth (Chaurasia *et al.*, 2005; Narayanamma *et al.*, 2009; Ananthi *et al.*, 2007). Mehta *et al.* (2017) reported higher bulb yield of garlic and net profit along with sustaining soil fertility with the application of 100% RDF with three foliar sprays [30, 45 and 70 DAS] of 0.5% polyfeed (19:19:19). Muthumanickam and Anburani (2017) reported that 100% RDF+WSF 1.0% NPK @ 13:40:13 recorded highest plant height, number of primary branches ,stem girth, number of leaves / plant, leaf area, leaf area index and dry-matter production (Table 1).

The spray of 1% NPK (19:19:19) starting from 30 days after transplanting at 10 days interval, along with 100% recommended dose of fertilizers (200:150:100) kg / ha, recorded highest plant height, number of primary branches, secondary branches, stem girth, number of leaves / plant and leaf area (Anburani, 2018). The balanced nutrition throughout the crop growth period helped in increasing the photosnthatic efficiency and source of plant, thereby increasing the yield. These results are in close conformity with the finding of Manjunatha (2004). Deepa Devi and Shanthi (2013 and 2016) reported that in chilli Polyfeed (NPK19:19:19) 1.0% sprayed 5 times (30, 45, 60, 75 and 90 DAT) along with 100 Per cent recommended dose of fertilizers increased plant growth parameters, yield attributes, yield and NPK uptake as compared to water spray and rest of the treatments. Similarly, Yield enhancement in different crops in frontline demonstration had been documented by Hiremath *et al.* (2007), Mishra *et al.* (2009), Kumar *et al.* (2010), Surywanshi and Prakash (1993), Kumar *et al.* (2013) and Kumar *et al.* (2017). Thus, it is evident that performance of technology tested was found to be better than the farmers practice under the same environment conditions. The farmers were motivated by seeing the results in term of producitivity and they are adopting the technologies. The yield under on- farm testing and potential yield of crop was compared to estimate the yield gaps which were further categorized into technology index and technology gap.

The technology gap showed the difference between potential yields over demonstration (on-farm testing) yield of the technology. The potential yield of the variety is 100 q / ha. The Technology gap 7 q / ha was recorded. The on-farm testing was laid down under

Table 1. Yield, technology gap, extension gap and technology index of demonstration

Variable	No. of trials	Yield (q/ ha)	Increase over farmers practice (%)	Technology gap (q/ha)	Extension gap (q/ha)	Technology index (%)
T_1., Farmers practice (NPK @ 60:50:0)	6	84				
T_2., RDF (NPK @ 70:48:50) + spray of water soluble fertilizers (NPK-19:19:19) @ 1% 45 and 75 DAT	6	93	10.71	7	9	7
Additional in T_2 treatment application		9				

Table 2. Economics (average of 3years) of chilli production under on- farm testing

Technology option	Yield q/ha	Cost/h (Rs.)	Gross return Rs./ha	Net return Rs./ha	Benifit: Cost Ratio
T_1. farmers practice (NPK @ 60:50:0)	84	60,670	1,26,000	65,330	1:2.08
T_2. RDF(NPK @ 70:48:50) + spray of water-soluble fertilizers (NPK-19:19:19) @ 1% 45 and 75 DAT	93	63,500	1,39,500	76,000	1:2.20
Additional in T_2 treatment application	9	2,830	13,500	10,670	*3.77

* incremental benefit: cost ratio.

the supervision of Krishi Vigyan Kendra's specialists at the farmers' field; there exist a gap between the potential yield and demonstration yield. This may be due to the soil fertitlity and weather condition. Hence, location specific recommendations are necessary to bridge the gap Chaurasia *et al.*, (2005).

Comparative high extension gap (9) indicates that there is need to educate the farmers and help them for optimizing the yield by adopting improved practices. More use of improved technolgies by the farmers will subsequently change existing trend of extension gap. Technology index shows the feasibility of technology at farmers' field. The lower value of technology index, more is feasibility of particular technology. The result revealed that technology index value was 7 (Table 1). It means the technology is suitable for Bharatpur district of eastern Rajasthan. The result consonance with Kumar *et al.* (2013).

The economic analysis of chilli production revealed that treatment T_2, RDF (NPK @ 70:48:50) + spray of water soluble fertilizers (NPK-19:19:19) @ 1% 45 and 75 DAT recorded higher gross return (₹ 1,39,500 / ha) and net return (₹ 76,000 / ha) with higher benefit: cost ratio (1:2.20) as compared to farmers practice. These results are in accordance with findings of Hiremath *et al.*, (2009). An additional cost of ₹ 2,830 / ha has increased additional net return ₹ 13,500 / ha with incremental benefit: cost ratio 3.77 suggesting higher profitability and economic viabilility. The RDF (NPK @ 70:48:50) + spray of water- soluble fertilizers (NPK-19:19:19) @ 1% 45 and 75 DAT. More and less similar results were also reported by Hiremath and Nagaraju (2009) and Chouhan *et al.* (2018) and Meena *et al.* (2019). Premsekhar and Rajashree (2009) also reported similarly as foliar application of 5 sprays of NPK (19:19;19) 1% along with normal recommended dose of NPK is found to be highly beneficial for maximizing the yield of COTH 2 hybrid tomato with high benefit: cost ratio (Table 2).

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Morphological and Anatomical Diversity of *Bulbophyllum* in India

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ABSTRACT

The Orchidaceae is one of the largest families of flowering plants comprising about 40 per cent of the Monocotyledons. India, due to its tropical location, physiological variation associated with favourable climatic conditions, has a moderately rich orchid flora of about 1350 species in 186 genera. The structure of leaf and leaf basis are taken primary importance in this paper. On this investigation, the anatomy of leaf of *Bulbophyllum* species is taken for the detailed study, to find out the ecological and taxonomic significance.

Key Words: *Bulbophyllum*, Leaf, Anatomy, Ecology.

The Orchidaceae is one of the largest families of flowering plants comprising about 40 per cent of the Monocotyledons (Ramesh and Khasim 2019). It comprises about 779 genera and 22,500 species (Mabberley, 2008). In India, orchids are concentrated mostly in Eastern Himalaya (Hooker, 1895), Western Himalaya and also Western Ghats. Orchids with their attractive range of varied flowers form excellent ornamental plants and they are rich source of medicines and aesthetic pleasure. In present work, 7 species of *Bulbophyllum* collected from different geographical areas were slected for study (Table 1a). The anatomy of leaf of all the samples are taken on the morphological structure is well defined from all the samples. *Bulbophyllum affine* (Arunachal Pradesh), *B. bisetum* (Darjeeling), *B. careyanum* (Sikkim), *B. cauliforum* (Darjeeling), *B. cornutum* (Darjeeling) and *B. crassipes* (Darjeeling), *B. Fischerii* (Darjeeling).

MATERIALS AND METHODS

Plant materials were collected from Arunachal Pradesh, Darjeeling and Sikkim Himalayas and at various altitudes over the period of 2 years (Table 1a). Vegetative organs such as leaves, stems, pseudobulbs and roots were fixed in FAA (5 cc formalin + 5 cc acetic acid + 90 cc 70 per cent ethanol) for 24 hours and then they were transferred to 70 per cent alcohol and stored in it for laboratory studies. Sections were stained with safranin and fast green. For leaf epidermal peelings, small bits of leaf were put in 10% potassium hydroxide solution and then boiled until the epidermis was loosened from the mesophyll and veins. These peelings were mounted in 50 per cent glycerine. For microtome sections, soft parts of the plant were dehydrated in alcohol and xylene series, infiltrated and embedded in paraffin wax (melting point 60-62°C) and sectioned with a rotary microtome at a thickness of 15-20 µm; double staining was done by safranin-fast green combination and sections were mounted in DPX mountant (Khasim, 2002).

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RESULTS AND DISCUSSION

The *Bulbophyllum* is probably the largest pantropical genus with approximately 2400 species (Sieder *et al.*, 2007). The Paleotropical region is the richest of this genus, with hundreds occurring in Asia, followed by Africa and the Neotropics. In India, it is represented by 87 species (Manilal and Kumar, 2004).

B. affine: Rhizome stout, long with dense roots all along; pseudobulbs cylindrical with slightly thickened bases; leaf oblong, obtuse with narrow base. In out line, leaf is angular at the midrib region (Fig. 1A). Cuticle is well developed on both surfaces. Adaxial epidermal cells are larger in their size than the abaxial epidermal cells. The guard cells are clearly seen with

cuticular ledges. The length and width of the stoma is 0.017 µm and 0.023 µm respectively (Table 1b).

B. bisetum: Creeping rhizome with roots; pseudobulbs conical-ovoid, to 2 cm long; leaves thick, fleshy to 15 cm long, lanceolate, obtuse. Inflorescence pendent, densely flowered; flowers olive green and brown, sepals dull-purple, petals purple, lip purple with yellow tip. Epidermal cells are rectangular in shape. Stomatal apparatus with 4 subsidiary cells (tetracytic) confined to abaxial surface only. The length and width of stoma is 0.019 and 0.021 µm respectively. Leaf is thick, fleshy. Adaxial epidermal cells are comparatively larger than abaxial ones (Fig. 1a).

B. careyanum: Pseudobulbs 8 cm long, smooth and 3 cm in diameter; leaf oblong - linear, 20 cm long and 2 cm broad, thick, leathery, tongue shaped. Epidermal cells are polygonal in shape. Stomata are paracytic and confined to abaxial surface only. In out line, leaf is almost flat, slightly angular groove in the midrib region (Fig. 1C). Abaxial side of mid-rib region broadly conical. Epidermis - Cuticle is well developed on both surfaces. Adaxial epidermal cells are comparatively larger than abaxial ones (Fig. 1B). The thickness of the cuticle is 0.009 µm (Table 1b). Guard cells with cuticular ledges (stomatal ledges) are observed (Ramesh and Khasim, 2017). The mid-rib vascular bundle is 0.084 m and the laminar vascular bundle is 0.051 µm (Table 1b). All vascular bundles are associated with sclerenchyma.

B. cauliflorum: B. cauliflorum is known as "Stem-Flowering *Bulbophyllum*". Stomatal apparatus with 2 or 4 subsidiary cells is present on the abaxial surface only. Two-celled absorbing trichomes are confined to abaxial surface only. Two-celled absorbing trichomes are found in abaxial epidermis. Assimilatory cells are thin-walled parenchymatous with chloroplast. Majority of mesophyll cells are hyaline, larger, pleated and function as water storage cells (Fig. 1D).

B. cornutum: A small sized, warm growing epiphyte with pseudobulbs enveloped in long stiff bristles and carry a single, apical, thick leaf. Inflorescence single-flowered. The epidermal cells are polygonal in shape. Absorbing trichomes are absent. Stomata with 4-6 subsidiary cells (cyclocytic) are confined to abaxial surface only. Adaxial epidermal cells are comparatively larger than abaxial ones. The adaxial epidermal cells at the midrib region are slightly elongated. Stomata are confined to abaxial surface only (hypostomatic distribution), 3-celled absorbing trichomes (Fig. 1E). Vascular bundles are in a single series. Larger midrib vascular bundle is in the centre and, small and large laminar vascular bundles on either side of it (Fig. 1E).

B. crassipe: Epidermal cells are isodiametric to polygonal in shape. Stomata with 4 subsidiary cells

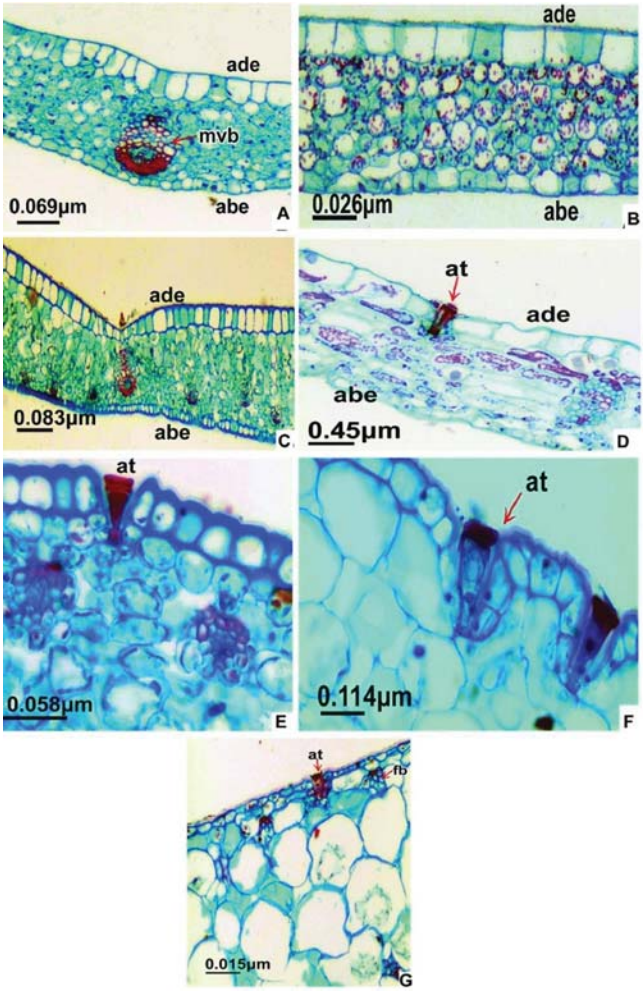

Fig. 1(A-G): Leaf Anatomy of Bulbophyllum

A. *Bulbophyllum affine,* Leaf cross section sowing larger adaxial epidermal cells and midrib vascular bundle.
B. *B. bisetum,* Leaf cross section showing adaxial and abaxial epidermis.
C. *B. careyanum.* Leaf cross section showing larger adaxial epidermal cells and midrib vascular bundle.
D. *B. cauliflorum.* Leaf cross section showing absorbing trichome towards adaxial epidermis
E. *B. cornutum.* Leaf cross section indicating elongated 3-celled absorbing trichome on adaxial epidermis.
F. *B. crassipes.* Leaf cross section showing absorbing trichomes towards adaxial epidermis.
G. *B. fischerii.* Leaf cross section indicating the absorbing trichome and fibre bundles toward adaxial epidermis.

(Table 1) are confirmed to abaxial surface only (hypostomatic distribution). Leaf is angular at the midrib region. Epidermis is well developed with turgid barrel-shaped cells which have thick cuticle on both the surfaces. The adaxial epidermal cells are two times larger in their size than the abaxial epidermis, prominent absorbing trichomes are seen (Fig. 1F).

Table 1a. Morphological and Anatomical Features of Ecological Interest

Sl. No.	Taxa	Habitat	External features	Ade cells size; Stomata, distribution; ssc	Absorbing trichomes
1	*Bulbophyllum affine*	E	Thick leaves, fleshy pseudobulbs	**ade** cells comparatively larger; with 2 or 4 subsidiary cells, prominent stomatal ledges, **h**; well-developed **ssc**	--
2	*B. bisetum*	E	Thick leaves, fleshy Pseudobulb	**ade** cells comparatively larger; with 4 subsidiary cells, h; ssc present	+
3	*B. careyanum*	E	Fleshy psueudobulb, leathery leaves	**ade** cells comparatively larger; with 2 subsidary cells (paracytic), stomatal ledges present **h**; well- developed **ssc**	--
4	*B. cauliflorium*	E	Long-sheathed rhizome, fleshy pseudobulbs	**ade** cells comparatively larger; with 2 or 4 subsidiary cells, **h**; small **ssc**	+
5	*B. cornutum*	E	Thick leaves, fleshy Pseudobulb	**ade** cells are comparatively larger; with 4-6 subsidiary cells (mostly cyclocytic, **h**; **ssc** present	--
6	*B. crassipes*	E	Leathery leaves, fleshy Pseudobulb	**ade** cells are comparatively larger; with 4 subsidiary cells (tetracytic), **h**; ssc present	--
7	*B. fischerii*	E	Leathery leaves, fleshy Pseudobulb	**ade** cells are comparatively larger; with 4 subsidiary cells (tetracytic), **h**; **ssc** present	--

B. fischerii: B. fischerii has small ovoid, 2- leaved pseudobulbs scattered on a slender creeping rhizome; leafless during flowering recemes and inclined. Epidermal cells are rectangular to polygonal in shape. Stomata with 4-5 subsidiary cells are present on the abaxial epidermis only. Epidermis cells are rectangular to squarish. Thick cuticle is covered on both the surfaces. Adaxial epidermal cells are two times larger in size than the abaxial epidermal cells shows fibre bundles towards adaxial epidermis. Vascular bundles are arranged in a single series. Large, midrib vascular bundle is in the centre and, other small and large laminar vascular bundles on either side it. All vascular bundles are associated with sclerenchyma (Fig. 1G).

LEAF - Epidermis : Epidermal cells possess smooth and thin walls in almost all investigated taxa belonging to tribe Dendrobieae. In most of the presently studied taxa, the size of the adaxial epidermal cells is comparatively larger than abaxial ones (Table 1a). Khasim (1996) reported adaxial epidermal cells that are three times larger than abaxial ones in *Paphiopedilum fairrieanum*.

Stomata : The stomata are hypostomatic in distribution, restricted to abaxial surface of leaf. Similarly, hypostomatic distribution is found in other groups of Orchidaceae (Möbius, 1887). Interestingly Vij *et al.* (1991) observed the hypostomatic leaves in mesophytic orchids. Rasmussen (1987) opined that hypostomaty is more frequent in mesophytic orchids, whereas amphistomaty dominates in those of dry and humid habitats.

Absorbing trichomes : The trichomes known to be absorbing in function, are 2 or 3-celled structures with dome-shaped apical cell and basal stalk cell. It preferred to call them as 'Handle cells'. However, in the present investigation, these are observed in some species such as *B. careyianum* and *B. fischerii*.

Hypodermis : In the presently investigated taxa, hypodermis is almost absent. However, fibre bundles at hypodermal position are appeared in *D. anceps*. In *B. careyanum* of present study, a single layer of hypodermis (distinguished from epidermis) without thickenings is reported.

Table 1b. Leaf: Anatomical features in *Bulbophyllum* (in µm)

Sl. No.	Accs. No. Anat. Feat	1	2	3	4	5	6	7
1	Absorbing trichome	-	-	+	-	+	+	+
2	Cuticle thickness	0.008	0.015	0.011	0.009	0.007	0.004	0.012
3	Stomatal width	0.023	0.018	0.021	0.019	0.016	0.024	0.028
4	Stomatal length	0.017	0.012	0019	0.015	0.019	0.011	0.021
5	Midrib vb. Size	0.089	0.075	0.062	0.084	0.058	0.078	0.071
6	Laminar vb. Size	0.041	0.047	0.052	0.051	0.044	0.049	0.057

Mesophyll : In all the investigated taxa, mesophyll is homogeneous, not differentiated into palisade and spongy parenchyma. Mesophyll tissue is tightly packed in some cases, which favours the fixation of carbon through C_4 pathway. Various tracheoidal elements including water storage cells with cellulosic thickenings and without thickenings are observed in the presently studied taxa.

Vascular bundles : In general, vascular bundles are arranged in a single series in all the presently investigated taxa. In all vascular bundles of leaf, phloem is situated towards abaxial side, and xylem towards adaxial side (Ramesh, 2018). The phloem and xylem ends possess with some amount of sclerenchyma (sclerotic sheath). Tracheids with helical thickenings and vessel-like tracheids are abundant in leaf and also other parts of plant body.

CONCLUSION

These data suggest that all the 7 species studied are xeromorphic in nature and can tolerate long periods of drought. *Bulbophyllum cauliflorum,* however, showed maximum xeromorphic features. The leaves of this orchid are very thick and has the thickest adaxial cuticle with extremely small and sunken stomata. Thus, it can be concluded that all the species studies are able to tolerate long periods of drought and efficient in water-use and these traits can be useful for conservation of these species under green house conditions also. The sps. *B. cauliflorum* is showing close affinity with *B. careyanum* which is a taxonomic significance, helps in classifying the large group of monocotyledons.

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Short Communication

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Exploring jamun diversity: few unique selections

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Jamun [*Syzygium cuminii* (L.) Skeels] is an evergreen tree of tropical and subtropical region. Sizable diversity of jamun is observed in Maharashtra, Rajasthan, Gujarat, Uttar Pradesh, Haryana, West Bengal, and the Western Ghats region (Daware *et al.*, 1985; Malik *et al.*, 2017, Tripathi *et al.*, 2018). Being a cross-pollinated crop, and propagated from time immemorial by seeds, considerable variability in fruit size, shape and biochemical constituents exists in it's collections. Selection is the only improvement method widely adopted and several varieties are being released (Keskar *et al.*, 1989). Big fruit size with small seeds and higher pulp recovery is the major trait preferred by consumers. Extensive surveys were undertaken in different parts of the country lead to several collections of jamun with superior quality and higher pulp recovery. These collections were planted at ICAR-Indian Institute of Horticulture Research, Bengaluru and in- situ and ex-situ evaluation of these collections is in progress. A few unique genotypes were identified.

SEEDLESS SELECTION

A seedless jamun collection was identified from Western Ghats. The collection does not have any seed and not even rudimentary seed is present and the whole fruit is edible. The tree is spreading type. The leaf length is 10.53 cm while the leaf width is 6.30 cm. The petiole length is 2.52 cm. It flowers during March - April, almost 15-20 days later than other jamun genotypes. The fruit matures in July. The fruits are available almost 15-20 days later as compared to Cv. Dhoopdal under Bengaluru conditions. The fruits are produced in clusters of up to 15 fruits. The tree yield more than 10000 fruits (10-15 kg/ tree). The fruits are oblong shape and weighing about 0.8 -1.3 g. The fruit colour is dark purple and pulp is pinkish white (Table 1). The juice content is 62.2 per cent and total soluble solids are 13.5 °Brix. The anthocyanin content (230 mg/100g) is higher than the Dhoopdal variety (124 mg/100g). The total phenols are 10.25 mg/g and total flavonoids are 227 mg (Table 2). There is no seed and only one pink spot is visible in transverse section of fruit (Figs. 1a & b).

ROUND THE YEAR SELECTION

This accession is identified from the field of Sri Narasappa, Ajjihalli village, Koratagere taluk, Tumukuru district of Karnataka, having passport data: latitude 13° 31'° N, Longitude- 77° 17 ° E and 841 m MSL. It bears fruits at least twice in a year with better yield and fruit characters compared to local. The tree is about 15-year-old and two- time bearer. The tree has

Fig. 1a & b: Cross -section of fruits

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Table 1. Comparison of Growth and fruit characters of unique accessions with Dhoopdal

Traits	Seedless selection	Round the year selection	Dhoopdal
IC number	IC-0635379	IC-0635373	IC-0621955
Tree growth	Spreading	Erect	Spreading
Leaf length(cm)	10.53	14.70	11.32
Leaf breadth(cm)	6.30	7.40	6.82
Petiole length(cm)	2.52	1.74	1.91
Flowering time	March -April	Feb- March & August -Sept.	Feb- March
Maturity period	July	June- July & Nov- Dec	June
Yield (Number of fruits/tree)	> 10000	>5000	> 3000
Yield (kg)	8-10kg	80kg (estimated)	40-50 kg
Fruit weight (g)	1.1	11.30	10.52
Fruit length (cm)	1.37	3.47	3.16

Table 2. Biochemical characters of fruit of accessions and Dhoopdal

Traits	Seedless selection	All round accession	Dhoopdal
TSS (°Brix)	13.5	13.84	17.33
Acidity (%)	0.17	0.35	0.21
Total sugar (%)	6.72	6.65	6.35
Reducing sugar	3.53	3.40	3.25
Anthocyanins (in terms of cyanidin-3-glucosides) mg / 100 g FW Pulp	230	156	124
Total phenols mg/ 100 g FW Pulp	1025	489	335
DPPH mg / 100 g FW Pulp	726.1	746	403
FRAP Antioxidant activity mg/ 100 g FW Pulp	1391	637	316
Seed analysis			
?-glucosidase Inhibitory activity	NA	93.1	123.7
Total phenolic content (mg GAE/g)	NA	74.1	59.9
Antioxidant activity (µM TE/g)- FRAP	NA	0.92	0.84
Antioxidant activity (µM TE/g)- DPPH	NA	1.39	1.14

AE- ascorbic acid equivalent, GAE- gallic acid equivalent; TE- trolox equivalent.

upright growth. The leaf length is 14.7 cm and leaf width is 7.4 cm with 1.74 cm petiole. It commences flowering in February-March and August -September. The harvesting is done in June - July and November - December under Tumkuru conditions. The fruits are produced in clusters of up to 9 fruits. The mean annual yield is about 80 kg / tree as against 40 kg / tree in local tree. The fruits are oblong in shape and weighing about 8 g - 13 g with an average weight of 11.3 g. The pulp seed ratio is 6.17 which higher than Dhoopdal (Table 1). The fruit colour is dark purple and pulp is pinkish white in colour. The fruit base is projected type. The total soluble solids is 13.84 °Brix. The antioxidant capacity is 746 mg and 637 mg AE / 100 g, as measured in terms of DPPH radical scavenging activity and FRAP reducing power, respectively. The anthocyanin content (156 mg /100g) and total phenols (489 mg / 100g) are higher than Dhoopdal variety (124 mg and 335 mg / 100g, respectively. The glucosidase Inhibitory activity, total phenolic content (mg GAE / g), antioxidant activity (µM TE / g) measured by FRAP and DPPH in seeds are 88.3±9.7, 72.2±3.8, 0.92±0.02 and1.39±0.08, respectively (Table 2).

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Short Communication

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Effect of different shade net on performance of fenugreek (*Trigonella foenum-graecum* L.) in summer season

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An experiment was conducted to assess the performance of leafy vegetable purpose fenugreek under different shade net under Saurashtra agro climatic zone of Gujarat during summer 2013-14 to 2015-16 at Agricultural Research Station (Fruit Crops), Junagadh Agricultural University, Mahuva. The experiment comprised five treatments consisting 50% green shade net, 75% green shade net, 50% white shade net, 75% white shade net and no shade net (open). The 75% white shade net produced highest plant height (14.13 cm) and green yield (1.13 kg/m^2) of fenugreek. Thus, it is quite logical that higher yield of green fenugreek in summer season can be obtained by using 75% white shade net house under Saurashtra condition.

Fenugreek (*Trigonella foenum-graecum* L.) is widely used as green leafy vegetable because of its nutritive and medicinal properties. It prefers cool conditions and as a result there is a shortage of it during summer and rainy season. Protected cultivation is one of the ways to get off-season production and also to enhance its yield and quality. Protected cultivation of vegetables could be used to improve yield quantity and quality (Ganesan, 2004; Shahak *et al.*). A shade net house can modify environmental conditions with reduced labour. The shade net houses commonly used as protected cultivation are designed for temperate or warm regions. These design need to be upgraded with climate control to overcome overheating in summer. Further, shade net house and poly houses are increasing and gaining popularity. Keeping these views in mind, an experiment was conducted during summer 2013-14 to 2015-16 at Agricultural Research Station (Fruit Crops), Junagadh Agricultural University, Mahuva in Bhavnagar District, Gujarat, India, to assess the performance of fenugreek under different shade nets in summer season (off-season).

The experiment was conducted at Agricultural Research Station (Fruit Crops), Junagadh Agricultural University, Mahuva, during summer season of 2013 to 2015. The experiment was laid out in Completely Randomized Design with four replications comparing five treatments, *viz.* 1) T_1: 50% green shade net, 2) T_2: 75% green shade net, 3) T_3: 50% white shade net, 4) T_4: 75% white shade net and 5) T_5: no shade net (open). Fenugreek cultivar, Gujarat Fenugreek-2, was used. A net house of 5m × 5m × 2.5m with green net and a net house of 5m × 5m × 2.5m with white net prepared with the use of wooden and aluminium poles. Soil inside the shade net house was turned to a depth of 20 - 25 cm. One month prior to planting, weeds and stubble were removed the soil brought to a fine tilth by ploughing with cultivator. Standard horticultural practices and plant protection measures were followed. Sowing of fenugreek seeds was done in last week of April and after 21 days of sowing the green fenugreek was harvested and growth and yield parameters were measured.

Plant height was highest under 75 % white shade net house (14.13 cm) compared to open field and other treatments. This may be due to enhanced photosynthesis and respiration due to favorable micro climatic conditions in shade net house. This agrees with those of Ramesh and Arumugam (2010) and Tehlan and Malik (2010).

The results indicated growing of leafy vegetables in different shade nets significantly increased yield of green fenugreek (Table 1). Treatment 75% white shade

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Table 1. Effect of different treatments on growth and green leafy yield of fenugreek

Treatment	Plant height (cm)	Leafy yield (kg/m^2)
T1: 50% green shade net	11.44	0.68
T2: 75% green shade net	12.28	1.04
T3: 50% white shade net	11.50	0.78
T4: 75% white shade net	14.13	1.13
T5: no shade net (open)	7.16	0.20
S.Em+	0.23	0.02
C.D. at 5 %	0.66	0.05
CV %	5.76	6.87

net produced highest green yield (1.13 kg / cm^2), but it at par with treatment 75% green shade net (1.04 kg / cm^2). Yield per hectare during summer season was maximum in shade net situation (Dixit *et al.*, 2005). Fenugreek and coriander grown in 75 per cent shade net situation gave maximum yield (Kotadia *et al.*, 2012). This might be due to that leafy vegetables are grown generally in winter, if it is grown in summer with protected conditions the yield was more. This might be also due to more plant height and leaf in shade net which developed carbohydrates through photo-synthesis and ultimately increased yield.

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Short Communication

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Evaluation of coloured sticky traps for monitoring white fly *(Bemisia tabaci)*, leaf miner *(Liriomyze trifolii)* and thrip *(Thrips tabaci)* in tomato *(Lucopersicon esculentum)*

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Tomato *(Lucopersicon esculentum)* growers face a miserable problem from thrip *(Thrips tabaci)*, whitefly *(Bemisia tabaci)* and leaf miner *(Liriomyze trifolii)* during late- *rabi* season. There is virtually no effective alternative to tackle the menacing effects of thrips, white fly and leaf miner and the only most common means of controlling infestation is through the use of chemicals. Preference of insects towards specific colour is a much known phenomenon. To understand the preference of colour by the thrip, white fly and leaf miner a study was conducted using different coloured traps (blue, yellow green and black) during late rabi season of 2017. The blue was the strong attractant for thrips, yellow colour for white flies and green colour for leaf miners in tomato crop. This study found that preferred coloured sticky traps as a monitoring tool and an alternative for tomato crop protection is less expensive and hazardous than using chemical pesticides.

For pest monitoring and management, trapping provides most convenient tools. Coloured sticky-traps are a simple and low-cost method for determining the relative abundance of insects and are used to monitor flying insect species on many crops (Lessio and Alma, 2004; Raja and Arivudainambi, 2004). Different coloured cylindrical sticky traps placed at a height of 157.5 cm are an effective means of controlling aphids. Therefore, a field experiment was conducted to determine the most effective colour of trap to attract white fly adults and thrip adults and nymphs.

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The field experiment was conducted during *rabi* season (January-March) of 2017 at farmers' fields. The plot size was 100 m^2 with a spacing of 50 cm (row- to -row) × 30 cm (plant- to -plant). Four different colours, yellow, green, blue and black, were used to trap the tomato insect pests. After 21 days of germination, the sticky cards of four colours each of 6 × 8 inch size (prepared by Green Agri Biotech, Assam) were placed, at random in field, 2 m between and 60 cm above the plants, with the help of bamboo stakes. No chemicals were used for pest management.

Traps were placed in the field between 10 and 11 AM. After 20 days of planting, the colour sticky cards were placed in the fields. The adult whiteflies, thrip adults and nymphs and leaf miner adults were collected from each trap, then counted and recorded, repeating weekly; a total of 7 collections were made. The completely randomized block design with four treatments and ten replications was followed. Insects which were stuck on coloured sticky traps were counted from ten square grids using hand held magnifying lens. Observations were taken at seven days interval commencing from 7 DAI (days after installation) till 49 DAI.

Results of study revealed that the thrip population was highly attracted towards blue colour, followed by yellow and green colour. The black colour was less preferred as compared to other three colours. The highest thrip population was trapped at 14 DAI, followed by 35 DAI and 28 DAI and lowest was at 7 DAI and 49 DAI on blue colour (Table 1). The mean number of thrip population was recorded the highest 3.7 (per square inch area) at 42 DAI and lowest was 1.6 (per square inch area) at 7 DAI on yellow coloured sticky trap.

The whitefly populations were highly attracted towards yellow colour followed by green and blue

colour. The black colour was less or not preferred by whitefly population. The data also revealed that mean population trapped per square inch area was the highest (9.5) at 28 days after installation, followed by 14 DAI and 35 DAI on yellow colour. The lowest was observed at 7 DAI (Table 2).various IPM module have been reviewed in potato by Bhatnagar and Singh (2013).

The leaf miner was highly attracted by green colour, followed by yellow and blue, whereas black colour was mostly not preferred. The highest mean number of insect trapped per square inch area was recorded 6.5 at 14 DAI, followed by 7.2 at 28 DAI, 6.8 at 21 DAI respectively, and the lowest was recorded at 7 DAI on green coloured sticky trap. The data revealed that

Table 1. Mean number of thrips per square inch area on different coloured sticky traps

Treatment	Mean no. of insects trapped per square inch area of sticky card						
	7 DAI	14 DAI	21 DAI	28 DAI	35 DAI	42 DAI	49 DAI
Blue	4.6	9.1	5.5	6.5	8.7	5.3	4.5
Yellow	1.6	2.7	2.0	2.0	2.3	3.7	2.8
Green	1.3	2.3	1.3	2.2	2.6	2.5	1.7
Black	0.4	1.0	0.1	0.1	0.9	0.4	0.2
T test	Sig	Sig	Sig	Sig	Sig	Sig	Sig
SE Mean	0.23	0.14	0.17	0.17	0.21	0.24	0.20
CD (0.05)	0.72	0.42	0.53	0.53	0.65	0.73	0.63
CV (%)	24.91	7.96	17.37	14.19	12.95	17.88	19.79

DAI, Days after installation

Table 2. Mean number of whitefly per square inch area on different coloured sticky traps

Treatment	Mean no. of insects trapped per square inch area of sticky card						
	7 DAI	14 DAI	21 DAI	28 DAI	35 DAI	42 DAI	49 DAI
Blue	1.6	1.6	1.9	2.4	1.7	1.3	1.1
Yellow	2.9	7.9	7.2	9.5	7.7	5.3	3.9
Green	1.8	6.5	5.5	6.4	4.7	3.7	2.7
Black	0.7	0.8	1.3	1.4	1.1	0.8	0.9
t test	Sig	Sig	Sig	Sig	Sig	Sig	Sig
SE Mean	0.20	0.23	0.21	0.24	0.18	0.21	0.18
CD (0.05)	0.61	0.71	0.66	0.74	0.54	0.66	0.55
CV (%)	25.33	12.19	11.91	10.92	10.28	17.14	18.71

DAI, Days after installation

Table 3. Mean number of leaf miner per square inch area on different coloured sticky traps

Treatment	Mean no. of insects trapped per square inch area of sticky card						
	7 DAI	14 DAI	21 DAI	28 DAI	35 DAI	42 DAI	49 DAI
Blue	0.7	0.7	0.5	0.5	0.4	0.1	0.2
Yellow	1.7	6.0	5.5	5.9	3.5	2.5	2.2
Green	2.5	7.3	6.8	7.2	5.7	3.7	3.1
Black	0.2	0.3	0.3	0.5	0.2	0.0	0.2
t test	Sig	Sig	Sig	Sig	Sig	Sig	Sig
SE Mean	0.21	0.16	0.24	0.26	0.23	0.14	0.19
CD (0.05)	0.64	0.50	0.75	0.81	0.70	0.42	0.58
CV (%)	36.25	10.21	16.58	16.59	20.69	19.12	28.89

DAI, Days after installation

yellow coloured sticky trap attracted highest mean number of insects (6.0) per square inch area at 14 DAI and lowest (1.7) at 7 DAI (Table 3).

The blue colour was found most effective attractant for thrips, yellow colour for whitefly and green colour for leaf miners in tomato crops. The yellow colour is mostly attracted by all the foliage feeding insects and be successively used for monitoring and trapping small sized insects in crop field. Idris *et al.* (2012) also reported that yellow was the most attractive colour to white flies, regardless of the trap design. Similar results were also reported by Prokopy and Owens (1983) who found that yellow was the most attractive and efficient trap to use in monitoring the white fly. Green colour was less highly attracted by white flies and thrips as compared to yellow colour, but black colour is less preferred as attractant by the insects. Both adults and nymphs of thrip and white fly were attracted to yellow followed by green and black. A related study evaluating height and colour was performed by Gharekhani, *et al.* (2014), who found that yellow sticky trap at a height of 70 cm above the ground were the most suitable for adult thrips infesting garlic onion and tomato crops.

The use of coloured sticky traps show good results for monitoring and managing foliage feeding insects in tomato field. For thrips blue colour was observed to be strong attractant followed by yellow, green and black. Yellow is the most attractive colour for whitefly followed by green, blue and black, and for leaf miner, the green colour was observed to be the most attractant followed by yellow, blue and black. Thus, blue and black colour were less preferred as attractant except the strongest attractant in thrips.

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New Varieties

Thar Srishti : First highly centric (locules) bael *(Aegle marmelos)* variety

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Bael *(Aegle marmelos)* 'Thar Srishti' was identified and released in 2020 by ICAR-CIAH, Bikaner, Rajasthan. It is first variety with highly centric seed cavity (locule arrangement) with attractive pulp and appealing ripened fruit colour having no off flavour. Its average yield / tree during 9th year (91.50 kg), fruit weight (1.55), fruit size (21.00 × 14.00 cm), fruit girth (43.53 cm), shell thickness (0.20cm), number of locules in cross section (14.00), peel weight (200.00 g), pulp weight (1.20 kg), fibre weight (62.32 g), total seed weight (19.00 g), total number of seed / fruit (98.15), TSS of pulp (36.75°brix), TSS of mucilage (51.50°brix), total sugar(21.40%), acidity (0.35%) and TSS / acidity ratio(128.33) were recorded under rainfed semi-arid conditions of western India. Belonging to mid maturity group (April), its fruit attain maximum size up to 20th October. Its fruits are comparatively less affected (18.13%) by sunscald due to dense canopy and lustrous and luxuriant growth with peculiar leaves. Colour of pulp is deep yellow after ripening and emits very less aroma. Fully mature fruits can be kept for 10-15 days and ripe ones for 7-9 days under ambient condition.

Full grown tree | Branches laden with fruits | Attractive and shining fruit colour

(a) Highly centric locule arrangement, (b) Scooped seed and mucilage and (c) Ready for fresh consumption

The locules embedded with seeds and mucilage, adhere in centre are with highly centric locule arrangement, rich in fine fibres and have no off flavour, sacs along with seeds and mucilage can easily scooped out by spoon and can be consumed fresh. It is very sweet with high pulp.

Thar Anant: Lycopene rich and heat tolerant variety of tomato

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Thar Anant: The tomato variety Thar Anant was developed through induced mutation followed by selection of desired phenotypic traits in the induced populations in the year 2020. The mutant having superior phenotypic traits was identified and homogenized based on the horticultural attributes and performance. It is having high flesh thickness (0.85 cm), deep red fruit colour rich in lycopene content (7.9 mg / 100 g) with medium acidity (0.42%) under semi-arid conditions. It is highly vigorous in growth with dark green dense foliage. The mutant has bigger size of inflorescence length (16.3 cm) and distinguished by indeterminate plant habit, fruit size, fruit color and yield potential over the parent. It is highly tolerant to

Different views of Thar Anant variety tomato

heat stress and drought having with high yield potential. The each fruit weight ranged between 120-130g with attractive deep red colour fruits of round shape. Each plant yield varied between 4.2 - 4.9 kg. The fruits mature in 70-80 days after transplanting, comes under medium maturity type. It is moderately

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Varieties developed by Dr Y S R Horticultural University, Andhra Pradesh, India

R V S K Reddy and T Janakiram

Dr Y S R Horticultural University, has come out with development of 23 varieties of horticultural crops. All of them are capable of increasing the farmers income. The varieties are resistant / tolerant to major pest and diseases. They are high yielding, enhancing the income by increasing yield by 15-30%, as compared to the existing ones. These are also suitable for mixed cropping system, ensuring more income per unit area and additional profit to farmers. Owing to resistance / tolerance to pests and diseases their cultivation minimizes the pesticide residues, reduces the cost of cultivation and ensuring safe food production (Table 1).

Varieties & Hybrids of Dr. Y.S.R. Horticultural University

Table 1. High yielding varieties with desirable horticultural traits

Crop	Varieties	Special Characters
Cashew	BPP-10	• High-yielding, cluster-bearing bold nut type (nut weight, 8.1g) with highest shelling percentage (29.3%) • Average nut yield, 20.89 kg/tree
	BPP-11	• Average nut yield, 17.2 kg/tree
Betelvine	Swarna Kapoori	• Highly vigorous with profuse branching and more number of laterals • 20-25 % higher leaf yield than local varieties • Leaf yield, 53,820 panthas/ha
Chilli (paprika)	LCA-436	• High yielding, with an yield advantage of 20-30% over Byadagi Dabbi • Erect and intermediate growth habit, fruits are medium (6-8cm) and bold • Early, 170-180 days duration • Yield, 3,800-4,000 kg/ha

	LCA-424	• High yielding with an yield advantage of 25-35% over Byadagi Kaddi • Erect and intermediate growth habit, fruits are Long (8-10 cm) • Early, 160-170 days duration • Yield, 3,500-3,800 kg/ha
Chilli	LCA-620	• High yielding with an yield advantage of 20-30% over LCA-334 (control) • Plants are tall and erect branching • Medium duration. Seed - seed, 170-190 days • Bears medium long, medium bold sized fruits (9-10 cm length and 3.5-4.0 cm girth) • Yield, 6,500-6,800 kg/ha • Bears uniform sized fruits from basal nodes to top or terminal growing point • Bold and medium long pods which make harvesting easy with less labour cost
	LCA-625	• High yielding chilli variety with an yield advantage of 25-35% over LCA-334 (control) • Plants are erect with tall growing habit and sturdy branching • Medium to long duration 190-210 days • Bears medium long slender sized fruits (8-10cm) • Yield, 6,500-7,000 kg/ha • Highly suitable for direct sowing among all the available OP varieties and can tolerate drought
Chilli Hybrid	LCH-111	• High yielding hybrid with an yield advantage of 15-20% over Indam 5 (control) • Plants are tall and erect • Pods are long with shiny bright red colour (13-14 cm length, 3.0-3.5 cm girth) • Yield, 7,500-8,000 kg/ha
Coriander	Suguna (LCC-236)	• Yield, 8-14 q/ha under rainfed conditions and 12-22 q/ha under irrigated conditions • Herb yield, 15-18 tonnes/ha in rabi • The plants grow to a height of 50-60 cm, with profuse primary and secondary branches and umbels • Suitable for Andhra Pradesh, Gujarat, Rajasthan, Tamil Nadu, Uttar Pradesh which performs better than existing varieties • Suitable for cultivation both under rainfed and irrigated conditions • Yield advantage of 15-25% over the popular cultivars Sudha and APHU Dhania 1
	Suruchi (LCC-234)	• Herbage yield, 3.5-4.5 t/ha greens in off-season (summer) under 50-75% shade net • Herbage yield, 15-18 t/ha in rabi season under open field conditions • The herb can be harvested between 35 and 55 days • Under shade net, yield advantage of 15-30% over existing leafy variety Sadhana
	Susthira (LCC-219)	• Yield, 12-15 q/ha under rainfed conditions and 12-18 q/ha under irrigated conditions • The plants are taller and grow to a height of 60-70 cm, with profuse primary and secondary branches and umbels • Suitable for Andhra Pradesh, Telangana and Tamil Nadu • Medium duration variety with 85-100 days duration • It gives stable yield under rainfed conditions and tolerates terminal moisture stress • Yield advantage of 15-25% over popular cultivars, Sudha and APHU Dhania 1, under normal conditions, whereas 20-30 % under moisture stress conditions
Fenugreek	Lam Methi-2 (LFC-84)	• Average yield, 7-9 q/ha under rainfed conditions and 12-15 q/ha under irrigated conditions • High yielding, growing up to 50 cm with profuse bearing • It is a medium duration which comes to maturity in 80-90 days • Grains are flat, rectangular shaped with attractive brown colour having better market acceptance • Yield advantage of 30-35% over the existing Lam Selection 1 variety
	Lam Methi-3 (LFC-103)	• Average yield, 7-9 q/ha (rainfed); 12-19 q/ha (irrigated) • Suitable for both rainfed and irrigated cultivation • High yielding variety which grows up to 50 cm with profuse bearing • It is a medium duration which comes to maturity in 90 - 95 days • Identified for release at national level, suitable for Andhra Pradesh, Telangana, Madhya Pradesh and Bihar • Yield advantage of 30-35% over the existing Lam Selection 1, variety
Ajowan	Lam Ajowan-2 (LTa-26)	• Average yield, 6-13 q/ha (rainfed); 12-15 q/ha (irrigated) • The plants grow up to 1 m height with profuse branching and flowering

		• Suitable for rainfed conditions of Andhra Pradesh, which performs better than existing desavali varieties with an yield advantage of 20 - 66%
		• Long duration variety under rainfed situation of Andhra Pradesh, which comes to maturity in 145- 175 days
		• Suitable for late Kharif season
Colocasia	Godavari Chema (KCS-3)	• Early maturing high yielding variety with 5 - 5½ months duration
		• Recommended for cultivation as pure crop and also as intercrop in banana and coconut plantations
		• Yield, 18-20 t/ha
Banana	Godavari Bontha	• Culinary variety and comparatively high yielder than Kovvur Bontha (control) with 8-9 hands and 90-100 fingers/bunch
		• Can be grown as pure crop and also as intercrop in coconut orchards
		• Average bunch weight, 23-24 kg
Turmeric	Lavanya (KTS-3)	• High yielding and long duration variety
		• Yield potential, 55-65 t/ha (raw rhizome yield)
Tamarind	Thettu Tamarind	• Heavy yielder with regular bearing habit
		• Plants are productive up to 70-80 years
		• Yield, 150-220 kg pods/plant (at 20 years old)
		• Pulp is 50-56%
		• Pods are big, broad, slightly curved with rounded ends and somewhat compressed
		• Pulp is firm, soft which is thick and deep brown
Coconut	Gauthami Ganga	• Yield, 85-94 nuts/palm/year
		• Dwarf stature (5.12 m at 22 years) and early bearing, comes to flowering in 36 months after planting
		• Higher quantity and quality of tender nut water and copra content, i.e. 59 and 26% over East Coast Tall
		• It has good combining ability useful for crossing programmes for production of new hybrids
	Vynateya Ganga	• Yield, 118 nuts/palm/year
		• It is a tall x dwarf hybrid (Philippines Ordinary Tall x Gangabondam Green Dwarf)
		• Semi tall hybrid, precocious comes to bearing in 48 months after planting. It is a dual purpose hybrid for yield (copra and oil) and tender nut water
		• Increased nut yield of 47 and 7, copra output of 119 and 22, oil yield of 120 and 17 and tender coconut water content of 23 and 17 percent over local check (ECT) and hybrid check (ECT X GBGD) respectively
	Abhaya Ganga	• Yield, 136 nuts/palm/year
		• It is a dwarf x tall cross (Gangabondam Green Dwarf x Laccadive Ordinary Tall)
		• Semi-tall hybrid, early bearing comes to flowering in 38-40 months after planting. Highest oil content, 72%
		• Recorded an increase in nut yield by 54, copra output by 95 and oil yield by 65% tender nut water content by 24% over local check (ECT) and 17, 10, 29 and 13.3% respectively over hybrid check (ECT X GBGD)
Acid lime	Petlur Selection-1	• Cluster bearing and high yielder than local varieties
		• Yields high during summer season, 210-220 kg fruits/plant/Year
		• High juice (55.8%), high citric acid (7.3 mg/100g) in fruits than other released varieties
		• Adoptable to climatic conditions in Andhra Pradesh and Telangana
Cassava	PDP CMR-1	• Yield potential, 43-46 t/ha
		• Semi spreading nature suitable to dense planting.
		• Medium duration crop with 8 - 9 months
Varieties having industrial potential		
Cashew	BPP-10	• Kernels show the export grade of W 210
		• Higher percentage of hermaphrodite flowers 55.21%
		• Early bisexual phase
	BPP-11	• Suitable for high density planting
		• The kernel count shows export grade of W240
Betelvine	Swarna Kapoori	• Leaves are large, smooth, light green in color with long petioles and good quality suitable for export
		• Best male parent in hybridization programme with continuous flowering throughout the year
Chilli (paprika)	LCA-436	• Proven for high colour (110-115 ASTA) and low pungency (13500-15500 SHU)
		• Suitable for pickling and powder

		• Readily accepted by the export industry
	LCA-424	• Proven for high colour (110-115 ASTA) and low pungency (15000-16000 SHU)
		• Readily accepted by the export industry
	LCA-620	• Proven for high colour and medium pungency
	LCA-625	• Suitable for dry spice as an excellent powder, oleoresins recovery for domestic and export market
		• Readily accepted by export industry and farmers due to colour retention
		• Fruits would retain colour (bright red on drying) even after two to three months of storage in open conditions and even if plucking is delayed after ripening
		• The pungency factor is the most striking feature of this variety (45,000-50,000 SHU)
Chilli Hybrid	LCH-111	• Proven for high colour and medium pungency (70-80 ASTA, 25,000-30,000 SHU)
		• Excellent hybrid as dry spice (powder) and high oleoresin content makes it suitable for the domestic and export market
Coriander	Suguna (LCC-236)	• Grains contain high volatile oil content (0.5 %)
		• Herbage yield of 15-18 t/ha in rabi
		• Moderately resistant to powdery mildew
	Suruchi (LCC-234)	• It has volatile herb oil content of 0.15% and leaf essential oil content of 0.032%
		• Has very good aroma, comparable to traditional variety Sadhana and better than cilantro types grown commercially
	Susthira (LCC-219)	• The variety has volatile herb oil content of 0.6%
Fenugreek	Lam Methi-2 (LFC-84)	• Higher diosgenin content (0.45 - 0.83%)
	Lam Methi-3	• Higher diosgenin content (0.72%)
	(LFC-103)	• Grains with attractive brown colour having better market acceptance
Ajowan	Lam Ajowan-2 (LTa-26)	• It has higher essential oil content (3 - 4%) with intense flavoring, aroma and pungency
Turmeric	Lavanya (KTS-3)	• Rhizomes are attractive yellow in colour with a curing percentage of 20%
		• Moderate in curcumin (3-3.2%) content with 55-65 t/ha of yield
Coconut	Gauthami Ganga	• Oil content, 69 % with tender nut water of 447 ml with TSS-7.20 Brix and potassium content of 2035 ppm
	Vynateya Ganga	• Higher copra content of 190.50 g/nut
	Abhaya Ganga	• Oil content, 72 %
Cassava	PDP CMR-1	• Starch content, 24-26%
Varieties tolerant to abiotic stress		
Chilli - Paprika	LCA-436	• Can give sustainable yield even under harsh climatic conditions
Chilli - Paprika	LCA-424	• Can give sustainable yield even under harsh climatic conditions
Ajowan	Lam Ajowan-2 (LTa-26)	• Tolerates moisture stress and is better under rainfed conditions
Cassava	PDP CMR-1	• Drought tolerant
Varieties tolerant to biotic stress		
Cashew	BPP-10	• Shows medium in pest incidence and also less susceptible to foliage, flower and nut feeding pests
	BPP-11	• Shows medium in pest incidence and also less susceptible to foliage, flower and nut feeding pests
Chilli Hybrid	LCH-111	• Besides being a high yielder, resistant to Cucumber Mosaic Virus (CMV)
Colocasia	Godavari chema (KCS-3)	• Less susceptible to phytophthora leaf blight disease compared to local varieties
Banana	Godavari Bontha	• Tolerant to thrips and aphids and moderately resistant to leaf spot diseases
Turmeric	Lavanya (KTS-3)	• Tolerant to leaf spot, leaf blotch and rhizome rot
Coconut	Vynateya Ganga	• Moderately resistant to ganoderma, bud rot and stem bleeding diseases
	Abhaya Ganga	• Moderately resistant to bud rot disease
Acid lime	Petlur Selection-1	• Tolerant to bacterial canker disease
Cassava	PDP CMR-1	• Completely resistant to cassava mosaic disease (CMD). Tolerant to sucking pests

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