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Constrains in commercialization of watermelon (*Citrullus lanatus*) Cultivation in Africa−a review

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ABSTRACT

Watermelon, [*Citrullus lanatus* var. *lanatus* L] is a major crop in Africa, especially facing the harsh effects of climatic change. It is a xerophytic crop that can be grown in subtropical and tropical parts of the world. Some constrains in commercialization of watermelon production are related to agronomic practices, post-harvest management and value-addition in Africa. Several products can be made from watermelon seeds, rind as well as their pulp, thereby boosting the food industry through its materials. However, watermelon production in Africa is hindered by several constrains, like weeds, pests, diseases and poor post-harvesting management. For the realization of true potential of watermelon production in Africa, more research is needed to come up with varieties which are tolerant to pests, diseases and weeds. The awareness in communities on its importance as a commercial crop in drought-prone areas also need attention.

Key Words: Curcubit, Post-harvest management, Watermelon seeds, Xerophyte, Climatic change

Watermelon [*Citrullus lanatus* var. *lanatus* L], cucurbitaceae family, is a warm season crop. Mostly watermelon is grown for dessert and seed in dry areas of Africa. Dessert type watermelon is eaten in salads and juices across the globe (Bahari *et al*., 2012; Gbotto *et al*., 2016). Citron watermelon [*Citrullus lanatus* (Thunb.) Matsum. & Nakai] can be used as stock feed, cooked into a thick porridge or cooked in a dry maize mixture. The seed type watermelon (*Citrullus colocynthis* L. Schrad.) is mostly grown in Central and West Africa where oil is extracted from its seeds (Jensen, 2012; Dube *et al*., 2021). Despite their versatile nature and adaptation to dry conditions its production and post-harvest management in Africa is hindered by several factors which are focused.

Watermelon in Africa

Watermelon production in Africa constituted 5.4% of the total area allocated for vegetable production in 2008 and there was no significant change again on the statistics carried in 2017 (Dube *et al*., 2021). China in particular tops the global production. In Africa, Algeria which has 1.87 million units per year is the top watermelon producer and is at the sixth position in the world ranking in watermelon production. In Zimbabwe and several other African countries, watermelon germplasm is usually shared among farmers (Walter *et al*., 2021). In some cases seeds from tasty watermelon are kept for next season. However, this process can be carried on only when working with open-pollinated varieties since hybrid seeds can produce a different plant the following season due to segregation.

The cultural practices of watermelon in several areas lack modern or improved management practices. Watermelon is not allocated its area of land and mostly intercropped with other crops. No application of fertilizers is done on watermelon unless the field where it is intercropped has organic fertilizers applied (Dube *et al*., 2021). In most cases, fertilization of watermelon depends on the crop where the plant is intercropped, thus needs of major crop determines the type of fertilizer to be applied in the field. Watermelon is not given individual attention in several African countries. Only a few lines of watermelon can be seen per hectare with no proper spacing being followed. Weed control also depends on needs of the crop where watermelon is intercropped as well as the application of pesticides.

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Weed problem

Common watermelon weeds are redroot pigweed (*Amaranthus retroflexus*), purple nutsedge (*Cyperus rotundus*), yellow nutsedge (*Cyperus esculentus*) and palmer amaranth (*Amaranthus palmeri*) (Vollmer *et al*., 2019). Yellow and purple nutsedge can penetrate the polyethylene mulch and compete with watermelon for nutrients, sunlight and other crop necessities ultimately affecting fruit quality and yield. Weeds like palmer amaranth grow at an alarming rate absorbing more nutrients than the watermelons, thereby affecting growth of the planst as well as stem and leaf colour (Sellers *et al.,* 2013). Palmer amaranth is a serious watermelon weed which causes serious reduction in yield ranging between 38 and 65% across the world.

Pests

Pests reduce quantity and quality of the produce (Adojutelegan *et al*., 2016). Major pests are melon flies (*Bactrocera cucurbitae*), aphids *(Aphidoidea*), spider mites (*Tetranychidea*), white flies (*Aleyrodidae* spp), epilachna beetles (*Epilachna varivestis*) and root-knot nematodes (*Meloidogyne* spp). The larvae of melon fly make small holes into watermelon fruit thereby causing serious problems forming a watery ooze on the surface which eventually turns brown. Tunnelled holes are visible on the fruit surface which eventually leads to rotting. The larvae feed on watermelon stems and flowers. *Bactrocera cucurbitae* causes serious problems, causing damage of 20-75%. Removing diseased fruits especially those showing dimples and oozes of a sap which may look clear can be used as a control measure.

The maggots can be killed by burning (Adojutelegan *et al.,* 2016). The aphids can be identified by excretion of honeydew, thus a sticky exudate which is produced by these aphids in large quantities turns black with the growth of a sooty mold fungus. Further, aphids cause leaf chlorosis and stunt shoots. Groups of green to blackish aphids can be found on tender shoots. Attacked leaves can be identified by being twisted and curled which have an impact on growth of watermelon.

Spider mites cause damage on watermelons. The higher the temperature, higher the chances of mite reproduction, thereby increasing the chances of a negative impact on yield (Lilly, 2013). Typical infestation symptoms include yellow to white speckling and affected plants can be covered with an orange cloud of webs and mites. To manage spider mites, constant irrigation and mulching as a way of water conservation can be used as well as spraying with miticides.

Watermelons attacked by white flies can be identified by the presence of sooty mould and honeydew. They suck the sap and cause severe viral diseases. White flies cause two major types of damage on watermelons which are direct and indirect damage. The direct damage is one when whiteflies suck juice causing leaf chlorosis and premature drop of these leaves which eventually leads to death of the plants. Indirect damage is a result of whitefly adults which spread a number of viruses from plants with diseases to healthy plants using their mouthparts. Practicing hygienic measures like removing the diseased fruits can help avoid the damage to other fruits as well as using pesticides like Lamba-Cyhalothrin (Lilly, 2013).

Epilachna beetles are also dangerous to watermelons. The beetles can also bite the stems persistently there by disturbing several processes in the plant like the movement of water and nutrients around the plant. The beetles can also make holes on the fruits making them susceptible to disease attack though their attack is mostly dangerous on young plants and older plants usually can be tolerant to their damage. The use of insecticides like Deltamethrin and Lambda-cyhalothrin can manage this pest (Zhao, 2013).

The root-knot nematodes (*Meloidogne* spp.) causes the roots to swell thus forming galls which shelter nematodes, providing places where they hide, reproduce as well as feeding. Leaf chlorosis is also a factor of nematode damage and leaves also wilt or are stunted. Since nematodes live in soil, they feed on roots of watermelon plants, reducing rate of water and nutrient absorption which eventually leads to a decline in productivity and health of plants. Nematode attack expose plants to bacterial or fungal attack and also can help in transmitting viral diseases.

Diseases

Major diseases are powdery mildew (*Podosphaera xanthii*), anthracnose (*Colletotrichum obiculare*), downy mildew (*Pseudoperonospora cubensis*) and fusarium wilt (*Fusarium oxysporum* f. sp. *niveum*) (Mukoka, 2021). Powdery mildew is a fungal disease which is prevalent in dry conditions with temperatures between 20-30^{0}C. The disease is identified by white powdery growth which starts from underneath the leaves then to the upper surface of leaves. It causes a serious decrease in plant canopy, reducing number of fruits per plant and decreasing its size of fruits. Reduced canopy usually causes sunscald of watermelon fruits leading them unmarketable. Powdery mildew also has a negative impact on reduced fruit quality, shelf-life as well as the flavour of watermelon. The disease constitutes about 50% of yield loses across the world and can be controlled by spraying of fungicides like Sulphur.

Anthracnose is a fungal disease which affects fruits, leaves and vines of watermelons. Development of the disease is highly favoured by warm and humid conditions with temperatures over 25°C. The disease can be identified by angular to round reddish brown spots on older leaves and these spots may dry, turn black or tear out. The spots can also appear as lesions on stems and can spread to fruits and they appear as sunken wet patches which normally turn pink to black. The affected fruits normally die causing yield losses of up to 63%. Rotating crops and planting the seeds which are clean can help in controlling the disease as well as the use of fungicides like Mancozeb and Copper oxychloride.

Downy mildew attacks watermelon leaves. The disease causing organism is air-borne and it occurs in cool moist weather with temperatures around 20°C. It is identified by tiny yellow spots on upper surface of leaves and can turn into brown and necrotic or else the whole leaf may become blighted. The damage on leaves eventually results in the deterioration of plant health thereby diminishing the production of profitable fruits. The disease degrade the foliage of the watermelon, resulting in having a crop which is unmarketable leading to yield losses of up to 50%. Downy mildew can be controlled by reducing the canopy density as well as spraying of Milthane super (Adojutelegan, 2016).

Fusarium wilt is a fungal disease which has chances of infecting watermelons at any growth stage. Pathogens of the disease can be spread by soil, drainage water or seeds. Fusarium wilt favours acidic soils with pH which ranges from 5 to 6, soil moisture which is low to moderate, sandy soils which are light and weather conditions which are dry. The symptoms of wilt may develop from a single or few runners and vascular tissue of lower stem as well as roots may show a brown colour. The plants have chances of being affected by fusarium wilt during their early stages of crop development though symptoms develop later particularly on the beginning of vines to run through fruit set. The leaves may show an appearance dull or greyish green colour and normally the vines which are affected may wilt, dry up turn brown and eventually die. Fusarium wilt can result in production loses of around 100%. The diseases can be best controlled by using crop rotation, using the seeds which are certified, removing and destroying affected plants and using the manure which has fully decomposed.

Black-rot or gummy stem blight (*Didymella bryoniae*) is a disease which can affect leaves, fruits and stems of watermelon. Black-rot favours warm and wet conditions for it to develop and symptoms expression. Thus, rainy, heavy fogs or dews with temperatures between 20°C and 30°C. The reduction in yield and quality of watermelon affected by black-rot is mainly a factor of a reduction in the number of fruits as well as the fruit weight. Other attributes of reduction are low sugar content as a result of *Didymella bryoniae* on the leaves and roots, fruit rot as well as sunburned fruits causing yield loses of around 50%. The symptoms of black-rot ranges from soft and discoloured watermelon fruits, gum coming out from cracked stems, brown lesions on the stem which later turn white and brown round or irregular lesions which appear on leaves and can be controlled using fungicides (Keinath, 2013).

The watermelon mosaic virus is a cucurbit crop disease transmitted by aphids. The disease causes mottling of leaves as well as stunted growth of the watermelon plant. Other notable identifiers are mottled appearance on the surface of fruits. The leaves can be distorted, chlorosis of veins reduction in leaf size as well as reduced growth rate at around 72%. The impact of watermelon mosaic virus infection is highly serious in early infections just before flowering stage and it leads to production losses of around 50%. If infections occur between stages of flowering as well as first fruit set, the losses which can be encountered there are around 26%. Climatic conditions which favour watermelon mosaic virus are warm weather and moisture with temperatures around 20°C and 30°C. Research carried in Zimbabwe in 2020 shows that viral diseases on watermelons cause serious damage on fruit quality thereby negatively impacting on the yield of these crops (Karavina *et al*., 2020). It is important to practice field sanitisation, thus removing weeds as a way of controlling watermelon mosaic virus since weeds are potential hosts of the disease as well as controlling the aphids.

Post-harvest management

Losses in watermelon production also occurs after harvesting especially when poor handling techniques are used (Kutyauripo and Rumbidzai, 2018, Okwori *et al*., 2017). Watermelon juice is mostly spoiled by microbes because of activities of candida pseudo tropicalis, *Candida tropicalis*, *Saccharomyles cereviciae*, *Serratia sepsis* and staphylococcus, saprophyticus (Ugodo, 2015). Watermelon is a fruit that can be preserved by room cooling. It can be kept at an average temperature of around 10-15°C, 90% relative humidity and can stay for about 14-21 days (Ahmad and Siddiqui, 2015).

It is important to avoid fruit scratching when handling and to remove diseased watermelon to avoid the spread of the diseases. Common post-harvest fungal diseases are black-rot and fusarium wilt which cause the rind to decay. Black rot is normally a darkish spot which is rotten and it appears at the end of a watermelon fruit. It usually occurs because of inconsistent supply of water. Dryness of soil due to lack of water for a long time results in calcium being bound to the soil and no or little calcium will be left for the plant to aid in the development of the fruit. Fusarium wilt is among the most economically dangerous watermelon diseases which is caused by a fungal pathogen which can remain viable in the soil for a period of up to twenty years. Exposing watermelons to ethylene causes ethylene damage and hollow heart is mainly of pre-harvest origin (Kutyauripo and Rumbidzai, 2018).

Value-addition

Value-addition is increasing the value of a product, especially by manufacturing, processing or marketing. A value-added product has a very competitive price as compared to its raw material. It is very important to utilise all the components of the watermelon as a way to come up with value added products which may have several healthy benefits as well as being nutritious (Gbaa *et al*., 2019). In watermelon, a ripe watermelon from the field is cheaper than a small tin of watermelon juice of which many of them can be made from one watermelon. The watermelon rind and seeds which some throw away after consumption of the pulp can be added value by processing them into watermelon jam and oil respectively. Uptake of commercial production of watermelon by African farmers is still very low and this subsequently affect value-addition chain. Some retail shops play a major role in the marketing and value addition of watermelons through slicing and packaging in transparent papers.

In Egypt, value-addition in watermelon started way back with the production of watermelon seed oil. The oil, called Kalahari oil in Egypt and was used by Egyptian kings. Anciently, the seeds were dried then pressed to extract the oil. Currently, a company called Botanical Beauty Egyptian watermelon seed oil company. The oil is used for the whole body, the face as well as the hair (Ziedrich, 2016). Research was carried out in in Malaysia on preparing jam using watermelon waste which was successful and the product which has an improved shelf life was produced which can last for more than three months (Souad *et al*., 2012). In China, a company called Shanghai Genyond Technology Co. Limited which makes full automatic plastic bottle watermelon juice filling machines. In Britain, watermelon jelly is produced by Jamnation Fine Foods (Ziedrich, 2016).

Watermelon seed can be used to make flour which can be incorporated in infant food formulations (Oyeleke *et al*., 2012). The flour is rich in protein, fibre and minerals so can be used very well for weaning food (Otutu *et al*, 2015). The watermelon seeds can also be used to make watermelon seed oil which is rich in protein. The watermelon rind which is a by-product from juice making process can be processed to make watermelon jam (Fila *et al*., 2013). Using the watermelon rind in value addition is important since the rind is sometimes thrown away. The watermelon pulp can also be used to make watermelon juice which can be utilised in the formation of watermelon wine with antioxidising properties (Okwori *et al*., 2017). This is the most important way to reduce postharvest losses since overripe watermelons can be taken and mixed with other fruit juices from banana or paw- paw in making mixed fruit wine. Watermelon juice can also be used to make fruit yoghurt when the juice is mixed with powdered milk and the homogenised (Ogodo *et al*., 2015).

The use of watermelon in yoghurt making assists much in the addition of vitamin C, the improvement of colour, appearance and odour to the product (Roy *et al*., 2016). Watermelon can also be used to make the watermelon powder which is used for fortification of pan bread. The watermelon powder is made from the watermelon rind and is useful in formulation of cake and bread recipes (Lee-Hoon and Norhidayah, 2016).

Opportunities in its production

More research on the crop is however is required across the whole continent on the aspects of breeding as well as production. Several factors hamper the commercialisation of watermelons in Africa. These factors include transportation of the watermelon since it is perishable, poor agro-management skills, unavailability of markets and industries for value-addition on watermelon. With the origins of watermelon being Africa, germplasm can be extracted from wild species as a way of supporting research on breeding programs.

Several landraces of the watermelon have significant characteristics for abiotic tolerance like drought and heat for instance higher biomass. These traits are helpful in improvement of crop tolerance to the changes in climate. To see the success of watermelon production in Africa as well as to come up with successive watermelon breeding, there is need to put much effort on germplasm prospecting. Public awareness is also key to see the rise in watermelon marketing standards in Africa. It is also of greater importance to improve on agronomic practices as far as the increase of watermelon production is concerned. Farmers can be trained on important aspects like pests, diseases and weeds control as well as the use of proper fertilizers.

Perspectives of watermelon

Since drought is a major issue of concern across the world watermelon production will eventually play a major role in boosting income of farmers. It will be important to come up with watermelon varieties resistant to disease and pest attack. The use of genes of a rootstock taken from a related cucurbit can help in combating soil pests as well as serious environmental conditions. There is a need however to have promotional campaigns to increase awareness on the population on its importance where processing industries will air their demands so as to increase production.

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Advances in research in jamun (*Syzygium cuminii*): a review

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ABSTRACT

Jamun (*Syzygium cuminii* Skeels) is an indigenous nutritious medicinal fruit; every part of the tree is utilized by both urban and rural dwellers. The fruit is good source of iron, sugars, minerals, protein, carbohydrate etc. Fully ripe fruits are eaten fresh and can be processed into beverages like jelly, jam, squash, wine, vinegar and pickles. Fruits and powdered seeds are used as an effective medicine against diabetes. It is an underutilized fruit with a wide range of adaptation to varied edapho-climatic conditions. For better utilization and improvement of its genetic resources, there is a need to understand various aspects. Therefore, basic biology, genetic diversity and varietal wealth, systematic phenology, production technologies, propagation, canopy architecture, biotic and abiotic stress management and value-addition have been discussed.

Key Words: Jamun, Phenology, Genetic diversity, Underutilized fruits, Canopy architecture

New vegetative shoots in jamun (*Syzygium cuminii* Skeels) tree emerge in two distinct flushes during February–May and August–November in semi-arid conditions. Flowering takes place in March-April and flowers are hermaphrodite (Singh and Singh, 2012b). However, in semi-arid parts of western India, peak period of panicle emergence is February, flowering and fruit setting in March. The inflorescence is terminal or lateral and develops on mostly one- year- old shoots and older branches too. Flowers are regular, bisexual with five free sepals, 8 stamens and a normal style. Before opening, the flower buds attain a size of 5.2 mm in length and 5 mm in diameter and require 28–30 days from the appearance of flower buds till the opening of flower. It is a cross-pollinated crop; pollinators are honeybees, houseflies and wind (Singh *et al.*, 2010, 2011, 2012b). The maximum fruit setting is observed when pollination is done one day after anthesis owing to maximum stigma receptivity (18.71–43.08%) and thereafter, fruit setting declines sharply (Mishra *et al.*, 2014). The maximum anthesis and dehiscence were recorded between 10 AM and 12 noon. The pollen fertility was higher in the beginning of the season. The maximum insect activity was observed between 11.00 AM and 3.00 PM (Singh *et al.*, 2013d).

Genetic resources

Jamun belongs to the family, Myrtaceae, having chromosome number 2n=40. It is a long lived, large and evergreen tree, attaining a height up to 25–30 m. Other species, viz. *S. alternifolium* (Wight) Walp. syn. *Eugenia alternifolia* Wight, *S. aqueum* (Burm. f.) Alston syn. *Eugenia aquea* Burm.f *S. aromaticum* (Linn.) Merrill & Perry. syn. *Caryophyllus aromaticus* Linn. *S. bracteatum* (Willd.) Raizada syn. *Eugenia bracteata* Roxb., S. *malaccense* (Linn.) Merrill and Perry.(syn. *Eugenia malaccensis* Linn.) *Syzygium samarangense* (Blume.) Merrill & Perry. syn. *Eugenia javanica* Lam., *S. jambos* (Linn.) Alston. (syn. *Eugenia jambos* Linn, *S. fruitecosum* (Roxb.) D C ,*S. densiflorum*, *S. uniflora* Linn. (Surinam cherry or Pitanga cherry), *S. malaccensis* trees are found growing naturally in different parts of country (Singh *et al.,* 2016, 2017c, 2020).

It is facing severe genetic erosion and extinction of its species as a result of urbanization and intensive agriculture. The genetic diversity of related wild species is of particular value in search for sources of resistance to biotic and abiotic stresses (Singh *et al.,* 2011, Makwana *et al.,* 2014). A large variability in

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seedling strains with respect to fruit shape and size, pulp colour, TSS, acidity and earliness are available, particularly in Uttar Pradesh, Bihar, Gujarat and Maharashtra, providing good scope for selection of better varieties (Singh *et al.*, 2019a). It was observed that fruit shape varied from round to oblong and that of apex of fruits varied from flat to pointed one; great variability in physico-chemical characteristic of fruits offers possibility of selecting a variety suitable for fresh market and processing.

Small seed size, high pulp content and better chemical properties are ideal characteristics (Singh and Singh, 2012b). The individual fruit weight, length, seed weight and pulp ranged in between 4.80–17.60 g; 2.22–4.51 cm; 1.30–2.36 g and 68.75–86.59%, respectively in genotypes of Gujarat (Singh *et al.*, 2010, 2021a). The total soluble solids among different accessions varied from 12.2° to18.40°Brix and titratable acidity from 0.79% to 1.25%. Variability in physico-chemical attributes in jamun germplasm has been reported (Singh *et al.* 2006b, 2010, 2019a; Ghojage *et al.* 2011). Compositional and biochemical attributes in the germplasm have been studied by Ali *et al.* (2013).

Ra-Jamun grown in North Indian condition produces big-sized oblong fruits with deep purple colour (Singh *et al.* 2011). Goma Priyanka and Thar Kranti are improved varieties of at CHES (ICAR-CIAH), Godhra, Gujarat (Singh *et al.*, 2017b, Singh and Singh, 2012, 2017). The fruit of Goma Priyanka are bold in size and good in taste having 16.87°Brix TSS and vitamin C (45.44 mg/100g). Thar Kranti is semi-dwarf, ripens in 75 days with high yield (Singh *et al.*, 2017). Rajendra Jamun-1 was released from Bihar Agricultural College, Bhagalpur, Bihar. It is early-maturing and high-yielding. CISH, Lucknow has also identified two promising genotypes, i.e. CISHJ-37 (Jamwant) and CISHJ-42 (Singh *et al.*, 2021a).

Propagation

Jamun, being heterozygous in nature, does not produce true-to-the-type from seeds, however, polyembryony has been reported to the extent of 20–50%, hence, nucellar seedlings may be utilized to produce uniform rootstocks for grafting and budding (Singh *et al.*, 2011). Jamun seeds have no dormancy; hence, fresh seeds can be sown 4–5 cm deep in the nursery (Singh and Singh, 2014). Seeds start germinating about two weeks after sowing. The seedlings become ready for grafting during spring (Singh *et al.*, 2006c, 2011).

Bud wood for grafting is available during the active growth period of spring or rainy season. The bud sticks with well-swollen buds are used for vegetative propagation. In case of budding, a healthy bud is selected from the axils of leaf. Softwood grafting and patch budding methods are successfully used for jamun propagation (Singh and Singh, 2014a, Singh *et al.* 2018a). The softwood grafting and patch budding during March and April recorded the maximum success of 90.12% and 85.24%, respectively under semi-arid environment (Singh and Singh, 2009 and Singh *et al.*, 2021a). In jamun, vigorous tap roots get disturbed during transplanting of grafts, affecting the growth and establishment of grafts in the field (Singh *et al.* 2006c 2017a). Therefore, *in situ* patch budding was tried at CHES, Godhra (Singh *et al.* 2011). The plants propagated by *in situ* patch budding in March and April recorded good success, i.e. 80.25% and 77.50% respectively. About 15–20 cm long mature shoots (2–3 months old) are defoliated 12–15 days prior to grafting operation (Singh *et al.*, 2010, 2011).

Establishment of orchard

There should be a gentle slope to facilitate proper irrigation and easy drainage to avoid the harmful effects of water stagnation during the rainy season. Jamun may be grown under various cropping systems, i.e. as an orchard crop in a pure land or as an agro-forestry species in mixed cropping systems (Singh *et al.*, 2011). After marking the places for the plants, pits of 90 cm× 90 cm× 90 cm are usually dug out during the summer months. The pits are filled with a mixture of top soil and 20–30 kg well-rotten farmyard manure. Planting is done during the rainy season when the soil in the pits has already settled. The plants should be irrigated immediately after planting. Jamun is planted at the distance of 8m x 8 m normal density and for high density at 5m x 5m and 5m x 25m with proper canopy management (Singh *et al.*, 2018b).

Canopy architecture and high–density planting

In jamun, canopy management is necessary to make the best use of resources for increased productivity. Being a vigourous tree, to control canopy, maximize the light penetration, and moderate the temperature and humidity, play a vital role in production of quality fruits (Singh *et al.*, 2018a). Canopy management manipulates the tree vigour and use the available sunlight and temperature to increase the productivity and quality of produce. The main central leader is allowed to grow for a few years, until 8 - 10 scaffold develop around the central leader. The central leader is then cut to form side laterals which in due course grow as modified leader system. In this training, the tree develops well-spaced limbs with strong crotches (Singh *et al.,* 2018b). The top being open, allows more sunlight to penetrate deep inside the tree.

This system is appropriate for training of jamun plants (Singh *et al.,* 2017c). To maintain the dwarf framework of jamun plant, toping of main stem (3–5 m) is required (Singh *et al.,* 2019b). It facilitates easy harvesting of ruits (Singh *et al.,* 2017c). It was also observed that pruning 50% annual extension growth after harvesting was effective in reducing the plant canopy and improving quality attributes (Singh *et al.,* 2017b, 2018b). At CHES, Godhra, high-density planting at spacing of 5m × 5m has been found efficient for the higher productivity of jamun (Singh *et al.,* 2018b). Effect of shoot pruning on yield and quality of Goma Priyanka variety of jamun was studied by Singh *et al.* (2017b). Singh *et al.,* (2018b) reported that planting at closer spacing with proper canopy management lead to higher yield and quality of jamun under dryland conditions of western India.

Irrigation management

Water is a limited natural resource in most of the semi–arid and arid regions. Therefore, due care should be taken for judicious utilization of water. Too much watering in jamun creates superficial root system. The irrigation should be done preferably in the evening. The pH of irrigation water should be 6.5 to 7.5 and it must be free from harmful salts (Singh *et al.,* 2011). Water deficiency in the soil particularly during development of fruit, affects the metabolic activity and fruit yield (Singh *et al.,* 2010). Excess and scarcity of water often cause considerable losses both in quantity and quality of jamun fruits. Therefore, optimum water use practices considering the water requirement and application techniques must be followed. Drip irrigation is a high-tech irrigation system effective in water scarce areas. In this system, required quantity of water is applied at low pressure to the root zone of crop through a network of pipes. Through this system, irrigation efficiency could be around 90% vis-à-vis 30–40% in the conventional methods of irrigation (Singh *et al.,* 2018a).

Orchard floor management

Nutrient management is generally not followed in jamun. However, an annual dose of about 20 kg of FYM during the pre-bearing period and 50–80 kg/tree at bearing stage is considered beneficial. Trees often produce more vegetative growth in nutrient rich soils, delaying the fruiting (Singh *et al.,* 2011). Under such conditions the trees should not be manured and irrigation should also be given sparingly and withheld in September-October and again in February-March. This helps in proper fruit bud formation, blossoming and fruit setting.

In general, 5 kg FYM, 125 g N, 50 g P_2O_5 and 50 g K_2O/plant/r year may be applied to one-year- old jamun plants. This dose should be increased every year in the same proportion up to 10th year, after which the fixed dose should be applied. Full dose of farm yard manure should be applied during July-August. Half dose of N, P and K should be applied in July and remaining dose should be applied by the end of August and or the first week of September under rainfed conditions (Singh and Singh, 2012a). Application 6 kg castor cake/plant/year along with standard dose of FYM and NPK after 5th year of plantation is found effective for improving vegetative growth, yield and fruit quality attributes (Singh *et al.,* 2011). Earthworm and microbe population in soil beneath plant canopy is found to increase with the use of FYM and cakes. Under rainfed conditions, foliar feeding is very useful in supplementing nutrients, particularly nitrogen and micronutrients. The optimum concentration of urea for foliar application is around 1.0% spray in April is effective to improve fruit retention, its growth and productivity. Supplementing micronutrients through foliar spray of 0.2–0.1% zinc sulphate has been observed to improve fruit quality in terms of TSS, total sugars and vitamin C content and result in the development of deep purple colour in fruits. Application of recommended dose of organic manure and bio fertilizers improved soil properties in terms of bulk density, hydraulic conductivity, pH and ECe, plant growth, yield and quality parameters are influenced by application of biofertilizers (Singh *et al.,* 2010, 2011). Compatible crop combination is necessary with regard to species, cultivars, planting method and sequence. Peas, gram, lentil, black gram, cowpea, cluster bean, cucurbitaceous crops and capsicum may be grown as intercrops in the jamun orchard (Singh *et al.,* 2011, Singh *et al.,* 2010).

Phenology

Flowering and fruit setting take place in March-April. Fruit drop starts just after fruit setting and only 15–30% fruits reach maturity. The flower and fruit drop are found at three stages. The first drop takes place during bloom or shortly thereafter, and this proves to be the pre-harvest drop as about 52% of the flowers drop off after 4 weeks of flowering. The second drop starts after 35–40 days of full bloom and apparently there is no distinction between the developing and aborting fruits. The third drop takes place 42–50 days after full bloom and continues till 15 July (Singh *et al.*, 2011). The extent of flower and fruit drop in jamun is reduced by two sprays of 60 ppm GA_3, one at full bloom and other 15 days after initial setting of fruits. The blossoms are important source of honey from *Apis dorsata* in North India (Singh *et al.*, 2010).

The fruit growth was faster initially and slowed down while reaching maturity and followed a sigmoid growth pattern in all the genotypes. The specific gravity showed increasing trend (>1) in the genotypes during development. Total soluble solids, total sugar and vitamin C increased as the fruits reached maturity. Titratable acidity showed declining trend while reaching the ripening stage. Deep purple colour on fruit surface was observed in all the genotypes during ripening (Singh *et al.*, 2010).

Abiotic stress management

The effectiveness of mulches in conserving moisture has generally been found to be higher under drought conditions and also during early periods of plant growth (Singh *et al.*, 2010). As soil moisture is one of the limiting factors for successful cultivation of jamun, use of mulch is very beneficial (Singh *et al.*, 2011). It reduces the loss of soil moisture, enhances the rate of penetration of rainwater or irrigation in the soil and controls the growth of weed, thus, eliminating the competition between weeds and the fruit trees. In general, mulching with grasses, paddy straw and rice husk reduces weed population and conserves soil moisture. Earthworm and microbe population in the basin soil increases with the use of different mulches. Leaf litter of jamun under the canopy is effective to retain soil moisture during summer (Singh *et al.*, 2010, 2011).

Harvesting and value-addition

Seedling Jamun plants start bearing 8–10 years after planting while grafted ones after 4–5 years. The fruits ripen in June-July. Fully ripe fruits are deep purple or black in color. Fruits should be picked immediately after ripening to minimize wastage of ripe fruits. Ripe fruits are picked manually and fruits are generally harvested daily and sent to market same day. The average yield of fruit from a full-grown seedling jamun tree is 80–100 kg/year and 60–70 kg/year from grafted one. Grading is required to get better returns for the produce (Singh *et al.*, 2010b). The fruits should be graded on the basis of size, ripening stages, fruit uniformity and cleanliness. Fruits pre-packed in leaf cups covered with perforated polythene showed less loss in weight and shriveling and appearance was better as compared to the conventional pre-packaging (Singh *et al.*, 1019c).

An experiment was conducted to study the effects of different packaging materials for transportation and storability of jamun fruits by Singh *et al.* (2011). It was found that the minimum spoilage loss was recorded in the fruits kept in corrugated fiberboard box with newspaper liner closely followed by corrugated fiberboard box with polythene liner (200 gauge, 2% ventilation). Same treatment also showed lowest respiratory activity and exhibited higher 3 days shelf- life at ambient storage. Studies conducted to evaluate the postharvest physiological changes and shelf life of fruits of 10 genotypes during storage at room temperature at CHES, Godhra by Singh *et al.* (2009) revealed that after harvest maximum Increase in physiological loss in weight, spoilage percentage, TSS, total sugar and reducing sugar and decrease in acidity, ascorbic acid with advancement of storage period were general phenomena in all the genotypes.

Due to prevalence of high temperatures (35-42°C) during harvesting, jamun fruits start deteriorating rapidly and it is necessary to prolong shelf life of fruits during storage. Pre-harvest spray of calcium chloride (1–1.5%) 20 days prior to harvesting was effective in improving the fruit quality and enhancing shelf life at room temperatures (Mishra *et al.*, 2018). GA_3 restricts ethylene accumulation in the fruit tissue and has been known to delay ripening process and regulate the nucleic acid and protein synthesis (Singh *et al.*, 2019b). Fruits treated with GA_3 (50 ppm) and stored in perforated polyethylene bags, had enhanced shelf life by restricting the transpiration and respiration at room temperatures (Singh *et al.*, 2019b).

Jamun, being highly perishable in nature, suffers from the heavy losses after harvest hence it is necessary to process the fruits into different value added products by employing different methods of fruit preservation. Jamun beverages R.T.S, nectar, squash, syrup, vinegar and cider are important postharvest products of jamun (Singh *et al.*, 2010, 2011, 2019c). Marketing problems are more in jamun due to high degree of perishability and season bound availability. About 75% of the farmers sell their produce at the farm level to the village merchants, retailers or to the pre-harvest contractors as small and marginal farmers cannot afford to transport the produce to distant markets (Singh *et al.,* 2011). Information regarding demand, supply, price, market outlook, knowledge of the consumer's preference, marketing channels is important for marketing of produce. Jamun seed powder also has tremendous potential in the global market (Singh *et al*., 2010).

Biotic stress management

The major pests of the crop are leaf-eating caterpillar (*Corea subtilis*), bark eating caterpillars (*Indarbela tetraonis* and *Indarbela quadrinotata*), fruit borer (*Meridarchis reprobata*), leaf miner (*Acrocercops syngramma* and *Acrocercops phaeospora*), leaf roller (*Polychorosis cellifera*), leaf webbers (*Argyroploce aprobola* and *Argyroploce mormopa*), fruit fly (*Bactrocera correctus*) and white flies (Singh *et al.,* 2011). Leaf eating caterpillar, jamun leaf miner, fruit borer and bark eating caterpillars can be controlled by spraying of Dimethoate 30 EC (2ml/l) at fortnightly interval, whereas jamun leaf roller, leaf webber can be managed with the spray with Chlorpyriphos 20 EC (2ml/l) at 15 days interval. White flies can be controlled by maintaining sanitary conditions in the orchard, which consist of picking up the affected fruits and burying them deep in the soil and area under the tree should be dug, so that the maggots in the affected fruits and the pupae hibernating in the soil may be destroyed. Pheromone traps are also useful for managing this pest. Anthracnose is major disease of jamun. The fungus incites leaf spot and fruit rot. Affected leaves show small-scattered light brown or reddish brown spots. Affected fruits show small, water soaked, circular and depressed lesions resulting into shriveling and fruits rot. This disease can be controlled by spraying Dithane Z-78 @0.2% (Singh *et al*., 2011, 2020 and Singh, 2019)

CONCLUSION

Jamun cultivation has still not been commercialized due to several reasons. The future of this fruit depends on selection of high-yielding cultivars having tolerance to abiotic and abiotic stresses. Further, emphasis should be given to development of high-quality trait- specific varieties, production technologies and popularization of value-added products as health promoting foods. Being a medicinal plant, there is a need for 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 various diseases. Jamun is a 'hot' commodity in markets and with firm evidences with regards to nutritional, health and economic security, the prospect for jamun research is enormous in our country.

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Tropical root-and tuber crops-based cropping systems — a review

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ABSTRACT

Multiple cropping is the best way of sustainable intensification of crop production, from the limited resources. More flexibility in planting and harvesting of tropical root and tuber crops provide ample scope for various crop production systems. Intercropping of legumes, cereals, and vegetables in root and tuber crops increased system productivity with land-use efficiency, though yields of sole crop of roots and tubers decreased. Intercropping root and tuber crops in plantation and fruit tree crops gave additional returns. Weed suppression, pest and disease reduction and improvement in soil nutrient status are the additional benefits of root and tuber crops involved in multiple cropping systems. In rice (*Oryza sativa* L.)-based cropping system in the coastal plains of Odisha, West Bengal, Karnataka, Tamil Nadu and Andhra Pradesh, sweet potato (*Ipomoea batatas* L. Lam.) is planted after harvesting of rice to take advantage of the residual soil moisture and fertilizers. Multiple cropping also reduces severity of pests and diseases. The climate smart root and tuber crops generate assured income under various cropping systems.

Key Words: Sweet potato, Cassava, Yams, Elephant-foot yam, Intercropping, Sequential cropping, Weed suppression, Land-use efficiency

Tropical tuber crops are the third most important food crops after cereals and grain legumes. They are used for food, medicine, animal feed and raw material for starch-based industries. The commonly cultivated tropical tuber crops are cassava (*Manihot esculenta* Crantz), sweet potato (*Ipomoea batatas* L. Lam.), yams (*Diosocrea* spp.), elephant-foot yam (*Amorphophallus paeoniifolius* (Dennst.) Nicolson), taro (*Colocasia esculenta* Schott), yam bean (*Pachyrrhizus erosus* (L) Urban), Chinese potato (*Solenostemon rotundifolius* L.), arrowroot (*Maranta arundinacea* L.) etc. Tropical tuber crops are the most important staple or subsidiary food to about 500 million global population. It is estimated that tuber crops provide about 6% of the world's dietary energy, apart from being good sources of vitamins, anti-oxidants, dietary fibres and minerals.

Worldwide, a considerable quantity of tropical roots and tubers are utilized for feed and fuel purposes. Tropical tuber crops serves as raw material for poultry and animal feed. For cassava, Nigeria and Brazil account for about 50% of its production for use as feed, whereas China imports cassava, mainly from Thailand, mostly for use in biofuel production. It was projected that the use of cassava for biofuel would increase from 1-8 million tonnes in 2019 (Alexandratos and Bruinsma, 2012). For sweet potatoes, China accounts for about 50% of the world production and for about 80% of world feed use, whereas Nigeria accounts for about 15% of world feed use. They also have immense industrial uses, in the production of starch, sago, alcohol, liquid glucose, vitamin C, besides medicinal properties.

CROPPING SYSTEMS

Cropping system involves sustainable land management that includes crop rotation or association through sequential cropping, intercropping, and relay and mixed cropping (Dumanski and Peiretti, 2013). Stability of crop production can be achieved through crop diversification, and there is a reduction in the risks associated with a dependence on a single crop that may suffer from environmental or economic fluctuations. Diversity in the diet can also be improved through the use of such systems (Gebru, 2015).

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Intercropping in sweet potato

Sweet potato, a short-duration (100-120 days) crop can be grown during rainy season in hilly and plateau regions and post-rainy season in plains with supplemental irrigation. It can be intercropped with cereals and pulses (Nedunchezhiyan *et al*., 2012a). Nedunchezhiyan *et al*. (2006a) also recommended sweet potato as an intercrop in upland rice (*Oryza sativa* L.) for a contingent plan against the crop failure as well as for soil and water conservation.

Nedunchezhiyan (2011) reported that when sweet potato was strip intercropped with other crops, its root yield in intercropping was higher than its sole crop. This was mainly due to increased yield characters in border rows of sweet potato (Nedunchezhiyan *et al*., 2011a). The sweet potato border rows in strip intercropping yielded significantly better than sole crop rows, especially when pigeonpea (*Cajanus cajan* (L.) Millspaugh) was intercropped. Maize (*Zea mays* L.) as an intercrop also increased the yield of sweet potato border rows compared to its monoculture. The sweet potato plant yield in border rows was 32.9, 38.9, 10.2 and 44.3% higher than the sole sweet potato crop. This yield increase was due to interspecies interference was minimal, while complementary use of other growth resources was maximized in border rows. Njoku *et al*. (2007) reported that intercropping okra (*Abelmoschus esculentus* L.) as intercrop in sweet potato did not affect the sweet potato root yield.

An analysis of sweet potato yield components indicated that number of storage roots/plant, root length and root diameter were significantly higher in border rows when sweet potato was intercropped with other crops (Nedunchezhiyan *et al*., 2011a). Further, intercropping supplements income over time and provides variety of products. In uplands, strip cropping of sweet potato (ridge and furrow) and pigeonpea (flat bed) (1.8 m strip each; 3:3 rows) produced higher root equivalent yield (13.5 t/ha), net return ($ 623.9/ha) and benefit:cost ratio (3.24) under rainfed conditions of Odisha, India (Nedunchezhiyan *et al*., 2010a). Nedunchezhiyan (2011) reported that intercropping rice, finger millet (*Eleusine coracana* L.), maize and pigeonpea in sweet potato indicated that 8-31% area would be required by a sole cropping system to recover the yield of intercropping system.

The aggressive competition ability of maize at early stage with sweet potato intercropping resulted in just 5.4% increase in sweet potato root yield compared to sole sweet potato (Nedunchezhiyan *et al*., 2010a). Pigeonpea being long duration utilized all the available resources after harvesting of sweet potato. Hence, it registered higher aggressivity index in sweet potato+pigeonpea intercropping (Nedunchezhiyan *et al*., 2011a).

Otherwise sweet potato in this intercropping recorded 27.7% more root yield than sole sweet potato. The aggressivity index was higher in border rows than in middle rows in strip intercropping involving sweet potato (Nedunchezhiyan *et al*., 2011a). The interspecies interaction decreased when moving away from the border. Strip intercropping in sweet potato reduced the percentage of sweet potato weevil (SPW) (*Cylas formicarius* L.) damaged roots. Less percentage of damaged roots was found in sweet potato+maize strip intercropping followed by sweet potato+pigeonpea intercropping (Nedunchezhiyan *et al*., 2010b).

Sweet Potato in Sequential Cropping

Sweet potatoes figure in the intensive irrigated rice/paddy and sugarcane (*Saccharum officinarum* L.) based cropping systems of Taiwan (Nedunchezhiyan *et al*., 2012a). It is grown as winter crop after wet rice to be followed by another rice crop, groundnut/peanuts (*Arachis hypogaea* L.) or soybeans (*Glycine max* L. Merr.). In such system sweet potato is planted directly into rice stubble or relay planted 20-30 days prior to rice harvesting. In sugarcane-based cropping system sweet potato is inter planted (in between sugarcane rows of 1.25 m) during early-August at the time of planting cane setts.

In India, cropping systems involving sweet potato vary from region to region (Nedunchezhiyan *et al*., 2012a). In Odisha, common sequences are maize-sweet potato-fallow and rice-sweet potato-fallow. In Uttar Pradesh, sweet potato is usually grown as a *kharif* crop in sequence to cereals or pulses. For Bihar, maize (*kharif*)-sweet potato-onion (*Allium cepa* L.) are the recommended sequences. A net income as high as $ 444.4/ha is obtained from such cropping system. In south India especially in the coastal belt, sweet potato is grown during summer following the second crop of rice. The sequences like rice-rice-sweet potato; rice-sweet potato-rice and rice-sweet potato-cowpea (*Vigna unguiculata* L.) are profitable and capable of reducing weevil damage in sweet potato.

The rice-sweet potato-cowpea produced maximum returns ($ 740.2/ha) and was therefore the most economic cropping sequence, followed by rice-rice-sweet potato ($ 484.6/ha) and colocasia/taro-sweet potato ($ 455.2/ha) (Nedunchezhiyan *et al*., 2012a). Rice-sweet potato-rice was also found economical ($ 442.5/ha). These treatments were also found to be highly effective to reduce sweet potato weevil (SPW) (*Cylas formicarius* L.) infestation (Nedunchezhiyan *et al*., 2012a).

Nedunchezhiyan *et al*. (2011b) reported that sweet potato can be planted under zero tillage immediately after harvesting of rice, when the soil is marshy. In such system of planting sweet potato recorded above 90% root yield of conventional method of sweet potato planting in rice-based system. Further, the zero tillage allowed planting of sweet potato 15-20 days in advance. In rainfed lowland rice fallow, under minimum tillage, variety Sourin, performed better than others (Nedunchezhiyan *et al*., 2013). The storage root of Sourin was short and elliptic with short neck. The storage roots develop bulking at shallow depth. These features led to more root yield in Sourin variety. In rainfed lowland rice fallow, under conventional tillage the variety, Kishan, produced more root yield (Nedunchezhiyan *et al*., 2013).

In rice-based cropping system in the coastal plains of Odisha, West Bengal, Karnataka, Tamil Nadu and Andhra Pradesh, sweet potato is planted after harvesting of rice to take advantage of the residual soil moisture and fertilizers (Nedunchezhiyan *et al*., 2012a). Sweet potato planted with minimum tillage in rice fallow required lower irrigation water than conventional method of planting (Nedunchezhiyan *et al*., 2013). In Odisha, rice-fallow-sweet potato is a popular three-year rotation in uplands which minimizing weeds infestation and sweet potato weevil incidence, rebuilding of soil fertility status and more rice productivity (Nedunchezhiyan *et al*., 2012a).

In Bangladesh, sweet potatoes are grown mainly in river beds and Char areas (Nedunchezhiyan *et al*., 2012a). In these lands, only one crop of sweet potato is grown during October-November to March-April. However, in some relatively high-lands broadcasted Aus paddy is grown immediately after harvesting of sweet potato. Where the land is medium high broadcasted Aus paddy transplanted Aman paddy-sweet potato pattern is found. In Sri Lanka, sweet potato is grown in sequence to rice or vegetables (Nedunchezhiyan *et al*., 2012a). Sowing of peanuts or winged bean (*Psophocarpus tetragonolobus* L.) in rotation with sweet potato reduced pests and diseases incidence. Further, the same rotation was also followed to maintain soil fertility in Papua New Guinea (PNG) (Bourke and Ramakrishna, 2009). In some highlands of PNG, vegetables were rotated with sweet potato. In this system vegetables were grown using fertilizers and the residues also benefit the subsequent sweet potato plantings (Bourke and Ramakrishna, 2009). Zou *et al*. (2020) reported changes in mycorrhizal colonization of citrus roots, when intercrops were grown. Sweet potato variety Sree Bhadra planted as preceding crop for flue cured virginia tobacco (*Nicotiana tobaccum* L.) nursery reduced 82.8% initial root-knot nematode soil population over control (Mohandas and Siji, 2012). Further sweet potato grown beds recorded 118.6% increase in healthy transplants yield over the control.

Sweet potato as an intercrop

Sweet potato being insurance crop against natural calamities, has more flexibility in adjusting any cropping system (Nedunchezhiyan *et al*., 2008a) is grown as an intercrop in plantation crops (Nedunchezhiyan *et al*., 2012a).

In West Coast of India, sweet potato is also grown as intercrop in coconut (*Cocos nucifera* L.) and arecanut (*Areca catechu* L.) gardens, both at the pre-bearing and mature phases. However, in mature stands of coconut and arecanut, productivity of sweet potato is drastically reduced for want of light. Similarly in East Coast of India, Nedunchezhiyan *et al*. (2008a) also reported relatively low sweet potato tuber yield in established coconut garden. However, it recorded net return of $ 206.1/ha with the benefit:cost ratio of 1.60. Intercropping sweet potato did not affect the growth and yield of coconut (Nedunchezhiyan *et al*., 2007).

In Papua New Guinea, sweet potato is cultivated from sea level to altitudes up to 2800 m. It is the dominant or co-dominant crop in various intercropping systems. Sweet potato is grown as intercrop with coffee in the New Guinea high land. In New Calidonia large rectangular beds of 1 m height are formed between coconut trees and intercropped sweet potato (Nedunchezhiyan *et al*., 2012a).

Intercropping in cassava

Intercropping in inter rows of cassava (additive series) with sesame (*Sesamum indicum*) and sunflower (*Helianthus annus* L.), cowpea, vegetable cowpea, peanut, soybean, mungbean (*Vigna radiata* L.), chickpea (*Cicer arietinum* L.), blackgram (*Vigna mungo* L.) and okra significantly reduced storage root yield of cassava and its components such as storage root number and weight per plant. The reduction of cassava storage root yield was 24–40% when sunflower was intercropped and 14–31% when sesame was intercropped compared to sole cassava (Adekunle *et al*., 2014). Intercropping vegetable cowpea, mungbean, chickpea and egusi melon (*Cucumeropsis mannii* L.) reduced storage root yield of cassava by 8.4 to 39.0% (Mbah, 2018), 50% (Hidoto and Loha, 2013), 29% (Ogola *et al*., 2013) and 30% (Ijoyah *et al*., 2012a), respectively. Suja and

Sreekumar (2015) evaluated short duration cassava with two types of cowpea (vegetable and grain types) as intercrops. They found that both type of cowpea were compatible with cassava as intercrop.

Intercropping of pulses, oilseeds, vegetables in cassava were found with higher system productivity and land-use efficiency. The LERs of cassava+sesame system varied between 1.2 and 1.5, cassava+sunflower system between 1.1 and 1.4 (Adekunle *et al*., 2014). Cassava+vegetable cowpea system recorded with greater LERs (1.24–1.5) (Mbah, 2018). The LER for cassava+peanut was 41% higher than sole cassava, evincing that the integration of peanut with cassava is considerably productive (Ogola *et al*., 2013). In cassava+mungbean intercropping system, the high LER (1.6) indicates that the system was highly productive (Hidoto and Loha, 2013). The LER for cassava+chickpea was 46% higher than sole cassava, evincing that the integration of chickpea with cassava was considerably productive (Ogola *et al*., 2013). The LER value of 1.8 for the intercropping system of cassava+sweet potato indicated that the system was highly productive and that the 80% land saved could be used for cultivation of other crops (Ijoyah *et al*., 2012b).

Intercrops in cassava suppresses weed growth thereby the weed biomass production is drastically reduces. Integration of pigeonpea with cassava significantly reduced the weed density by 26.5% relative to the sole-cassava planting (132 weeds/m^2), whereas the weed dry biomass was reduced by 15.6% in the cassava+pigeonpea system relative to sole cassava (76 g/m^2) (Ravi *et al*., 2020). The lower weed biomass under the cassava+pigeonpea system relative to sole cassava could be adduced to greater shading effects on weeds by cassava and pigeonpea than by cassava alone. The weed control efficiency of cassava+vegetable cowpea system was 44.5% whereas in sole crop of cassava it was 14.0% (Ravi *et al*., 2020).

Cassava-based intercropping systems could reduce mealybug populations by 37% (Delaquis *et al*., 2018). A survey by Night *et al*. (2011) on cassava pests and diseases in Rwanda, where cassava green mite (*Mononychellus tanajoa* L.) and cassava whitefly (*Bemisia tabaci* L.), a vector of CMV were the most abundant pests, revealed that intercropping was associated with lower pest population, disease incidence and severity. Intercropping bean, maize, sweet potato and sorghum, with cassava could reduce CMD incidence in cassava to 29% relative to a sole crop of cassava (40%), whereas cassava green mite incidence was reduced to 41% relative to sole crop of cassava (48%) (Night *et al*., 2011).

Cassava in sequential cropping

Short-duration cassava-based sequential cropping system proved to be sustainable under lowland conditions in Kerala, India. Short-duration, early-bulking cassava varieties, harvestable by 6–7 months, hold promise, as these varieties are ideal for better utilization of resources by small farmers as well as diversification of on-farm enterprise and related income sources (Suja *et al*., 2010a, b, 2011; Suja and Sreekumar, 2015). Suja and Sreekumar (2015) evaluated the performance of short-duration cassava and two types of cowpea (vegetable and grain types) under sequential cropping. Both vegetable cowpea and grain cowpea were equally compatible with short-duration cassava and recorded root yield of cassava 26.1 t/ha. Further they concluded that for cowpea/veg. cowpea-cassava saves the entire P and half of the N recommended for cassava (N-P_2O_5-K_2O 50-0-100 kg/ha). Sequential cropping of vegetable cowpea followed by short-duration cassava (under full N), proved to be the most profitable production system, generating the highest return and best benefit:cost ratio (2.15) (Suja and Sreekumar, 2015).

Sequential cropping systems involving short-duration cassava (6-7 months) in rice-based systems have been developed in India (Suja and Nedunchezhiyan, 2018). In rice-based short-duration cassava+pulse system, rice was planted during the first season, followed by short-duration cassava intercropped with greengram, blackgram, or soybean. In this system, there was a significant reduction (26%) in storage root yield of cassava under intercropping (23.4 t/ha) relative to sole cassava yield (30.8 t/ha). Intercropping short-duration cassava with blackgram under a reduced fertilizer level was preferred due to an acceptable reduction in cassava tuber yield (25.9 t/ha; -19%) compared with sole cassava (32.2 t/ha). Rice-short-duration cassava+black gram were productive (tuber yield 26.7 t/ha) and resulted in greater energy efficiency (191.1 × 103 MJ/ha), storage root equivalent yield (40 t/ha), and production efficiency (112 kg/ha/day). In addition, this system was profitable relative to sole cassava and saved half the FYM and N inputs, and the full P input (Suja and Nedunchezhiyan, 2018). Cultivating rice after harvesting cassava+legume intercropping, which had enhanced the soil fertility, had beneficial effects on growth and productivity of rice crop (Gbanguba *et al*., 2014). Cassava+legume intercropping resulted in more plant height (17.4–28.0 cm), number of panicles/m^2 (131-173), number of tillers/stool (12.6–14.6), number of grains/panicle (3.3–7.1), and grain yield (2.1–3.2 t/ha) in rice relative to plants in natural fallow (Gbanguba *et al*., 2014).

Cassava as an intercrop

The performance of cassava as an intercrop with coconut has been extensively researched in India. Coconut palms allow 40–60% solar radiation to reach the ground surface, depending on coconut palm age, and utilize 25% of land area effectively when planted at a spacing of 7.5 m × 7.5 m (Nedunchezhiyan *et al*., 2008b). A low evaporative demand and reduced maximum temperatures under a coconut plantation can provide scope for successful cultivation of subsidiary crops. The coconut yield was enhanced by 5–15% in a cassava intercrop, while storage root yield of cassava was reduced by 33% relative to a sole-cassava yield. However, intercropping coconut palms with cassava increased the net returns relative to a sole crop.

Nedunchezhiyan *et al*. (2008b) evaluated growth and productivity of genetically improved cassava varieties under 30-33 year-old coconut palms. Plant height; number of storage roots/plant; length, girth, and weight of storage roots; yield/plant; and storage root yield/ha varied as follows among varieties: 158–182 cm, 5.0–6.8, 21.7–23.9 cm, 9.2–10.8 cm, 104–141.8 g, and 9.64–13.2 t/ha, respectively. The 50–69% reduction in storage root yield of cassava varieties under coconut palms relative to sole crop yield under open sunlight was mainly due to a 50% reduction in net photosynthetic rate under coconut palm shade (Nedunchezhiyan *et al*., 2012b). The mean coconut yield varied between 82 and 84/tree, as the cassava intercropping, regardless of varieties, did not affect growth and yield of the coconut trees. In the Philippines, integration of root crops such as cassava with coconut, using adequate fertilizers, is a popular intercropping practice.

Intercropping in yams

Intercropping of maize, sorghum (*Sorghum bicolour* L.) and redgram/pigeonpea increased the tuber yield of greater yam apart from additional yield from intercrops compared to sole cropping of greater yam (Nedunchezhiyan, 2007). Production efficiency of yam+maize/ sorghum/ pigeonpea was higher than sole yam. Similarly energy output: input ratio and energy use efficiency were higher in yam+maize/ sorghum/ pigeonpea than sole yam (Nedunchezhiyan, 2007).

The reduction in anthracnose (*Colletotrichum gloeosporioides*) incidence in greater yam was 58-62.3% when included as an intercrop (Nedunchezhiyan *et al*., 2006b). Greater yam+maize intercropping system recorded 36.7% higher tuber equivalent yield than sole greater yam with gross and net return of ₹ 93625 and 38535/ha, respectively (Nedunchezhiyan *et al*., 2006b). Inclusion of maize as intercrop in greater yam gave additional net return of ₹ 22055/ha (Nedunchezhiyan and Byju, 2006). Yam+maize intercropping system produced maximum net return of ₹ 66625/ha when adequately fertilized. Intercropping of pigeonpea was found system advantage of 31.4% over sole yam crop (Nedunchezhiyan and Byju, 2006). Input management for greater yam+maize intercropping is very vital to achieve higher yields. Greater yam+maize intercropping system a fertilizer dose of N-P_2O_5-K_2O 100-75-100 kg/ha (125% recommended dose of fertilizer of greater yam) along with mulching (2 t/ha dried farm waste) was recommended for Bhubaneswar, Odisha conditions (Nedunchezhiyan *et al*., 2010c).

Mulching of farm organic waste (2 t/ha) to yam+maize intercropping system has enhanced yam and maize yields by 16.9 and 14.9%, respectively. Application of N-P_2O_5-K_2O 120-90-120 kg/ha to the yam+maize intercropping system resulted in 22.4 t/ha yam tubers and 2235 kg/ha maize cobs. Yam + maize intercropping yam density of 12500 plants/ha was found optimum with the fertilizer rate of N-P_2O_5-K_2O 420-440 kg/ha.

Nedunchezhiyan (2010) reported that in greater yam+maize intercropping system higher total productivity (23.0 t/ha), productivity efficiency (109.5 kg/ha/day) and net return (₹ 55700/ha) was obtained with the application of N-P-K 120-39.3-100 kg/ha along with mulching (2 t/ha). Combined application of plant residues with fertilizer improved soil organic carbon, total N, exchangeable Ca and Mg compared with application of NPK fertilizer. Incorporation of residues with reduced NPK fertilizer application may be a sustainable soil fertility management option for continuous yam production (Hgaza *et al*., 2012). Manure application did not have a significant effect on yam total biomass production nor on tuber yield when applied on fields after fallow. Crop residue application had a positive significant effect on yam tuber and total biomass production when applied after cotton and maize and with adequate rainfall amount and distribution.

Yam as an intercrop

In young coconut plantations (>10 years), plenty of sunlight is available which allow intercrops to cultivate. In order to utilize these natural resources efficiently along with soil nutrients and water, easily adaptable and cultivable yams and aroids are recommended. Initially intercropping received little attention in cashew. But Intercropping has become popular with the systematic establishment of large-scale orchards. It is practised during 4-5 years when there is sufficient space between crop rows with the main objective of deriving some income until cashew starts giving economic returns. Depending on soil and climatic conditions and local situations yam can be grown as intercrop (Visalakshi *et al*., 2015). Nedunchezhiyan *et al*. (2008c) reported that higher tuber length, mean tuber girth and tuber yield/plant were obtained with larger greater yam sett size and planting at wider spacing under established coconut garden. Greater yam planted with 200 g sett size at 90 cm x 90 cm as intercrop in coconut garden recorded the highest net returns and benefit : cost ratio of 2.06 (Nedunchezhiyan *et al*., 2008c). Intercropping of greater yam did not affect the growth and nut yield of coconut. In established coconut garden (cv. West Coast Tall) in the age group of 25-30 years, trailing genotypes of *Dioscorea viz*. Sree Priya (*D. rotundata*) and Sree Keerthi (*D. alata*) could be profitably intercropped. They found an increase of net profit to the tune of ₹ 9600-10260/ha with the intercropping of trailing type of *Dioscorea*. The highest net returns of ₹ 37750/ha and benefit:cost ratio of 2.06 was realized when greater yam was planted with 200 g sett size at 90 cm x 90 cm spacing under coconut plantation (Nedunchezhiyan *et al*., 2008c).

Intercropping in elephant-foot yam

Growing intercrops in elephant-foot yam is a wide spread practice. A comparatively wider spacing of 90 cm x 90 cm has been identified as optimum for planting elephant-foot yam. Further, it takes long time to give sprouts and it takes nearly 90 days to cover the ground surface. Hence, during the earlier stage of crop growth, enough sunlight and inter space are available and there is a possible of growing bushy, short duration vegetable intercrops like onion, French bean, cowpea, cauliflower etc. and also short duration pulses like greengram, blackgram, cowpea etc. (Nedunchezhiyan and Byju, 2005). These crops offer little competition to elephant-foot yam. After harvesting of greengram or blackgram, the haulms could be re-used as mulch or incorporated. Because of mulching at later stage higher yield was noticed in elephant-foot yam compared to sole crop at Bhubaneswar, Odisha. The net additional income of ₹ 15000/ha was obtained in such cropping. In Wayanad (North Kerala), Elephant foot yam was planted in November at 120 cm x 120 cm spacing. During initial stage, farmers grow cucumber or *Amaranthus* as intercrop and harvest within 60-75 days after sowing.

In Tamil Nadu (India), vegetable cowpea cv. Co2, cluster bean (*Cyamopsis tetragonoloba* L.) cv. Pusa Navbahar), okra cv. Parbhani Kranti, aggregatum onion (*A. cepa* var. *aggregatum* L.) cv. Co4) and amaranthus (cv. Co3) were grown as intercrop in elephant-foot yam two years trial. The results indicated that intercropping elephant foot yam with vegetable cowpea recorded higher elephant-foot yam corm yield (49.3 t/ha) than elephant-foot yam sole cropping. The highest economic returns were obtained when elephant-foot yam was intercropped with vegetable cowpea. Similar result was reported under West Bengal conditions also.

In simultaneously planted/sown elephant-foot yam+greengram intercropping system, application of mulch was found significant effect on corm yield. Nedunchezhiyan *et al*. (2008d) reported mulching of elephant-foot yam+greengram immediately after planting/sowing increased elephant-foot yam corm yield by 21.6% over no mulching. However such effect was not noticed in greengram. Productivity efficiency (kg/ha/day), production efficiency (₹/ha/day), net returns (₹/ha) and benefit:cost ratio were higher with the mulching than no mulching of elephant-foot yam+greengram intercropping system (Nedunchezhiyan *et al*., 2008d). Weeds often germinate and grow earlier than elephant-foot yam, which can be suppressed by growing intercrops (Nedunchezhiyan *et al*., 2021).

Elephant foot yam as an intercrop

The presence of annuals as intercrop has a positive influence on the growth characters of plantation and horticultural crops. Elephant-foot yam very well adapted to fairly long moist growing season and relatively low temperature which usually prevailed under perennial plantations. In a two years trial at Kasaragod, Kerala, India the performance of elephant-foot yam was better under shaded conditions compared to open. From the soil temperature measurements made during the crop period it was observed that the soil temperature remained high September to November (post rainy season). As a result of more temperature in the soil the crop attained senescence at a much earlier stage resulting in poor productivity in the open. However, under shaded conditions the soil temperature relatively remained low and resulted in better productivity of the crop.

Elephant-foot yam as an intercrop was more profitable than other tuber crops in coconut gardens. Net income from coconut+elephant-foot yam was higher than sole crop. Higher coconut yield, net income, profitability and benefit cost ratio were observed in multi species cropping system of coconut+nutmeg+banana cv. poovan+annual moringa (*Moringa oleifera* L.)+ elephant-foot yam+bitter gourd (*Momordica charantia* L.) than sole coconut. The elephant-foot yam as a component crop in coconut-based cropping system could improve the over all nut yield of coconut, net returns from coconut gardens, employment potential as well as the benefit:

Intercropped elephant-foot yam in banana and papaya recorded 80-90% corm yield of the sole elephant foot yam (Nedunchezhiyan *et al*., 2002). There is no reduction in bunch characters like bunch weight, number of hands/bunch, number of fingers/hand and finger weight in intercropped banana. Similarly, intercropping of elephant-foot yam did not affect fruit number and weight of papaya. This indicated that intercropping elephant-foot yam did not competing with main crop for nutrients if nutrients applied individual crops on net area sown/ planted basis, rather the left over nutrients from intercropped area is utilized by the banana and papaya. Inclusion of elephant-foot yam as intercrop in banana and papaya increased net returns ₹ 21100 and 20200/ha over respective sole crops (Nedunchezhiyan *et al*., 2002).

Intercropping of elephant-foot yam with Nendran banana was found to be efficient from the values on land equivalent ratio and higher net income. Further, there was no adverse effect on the growth and yield of Nendran banana due to intercropping. Elephant-foot yam could be raised along with banana and vegetable cowpea successfully under the partial shade of coconut. Under such a situation, half the recommended dose of N and P and full dose of K was found sufficient for the intercrops. Growing green manure crops in bael planted in degraded lands and *insitu* incorporation reduced manures and fertilizers requirements (Singh *et al*., 2021).

Elephant-foot yam in sequential cropping

Elephant-foot yam can be grown as sequential crops in rice fallows. In such systems resource use efficiency, farm income and employment opportunities were higher. In lowlands of Kerala, elephant-foot yam-cowpea (mulch and green manure)/cowpea for pod production gave the highest net returns than other cropping sequences. In Wayanad (North Kerala) farmers regularly followed crop rotation, after three crops of elephant foot yam one crop of banana was raised. The population of *Radopholus similis* L. was reduced in crop rotation banana-paddy-elephant-foot yam. Summer Guinea grass, winter rye, buckwheat and winter wheat crop rotation and cover crops reduce root rot of *A. konjac*. Nematodes a major problem in elephant foot yam was effectively managed by rotating with nematode resistant colocasia (Tamil Nadu), sugarcane, banana, greengram, blackgram, vegetables etc. (Andhra Pradesh). Rotation with sweet potato especially Sree Bhadra variety will help to reduce root knot nematode population in the soil (Mohandas and Siji, 2012).

Banana+knoll khol-elephant foot yam cropping system recorded 72.6 t/ha banana equivalent yield with the gross return of ₹ 3.62 lakh/ha and benefit cost ratio 3.41 under Assam conditions (Das *et al*., 2013). Also increase of 21.2, 14.0 and 14.0% bunch weight, number of hands per bunch and number of fingers per hand contributing to 21.2 % increase in yield due to complementarity.

Intercropping in taro

Taro is a tuberous vegetable crop consumed after boiling and seasoning. Tubers are used for chips production and starch making. Taro starches are used in talc along with kaoline. Young leaves and petioles are also consumed as green vegetable. Culled tubers are used as animal feed especially for pigs.

In upland ecosystem, taro is grown as sole crop as well as intercropped with maize. In lowland ecosystem, it is grown as sole crop.

Intercropping in yam bean

Yam bean is popularly known as potato bean. In India it is called 'Mishrikkand' in Bihar, 'Kesaru' in Eastern Uttar Pradesh and 'Sank alu' in Orissa, West Bengal and Assam. The starchy conical or turnip shaped fleshy tubers are eaten. High sugar content in tubers imparts sweet taste when eaten raw. The fresh tubers are used as salad and can also be made into chips. The young tubers have crisp juicy and refreshing flesh. The over matured tubers become fibrous, hence unsuitable for consumption. In China mature dried roots are reported to be used as a cooling agent for people suffering from high fever. In many countries young immature pods are used as a vegetable. The stem is tough and fibrous and is used for making fish nets in Fiji. The mature seeds have high content of alkaloids and insecticidal properties. In many developed countries the tubers are processed, canned and many sweet preparations are made.

Yam bean is propagated through sexually developed seed. Generally it is cultivated as sole crop. Maize is intercropped in yam bean to provide staking support apart from additional yield. Yam bean also intercropped in sweet potato fields to reduce sweet potato weevil incidence.

Conclusion

Meeting food self sufficiency remains the major challenges under climate change. Inclusion of climate resilient root and tuber crops in various cropping systems is the best alternative to achieve food demand of 2050. Root and tuber crops based multiple cropping systems not only highly productive but also suppress weeds, pest and diseases growth and spread.

Future research

- Developing greater shade tolerant high-yielding varieties of root and tuber crops
- Investigations on rooting pattern and spacial arrangements of root and tuber crops in the cropping systems
- Investigations on carbon sequestrations in root and tuber crops based cropping systems
- Investigations on allelopathic interaction between the various components in root and tuber crops based cropping systems
- Socio-economic evaluation of root and tuber crops based cropping system

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Citrus (*Citrus* spp.) cultivation in Andhra Pradesh—a case study

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Citrus genus is known for its beneficial effects on health for centuries. The genus Citrus includes more than 162 species belonging to the family Rutaceae and sub-family Aurantoidae. In India, citrus is being cultivated in Andhra Pradesh, Maharashtra, Assam, Punjab, Karnataka, Telangana, Bihar, Madhya Pradesh and Gujarat. India is rich in genetic diversity of citrus. The soil and climatic factor prevailing in the country favour its cultivation. It is cultivated throughout tropical and subtropical regions of the country. The major citrus species commercially cultivated in India are mandarins, acid limes and lemons, and sweet oranges. Pummelo and grapefruit are cultivated in limited scale and mainly confined to homestead gardens.

Citrus Crops in India

In India, citrus crops (mandarins, sweet orange, limes, lemon etc), hold a prominent place among major commercial fruits covering an area of about 10.58 lakh ha with an annual production of 14.03 million tonnes and a productivity of 13.26 t/ha. In comparison to 1991-92 (3.87 lakh ha, 2.82 million tonnes: 7.21 t/ha) there was three fold increase in area, seven fold increase in production and two fold increase in productivity. The steady increase in production of Citrus crops in India might be attributed to various factors like commercialization of new varieties and high-yielding grafts, canopy management, rejuvenation of senile orchards, effective management of citrus decline etc.

Citrus in Andhra Pradesh

Andhra Pradesh has a lot of scope to emerge as a citrus hub by expanding the area in acid lime and sweet orange. Presently the area under citrus crops is 1.39 lakh ha with a production of 2.99 million tonnes and a productivity of 21.52 t/ha. The technology awareness coupled with technological developments and potential for export of varieties has resulted in manifold increase in area and production of citrus crops. The climate prevailing in Andhra Pradesh is highly conducive to citrus crops which has led to drastic increase in production. Microirrigation systems have proved to be very useful in meeting the water requirement of Citrus crops which has contributed to area expansion under acid lime and sweet orange through Andhra Pradesh Microirrigation Project. Renewed efforts are being made consistently by the Dr YSR Horticultural University to develop and refine the varieties and technologies through certified disease-free quality planting material to increase the production (Figs 1, 2 and 3). The varieties released namely, Balaji of acid lime and Sathgudi of sweet orange are important milestones that have contributed for increased productivity from 13.55 (2000-01) to 21.52 t/ha (2020-21).

Sweet orange and acidlime

Sweet orange and acid lime are important crops grown at large scale in Andhra Pradesh with highest productivity in the country. The Citrus Research Station, Tirupati started as Citrus Bud Certification scheme in 1968, later converted to Citrus Improvement Project in 1977 to work on all aspects of Citrus crop. Virus Indexing Laboratory has also been set up for indexing sweet orange mother plants against greening,

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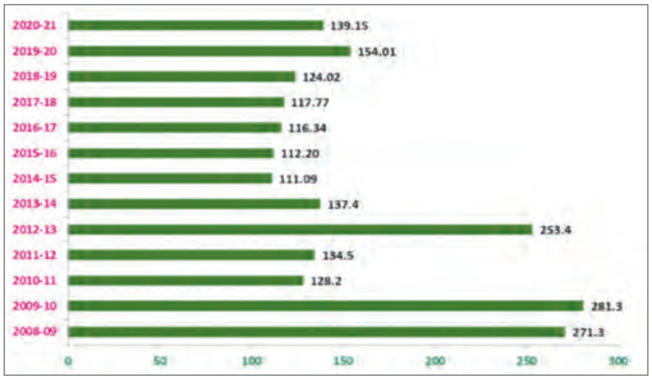

Fig 1. Area under citrus crops in Andhra Pradesh ('000ha)

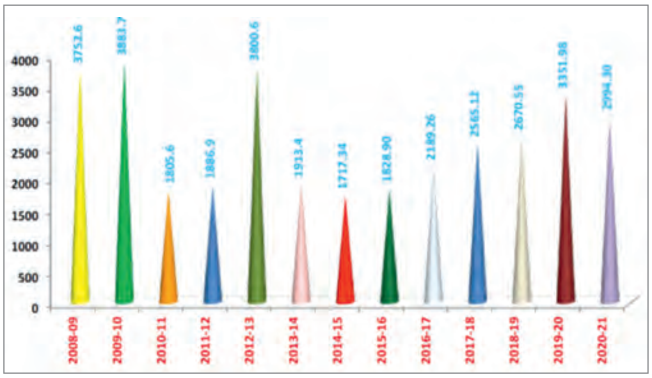

Fig 2. Production of citrus crops in Andhra Pradesh ('000tonnes)

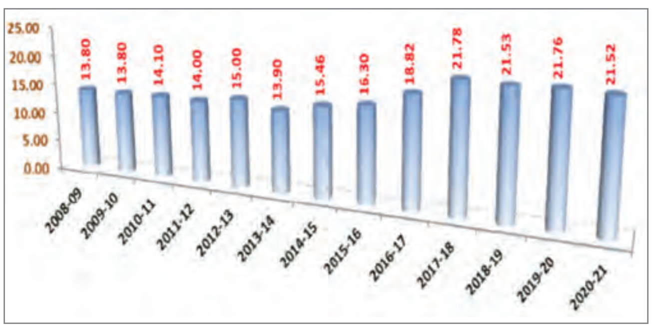

Fig.3 Productivity of citrus crops in Andhra Pradesh (tonnes/ha)

CMV and CYMV diseases. Sweet orange Sathgudi as well as acid lime Balaji are very popular among farmers. Rangpur lime standardized as a promising rootstock for sweet orange in Andhra Pradesh, is most utilized rootstock due to its heavy and early bearing and drought resistance. It is also resistant to tristeza and moderately resistant to *Phytophthora.* Trees budded on Rangpur lime are very vigorous and adapt well to great variety of soils.

Hence it is imperative on the part of Citrus Research Station, Tirupati, to produce disease-free and high-yielding sweet orange var. Sathgudi budded on Rangpur lime rootstock to supply to farmers. There is a huge demand among farmers of Andhra Pradesh, Telangana, Karnataka and Tamil Nadu for the past 20 years. To produce disease-free sweet orange bud wood, about 410 sweet orange mother plants free from Citrus greening, CMV and CYMV are being maintained in the screen house of 4,000 m^2, exclusively for collection of healthy bud wood which has the potential to supply bud sticks sufficient to produce 2.5 lakh budlings per annum.

A separate shade net house is established in 2,550 m^2 for growing healthy acid lime seedlings of Balaji. About 350 trees of Rangpur lime are maintained which yields around 50-60 kg of seed which is sufficient to produce 3.0 lakh seedlings to be used as rootstock for budding sweet orange var. Sathgudi. The facility with screen house for maintaining disease-free scion block is replicated at Horticultural Research Station, Mahanandi, for production of sweet orange var. Sathgudi budlings. Altogether sweet orange budlings are produced at Citrus Research Station, Tirupati; Citrus Research Station, Petlur (with scion material from CRS, Tirupati) and Horticultural Research Station, Mahanandi.

Sweet orange in Andhra Pradesh

In 2003-04, its productivity in India was 10.40t/ha, while it was 12.28 t/ha in Andhra Pradesh. After introduction of Sathgudi cultivar, the productivity recorded in 2010-11 was 15.00t/ha in Andhra Pradesh, while it was 8.40 t/ha in India. A decade after introduction of high-yielding sweet orange cultivar (2010-11), the productivity in India was 8.40t/ha., there was significant increase in productivity of 15.0 t/ha in Andhra Pradesh with a jump of 78.57%. After two decades of release, *i.e.* 2018-19, productivity in India was 17.90t/ha., while it was 24.00 t/ha in Andhra Pradesh. The overall increase in productivity over two decades is 34.00% due to cultivation of high-yielding "Sathgudi" variety, technologies developed to enhance the yield, innovative integrated pest and disease management practices using biopesticides and eco-friendly methods through AICRP, Tirupati centre and dissemination of information through various extension agencies.

Andhra Pradesh ranks first in area of sweet orange (63.14 % in 2012-13, 29.43 % in 2013-14, 26.49% in 2014-15, 31.94% in 2015-16 and 42.91% in 2016-17), followed by Telangana(31.47%), Maharashtra (28.74%), Madhya Pradesh (5.92%), Karnataka (0.92%) and Punjab (1.50%) in 2016-17.

Andhra Pradesh ranks first in terms of production of sweet orange (86.96 % in 2012-13, 34.24 % in 2013-14, 28.78% in 2014-15, 36.48% in 2015-16 and 51.07% in 2016-17), followed by Telangana (25.71%), Maharashtra (20.47%), Madhya Pradesh (5.67%), Karnataka (0.88%), and Punjab (0.74%) in 2016-17.

Acid lime in Andhra Pradesh

In 2000-01, productivity in India was 8.40t/ha, while it was 12 t/ha in Andhra Pradesh. After introduction of Balaji acid lime cultivar CRS, Tirupati centre, the productivity recorded in 2008-09 was 15 t/ha in Andhra Pradesh, while it was 8.10 t/ha in India. A decade after release of Balaji (2010-11), the productivity in Andhra Pradesh was 15t/ha with a jump of 66.67% against the productivity of India (9t/ha), Similarly in 2015-16, the productivity in India was 9.9 t/ha, while it was 16.46 t/ha in Andhra Pradesh with an increase of 69.12% and after two decades of release, *i.e.*, 2019-20, productivity in India was 11.46t/ha., while it was 16 t/ha in Andhra Pradesh.

The overall productivity increase over two decades is 60% due to cultivation of canker tolerant high-yielding "Balaji" variety, technologies developed to enhance summer crop yield, innovative integrated pest and disease management practices using biopesticides and eco-friendly methods through AICRP on Citrus, Tirupati and dissemination of information through various extension agencies, in line departments etc.

Andhra Pradesh ranks first in terms of production of acid lime (35.47 % in 2000-01, 31.58 % in 2011-12 and 18.62% in 2019-20) followed by Gujarat (18.71%), Maharashtra (12.75%), Karnataka (11.81%), Bihar (5.89%) and Madhya Pradesh (5.73%). Similarly in 2017-18 Gujarat had a share of 19.24 % followed by Andhra Pradesh (17.85%), Madhya Pradesh (9.74%), Karnataka (9.73%), Maharashtra (7.96%) and Telangana (5.66%).

VARIETIES

Sathgudi

It is popular high-yielding variety (16-18t/acre) in south India because of wider adoptability and better consumer acceptance. The fruit is almost spherical in shape with smooth, thin, semi glossy, finely pitted rind and orange colored when fully mature. An individual fruit weighs 140/-150g, containing 10-12 segments, 10-14 seeds, 49% juice, 8.5^{o} –9^{o} Brix, 0.65% acidity and 47mg of ascorbic acid per 100g of juice

Balaji (Acid lime)

Tolerant to citrus canker. Annual yield: 3000–5000 fruits/tree. Fruit weight: 40-50g. Fruits spherical, smooth and develops attractive yellow colour when fully ripe. Peel is very thin, adhering to segments. The juice sacs are slender and spindle shaped, juice 47%,TSS $6\text{-}7^{O}$brix, acidity 6.8-7% and ascorbic acid 25-27mg/100g of juice. Average number of seeds: 7/fruit.

Petlurpulusunimma-1 (Acid lime)

If is cluster bearer and high yielder than local varieties. Tolerance to bacterial canker disease. Juice percentage: 55.8. Citric acid: 7.3 mg/100g. Yield during summer season: 210-220 kg fruits /plant/year.

Production technologies

The technology has been developed to enhance the summer crop yields of acid lime (*Citrus aurantifolia* Swingle), the treatment with GA_3 50 ppm in June + Cycocel 1000 ppm during September is most promising and economically viable technology with highest benefit: cost ratio (2.43) (Mukunda Lakshmi *et al*., 2014).

Application of 75% recommended dose of nitrogen [1125g/plant] and 300 g potassium plant through drip irrigation at 15 days interval in the form of urea and single superphosphate each at 46.88g and 12,5g/plant/application increases yield by 2.02 t/ha in sweet orange cv. Sathgudi over control. There is a saving of 25% of nitrogen [226.22 kg urea] and potassium [46.43kg murite of potash] per hectare over conventional method of applying 100% recommended dose of fertilizers to the basins **(**Venkata Ramana *et al*., 2014**).**

Application of 75% RDF + AM (500 g/plant) + PSB (100 g/plant) + *Azospirillum* (100 g/plant) + *Trichoderma harzianum* (100 g/plant) has given highest yield (28.14 t/ha) with highest benefit: cost ratio of 2.25 and shelf-life of 20.5 days in sweet orange (Mukunda Lakshmi *et al*., 2017).

Dry weather period during fruit development (May- June) and flowering and fruit set (Jan- February) are the two critical stages for water requirement in Sathgudi sweet orange. If there is any water shortage during these two critical stages results in 16 - 18 % yield reduction. Hence, there is a need to enhance irrigation requirement based on Evaporation Replenishment during the critical periods to get economic yields (15t/ha) in sweet orange growing areas of Andhra Pradesh (Mukunda Lakshmi *et al.,* 2020).

The highest sweet orange fruit yields (46.91 kg/plant and 13 t/ha) can be achieved through drip irrigation with the application of 743 litres/plant during Jan-Feb (Flowering and fruit set), 1645 litres/plant during March-April (fruit set and growth), 1292 litres/plant during May- June (fruit development), 739 litres/plant during July-August (one month before harvesting), 236 litres/plant during Sep-Oct (harvesting), 295 litres/plant during November and imposing bahar treatment (water stress) during December should be followed for taking the *Ambe bahar* in sweet orange in Andhra Pradesh. This irrigation treatment not only helps in efficient utilization of water besides water saving of 15% per plant, but also supports the economic development (BC ratio of 1.48) of sweet orange farmers of Andhra Pradesh (Mukunda Lakshmi *et al*., 2019).

Drip irrigation with 90% ER and fertigation with 70% RDF (1050: 245: 280 g N, P_2O_5 and K_2O) was found to be superior with respect to vegetative growth and yield (53 kg/plant and 14.18 t/ha) for 10 years old Sathgudi sweet orange orchards at Tirupati (Mukunda Lakshmi *et al*., 2019).

Acid lime cropping system studies revealed that marigold and cucumber were found to be profitable intercrops in pre-bearing orchards of acid lime with a cost: benefit ratio of 4.3 and 3.69 respectively.

Standardized organic farming in acid lime in var. Petlur pulusu nimma variety with vermicompost (equivalent to RDN), *Trichoderma viride* (1kg in 100 kg vermicompost), Azadirachtin 1% (10000 ppm) @ 5 ml/ litre as foliar spray and *Pseudomonas fluorescence* was found to be the efficient practice.

Acid lime trees mulched with paddy straw @ 7 kg/plant or mulching the tree basins with100 microns transparent polythene film recorded significantly higher number of total fruits, yield and also improved the growth parameters (Dr YSR Hort. Univ., 2020)

Insect pest management

Among different biopesticides tested against citrus butterfly, *Bacillus thuringiensis* (0.1%) was found to be effective providing >80% pest control up to 14 DAS. The next best alternatives include NSKE (5%) and neem oil (1%) (Sarada *et al*., 2014).

In sweet orange, for effective control of citrus mites, two sprays of ethion 50 EC (0.05%) or propargite 57 EC @ 0.057%, first at initiation of pest infestation while second spray after 15 days thereafter, are recommended. In the same way for managing the rust mites in sweet orange two sprays with the above chemicals at marble stage and 20 days later are recommended (Dr YSR Hort. Univ., 2018-19)

Foliar application of Novaluron 10EC (0.005%) @ 0.5 ml/l or Azadirachtin (1%) @ 4 ml/l or petroleum oil spray (5 ml/l) twice at 15 days interval coinciding with peak activity of the pest was recommended against *Citrus psylla* up to 14 days in sweet orange (Sarada *et al*., 2014).

Spraying of Azadirachtin formulation 10000ppm @5ml per litre of water followed by spinosad (0.002%) was found to be the most effective and recorded lowest incidence of citrus leaf miner (5.00%) followed by thiamethoxam (5.45%) up to 14 days after spray (Sarada *et al*., 2015).

Spraying of Azadirachtin 10000 ppm @ 5ml/l followed by thiamethoxam(0.025%) was effective in reducing the population of aphids, blackfly and psyllids as compared to dimethoate (local check)@0.06% and for thrips management on leaves and fruits, azadirachtin 10000 ppm @ 5ml/l followed by spinosad (0.002%) found to be more effective as compared to dimethoate (local check) @ 0.06% with a mean yield of 24.96t/ha and a B: C ratio of 2.48.(ICAR- AICRP on Fruits, Annual Report, 2018-19)

Disease management

Soil drenching of Mancozeb 75WP @ 2g/l with 25 liters of solution and after 25 days, application of *Trichoderma reesei* (TCT_{10}) (100g/tree) (10^7) and *Pseudomonas fluorescens* (100g/plant) (10^8) with 2kg neem cake and 25 kg FYM twice in year during June-July and December-January is effective in management of dry root rot caused by *Fusarium solani* (Gouri Sankar *et al*., 2014 , Gopal *et al*., 2014 and Gopi *et al*., 2017).

Foliar application of Bacteriomycin (200 ppm) + copper oxychloride (3000 ppm) twice is effective to manage the bacterial canker in acid lime during the August and September (Kavitha *et al*., 2021)

Foliar application of Pyraclostrobin (0.1%) followed by Tebuconazole (0.1%) proved effective against greasy spot of acid lime (Kavitha *et al.,* 2014)

Acid lime postharvest losses due to sour rot incidence is the major constraint in December–January harvested fruits and it can be effectively managed with pre-harvest foliar application of 0.1% boric acid. Acid lime var. Balaji is more susceptible to sour rot during transit and pre-harvest foliar application of Benomyl (0.1%) and Carbendazim (0.1%) reduced the spoilage of fruits during storage due to sour rot disease (Kavitha and Rajulu, 2014).

The IDM package was developed to manage dry root rot in acid lime (drenching the trees with Mancozeb (3g/l) followed by the application of *Trichoderma viride* @ 10kg/plant (1kg of *Trichodermaviride* + 100 kg FYM + 10Kg neem cake) (Rajulu and Kavitha, 2014).

Biofertilizers

Biofertilizers include various organisms mainly bacteria, fungi, and algae that have a strong relationship with plant roots and inhabiting the root system or rhizosphere, like nitrogen fixers, phosphorus solubilizers, phosphorus mobilizers, and potassium solubilizers, controlling citrus canker (Othman and

Panhwar, 2014). The soils of citrus orchards in arid and semi-arid regions are characterized by alkalinity and low contents of organic matter, therefore, annual application of high rates of inorganic fertilizer is usually practised by growers to maintain citrus productivity. Besides, annual application resulted in accumulation of high level of soil phosphorus, which leads to decrease in the efficiency of phosphorus, also, soil and water table are polluted with nitrite and nitrate, also, besides affecting farmers income.

The inoculation with biofertilizers particularly mycorrhiza at various growth stages of citrus orchards, particularly under stressed conditions is the right strategy to stimulate tree growth and productivity. The biofertilizer application enhancing the growth of citrus through increased availability of different nutrients in soil acquisition, improved absorption and utilization, modifying soil pH, secretion of various organic materials in rhizosphere like organic acids, plant growth regulators which positively stimulated plant growth.Various potential biofertilizers could be used like *Azotobacter, Beijerinkia, Clostridium, Klebsiella, Anabaena, Nostoc, Rhizobium, Frankia, Anabaena azollae* and *Arbuscular mycorrhiza*, for that, there is more interest in stimulated biofertilizers in citrus orchards as a part of integrated nutrient management for sustainability.

Challenges in citrus cultivation

Non-availability of quality planting material, biotic and abiotic stresses are severely affecting citrus production and productivity (Anbalagan *et al*., 2021). The area under citrus is constantly increasing every year and currently requires 2 crore plants per year. Mandarins, sweet oranges, grapefruit and pummelo are produced by budding with either Rough lemon or Rangpur lime as rootstocks and acid lime is mainly propagated through seeds. The research institutes supplying genuine disease-free quality planting material could not even able to meet 1% of the demand. The farmers are getting poor quality planting material from other sources which severely hampers citrus production-.

Citrus trees are affected by several insect pests, fungal, bacterial and viral diseases. Of these, Phytophthora (*Phytophthora* spp.), twig blight (*Botryodiplodia theobromae*, *Colletotrichum* spp.), citrus canker (*Xanthomonas citrus* ssp. *citri*), citrus scab (*Elsinoe fawcettii*), citrus greening (*Candidatus liberibacter asiaticus*), Citrus tristeza virus (CTV) and nematodes (*Tylenchulus semipenetrans)* cause huge economic losses. Phytophthora and citrus greening are becoming most lethal diseases of citrus in India which is mainly responsible for citrus decline, particularly mandarins and sweet oranges. Canker is one of the serious problems in acid lime which affects the production, productivity and quality.

Abiotic stresses like salinity, drought, alkalinity, flood, and extreme temperatures limit the citrus production. Drought and salinity are most important abiotic factors affecting the production and productivity of citrus in India. Drought causes imbalance between water uptake and transpiration which leads to reduction in leaf gas exchange and net photosynthesis thereby affecting the production. Salinity is caused by Na^+ and Cl^- ions which could cause osmotic and ion injury to plants leading to reduction in production and productivity. Citrus trees accumulate Na^+ and Cl^- ions in their leaves thus altering the physiological and biochemical mechanisms.

CONCLUSION

The production and productivity are affected by non-availability of disease-free quality planting material and several biotic and abiotic factors. Besides, citrus industry is steadily growing. Further, the demand for citrus fruits has increased after Covid-19 pandemic because of its rich nutrients and better health awareness. Adoption of drip irrigation and water conservation measures are necessary for sustainable citrus crop production. Organic and biofertilizers must be a part of the integrated fertilizing system as partial supplement for inorganic fertilizers to sustain citrus productivity, increase citrus tolerance for biotic and abiotic stresses, and to preserve soil health. Focus should be given to increase fruit quality so that export market could be increased from 15-20% to 30-40%. The focus on processing and value-addition should be given priority and it may be the key factor for increasing the income of farmers.

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Evaluation of cultivation of tubers and spices in polypropylene bags: an option

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ABSTRACT

Majority of farmers growing tubers and spices are small and marginal ores. They are resource poor and predominantly rainfed farmers. Initial investments on planting material of these crops are too high. In an effort to help them to overcome these uncertainties of crop losses due to weather and disease, the present research on growing tubers and spices in used polypropylene bags was done. The productivity was double to that of traditional cultivation practices.

Key Words: Jawahar model, PPB, DFI, Tubers, Spices, Bags, Productivity.

Madhya Pradesh has about more than 70% of small and marginal farmers (SMFs) (Meshram *et al.*, 2020). Among them, majority practises rainfed farming. Low input intercropping; crop diversification and intensification are promoted through Jawahar model for doubling income of resource constrained marginal farmers (Thomas *et al.*, 2021). It is need to help SMFs in Madhya Pradesh particularly and India as whole. The major intervention in the model is intercropping of tuber crops in polypropylene bags (PPB) filled with substrate. Just like architecture, plantation architecture is also required to accommodate more plants per unit space without compromising the resources and yield of the main crop.

MATERIALS AND METHOD

The Jawahar model for doubling the income of resource constrained marginal farmers is established in Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur (Patent application no. 201921044327A, dated 15.11.2019). The consortia consisted of *Trichoderma viridae*, *Pseudomonas* spp., phosphorous-solubilising bacteria (PSB), *Vesicular Arbuscular Mycorrhiza* (VAM) and *Aspergillus niger*. Spacing of 6 feet was maintained between plant-plant and row-row. In between the *C. cajan* plants, 35 kg substrate filled PPBs (17 X 22 inches) were placed, *i.e.* 3 feet apart. The circumference (mouth) of PPB filled with substrate was 94cm. Onion, garlic, turmeric and ginger were planted in 35kg substrate filled PPB. The PPB to PPB spacing was 3 feet and arranged in separate row.

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Turmeric (*Curcuma longa* L.)

Sonali, Ranga, Rashmi, Suroma, Roma, mango turmeric and black turmeric varieties plants were raised from fingers (30 g) in substrate filled black poly bags. These plants were transplanted in PPB during first week of July 2019. The experiment had three replications in a randomized block design. Single plant of turmeric was transplanted in each PPB. They were irrigated by plastic pipe at the rate of 10 L/PPB at an interval of 15 days, from November to February, thereafter at 10 days interval till harvesting. Number of shoots and its length were recorded. The crop was harvested during first week of April 2020.

Onion (*Allium cepa* L.)

Seedlings of onion (ADR) raised in nursery were transplanted in another set of 35kg substrate filled PPBs during third week of November 2019. The seven treatments consisted of planting seedlings varying from one to seven seedlings per PPB. The experiment was laid out in completely randomized design (CRD) with unequal repetition. The crop was harvested in first week of April 2020.

Garlic (*Allium sativum* L.)

Garlic (G-50) cloves were planted in third set of substrate filled PPB in fourth week of November 2019. The nine treatments consisted of planting of cloves varying from 2 to 11 per PPB, in CRD with unequal repetition. The crop was harvested in first week of April 2020 and weight of bulbs per PPB was recorded.

Ginger (*Zingiber officinale L.)*

Ginger (Suprabha) fingers weighing 30g each were directly planted in fourth set of substrate filled PPB in first week of July 2019. Moisture stress and no moisture stress conditions were the two treatments. The crop was harvested in first week of April 2020 and for statistical analysis of the data 't' test was done.

Some vegetables were also planted as intercrops in Jawahar model field. The selection of these crops depends on the requirements.

RESULTS AND DISCUSSION

Turmeric

The mean number of shoots of turmeric per PPB varied from 3.33 (Mango Turmeric) to 8.73 (Sonali) at 60 DAT. Sonali was significantly superior in all varieties, while others were at par with each other. The mean height of shoots at 60 DAT varied from 65.67cm (Black Turmeric) to 101.13cm (Roma). Roma (101.13cm) and Sonali (98.20cm) were significantly tallest over rest of the varieties that were at par among themselves. The mean shoot height of Sonali and Roma were also at par with each other. At 90 DAT, mean shoot height varied from 66.93cm (Black Turmeric) to 104.67cm (Roma). It was again significantly higher in Roma (104.67) and Sonali (100.47 cm) over rest of the varieties that were at par with each other. Roma and Sonali were also at par with each other in terms of mean shoot height.

The increase in shoot length at 90 DAT was highest (9.97%) in Mango Turmeric, followed by Rashmi (5.93%), Ranga (3.57%), Roma (3.49%), Suroma (3.08%), Sonali (2.31%) and Black Turmeric (1.93%). The mean yield of rhizome per PPB varied from 185.81g (Black Turmeric) to 1072.33g (Sonali). All the varieties had significantly higher yield than Black Turmeric. The mean rhizome yield/PPB among Sonali (1072.33 g), Ranga (1011.33g) and Suroma (922.33 g) were at par with each other. Similarly, Rashmi, Suroma, Roma and Mango Turmeric were also at par with each other in mean yield per PPB.

Kumar and Gill (2010) reported mean number of shoots/turmeric plant varied from 2.4 to 2.7 in flat bed planting method, while 2.3 to 2.8 in ridge bed method. In our study, it was quite high with 3.33 - 8.73 shoots/ plant depending on the variety. The mean shoot length reported by Kumar and Gill (2010) varied from 42.6cm to 46.00cm, against 66.93 cm (Black Turmeric) to 104.67cm (Roma) at 90 DATs. Anal (2019) reported tallest plant height of 103.95 cm in NDH-98 turmeric among ten genotypes. The highest per plant rhizome yield of 270 g in NDH-98. The yield was almost six times more per plant. Mirjanaik and Vishwanath (2020) reported highest clump weight of 777.69g with broader plant spacing.

Thus, it is clear that turmeric in PPB attains better growth and yield. It is may be because no weed competition and better nutrient availability.

Onion

The mean weight of individual bulb was lowest (25g) in PPB with two seedlings closely followed by those with seven (29.63 g), three (48.33 g), one (50 g), five (52.13 g), six (60.76 g) and four seedlings (83.6 g). Thus, the mean yield of bulb per PPB varied from 50 g (one seedling / PPB) to 364.53 g (six seedlings / PPB). The mean bulb yield per PPB in T_7 (seven seedlings), T_5 (five seedlings), T_4 (four seedlings) and T_6 (six seedlings) were at par, but significantly higher than those in T_1 (one seedling), T_2 (two seedlings) and T_3 (3 seedlings/ PPB). The data revealed that it is economically viable if six seedlings are planted in a PPB, as total yield was 364.53 g bulbs/PPB with the mean weight of individual bulb was 60.76 g.

Ngullie and Biswas (2017) reported mean bulb weight of onion to increase from 40.44 g (20 cm x 10 cm) to 71.44 g (30 cm x 15 cm). The highest mean bulb weight was 83.6 g when 4 onion seedlings were planted per PPB while 60.76 g with 6 seedlings per PPB. The intra-plant spacing varied from 13.4cm to 94 cm in PPB. The highest bulb weight was 83.6g and 60.7 g in spacing of 23.5 cm and 15.7 cm respectively. The overall highest yield of 364.53 g was obtained with the spacing of 15.7 cm. Ngullie and Biswas (2017) recorded highest bulb weight of 53 g in spacing of 30cm x 15cm. The PPB can be placed closely, accommodating more plants in circular geometry than that in conventional geometry. Our study confirms that onion in PPB is a better option, rather than planting them directly in field by SMFs.

Garlic

The mean bulb yield per PPB varied from 39.63 g (1-2 cloves/PPB) to 117.95 g (8 cloves/PPB). The treatment T_5 (6 cloves), T_7 (8 cloves), T_8 (9 cloves), T_9 (>10 cloves) and T_6 (7 cloves/PPB) recorded significantly higher mean bulb yield /PPB over that in T_1, T_2, T_3 and T_4. All the formers treatments were at par with each other.

The mean weight of individual garlic bulb varied from 10g (T_9) followed by 11.63 g (T_8), 13.51 g (T_6), 14.74 g (T_7), 15.88 g (T_4), 19.40 g (T_5), 19.82 g (T_1), 20.25 g (T_3) and 20.89 g (T_2). Thus, T_5 with mean total bulb yield (91.4 g) and mean weight of individual garlic bulb (19.40 g) was the best planting approach for garlic production in PPB. Murmu *et al*., (2019) reported highest bulb weight of garlic (11.60 g) with spacing of 12 cm x 10 cm planted on 14 December. The highest mean bulb weight (20.25 g) was obtained when 4 cloves were planted per PPB in fourth week of November 2019.

The spacing (plant-to-pant) varied from 9.4cm to 31.3 cm. The highest bulb weight 20.89g (T_2) and 20.25g (T_3) when the spacing was 31.3cm and 23.5cm respectively. But highest total bulb yield (91.4 g) was obtained in the PPB with the intra-plant spacing of 15.7 cm, *i.e.* 6 plants per PPB. Murmu *et al*. (2019) observed that with the spacing of 12cm x 10cm, the mean bulb yield was 11.60 g. However, bulb weight was 13.51 g and 14.74 g in intra-plant spacing of 13.4 cm and 15.7 cm respectively. These results are also in close conformity with Kavita *et al.* (2018) and Singh and Dubey (2015).

In markets where there is a demand for green leaves of garlic, farmers can grow in close spacing of 8-10 cloves per PPB. Green garlic fetches higher prices and earlier than the bulbs, which may help SMFs with earlier cash inflow.

Ginger

The overall mean yield of fresh rhizomes per PPB varied from 185.73 g (moisture stressed condition) to 385.97 g (no moisture stressed condition). The highest yield of ginger (655g) was recorded under no moisture stressed condition while it was 400 g under moisture stressed condition. Mahender *et al.* (2015) reported highest rhizome yield of 204.01 g ginger/plant, but according to Datta *et al.* (2017) it was 225.33 g and 321.66g/plant respectively with a spacing of 20 cm x 15cm and 30cm x 25cm. Under moisture stressed conditions, the overall mean rhizome yield/ plant was 175.73 g but it was quite high (385.97g) without moisture stressed condition.

Ginger is moisture sensitive crop. Thus, growing it in PPB overcomes such situation in case of heavy rains. Secondly, rhizome rot is very common in ginger causing crop losses. In PPB, disease remains confined to the PPB and helps to manage it better.

CONCLUSION

Tuber and spices are sensitive to water stagnation. Planting it in field requires high labour cost of earthing and weeding. Soil-borne diseases and nematodes once infested spreads in the entire field, reducing the total yield. In case of growing tuber and spices in PPB, no field preparation and weeding are required. In any infestation, that particular PPB can be handled separately, checking the spread of incidences. Crop in PPB can be grown organically; nutrients also remain in the bag making it continuously available to the plants. The substrate can be solarised individually during next cropping season. Similarly nutrient content of individual bag can also be managed, ensuring uniform nutrient management strategy.

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Standardization of propagation methods in minor wild fruit crops

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ABSTRACT

The study was carried out to find out the ideal propagation techniques of wild and minor fruit crops at ICAR-IIHR, Bengalure, during 2016-19. Two year's data revealed that fresh seeds of most of the species, viz. karonda (*Carrisa carandas*), wood apple (*Feronia limonia syn. Limonia acidissima*), avocado (*Persea americana*), noni (*Morinda citrifolia*), wild jamun (*Syzygium cumini*), Alangeum (*Alangium salvifolium*), carombola (*Averhoa carambola*), Canito (*Chrysophyllum cainito*), bael (*Aegle marmelos*), kokum (*Garcinia indica*), yellow mangosteen (*Garcinia xanthochymus*) and Malabar tamarind (*Garcinia gummigutta)* did not have dormancy and their germination was more than 60 per cent. Although the days taken for germination varied in these fruits. Some fruits, viz. mulberry (*Moris alba*) gave good response (80%) for multiplication through cuttings. Air-layering was found successful in Governor's plum (*Flacourtia indica*), Karonda (*Carrisa carandas*), natal plum (*Carrisa macrocarpa*), *Citrus hindsi,* Surinam cherry (*Eugenia uniflora*) and West Indian cherry (*Malpighia emarginata*) with 75 % and 60 % survival. The grafting was found successful (90%) in avocado (*Persea americana*) and wood apple (*Feronia limonia*).

Key Words: Propagation, Standardization, Underutilized fruits, Wild fruits, Grafting

India is endowed with a rich genetic diversity of tropical fruits. It is home to several wild, unutilized, underutilized and minor fruits. The minor or underutilized fruit crops aregaining importance due to their significant role in human health, nutrition, medicinal and therapeutic uses, income security and ecologicalbalance (Tripathi *et al*., 2018, Tripathi *et al*., 2019). It is established fact that to harness the maximum efficiency from a crop cultivation, use of genuine planting material is foremost requirement. However, information on propagation techniques for these species is scantily available. Further vegetative propagation is essential for due to heterozygous nature of fruit plants (Singh and Singh, 2006; Singh and Singh, 2007). Most of the wild fruits are still multiplied by seeds but germination is generally poor. There are several issues such as hard seed coat, dormancy, improper seed maturity, poor viability which influence the germination (Tripathi *et al*., 2015). Some efforts also have been made to multiply them by vegetative means. Sundriyal and Sundriyal (2002) found success in multiplying some of the wild fruits of Sikkim through cuttings. Ghosh *et al.,* (2010) successfully multiplied some minor fruits by layering. Since noattempt has been made earlier to standardized the propagation method of several wild fruits and very little information is available on multiplication of these fruits. Thus, an experiment was conducted.

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MATERIALS AND METHODS

The experiment was conducted at ICAR- Indian institute of Horticultural Research, Hessaraghatta, Bangaluru, during 2016-2019 on selected wild and underutilized fruits to multiply them by seed and vegetative propagation methods. The mature fruits of all these species were collected from different sources. The freshly collected seeds were sown in replicated trials. The per cent germination, day to start germination, final plant stand and plant height were recorded. The cuttings were taken up in rainy season and hard wood and semi- hard wood cuttings were used. In grafting, one-year-old rootstocks were selected and cleft grafting method was used with 3–4-month-old scion sticks. Air-layering was done in July and 8-10-months-old matured shoots of pencil thickness were selected and 2.5 cm wide ring of bark was removed.

This was tied with sphagnum moss using standard procedures. These were replicated three times, in randomizedblock design (RBD). The data on success of different methods and final stand of seedlings, cuttings, layered or grafted plants and plant height were recorded.

RESULTS AND DISCUSSION

The seeds germinated rapidly, showing higher percentage of germination, viz. karonda (90.3%), wild jamun (89.0%), wood apple (81.3%), avocado (80.3 %) and *Morinda citrifolia* (80.6%). Kokum (70%), *Garcinia xanthochymus* (75%), *Garcinia gummigutta* (78.3%), Alangeum (76.8%), carombola (75.6%), canito (72 %) and bael (76.3%) also recorded considerably higher seed germination. Moderate seed germination was observed in sour sop (53 %), bilimbi (53.3 %) and Manila tamarind (53.3%). Lower germination was recorded in West Indian cherry, Surinam cherry, Lasoda, Jamaica plum and yellow raspberry. Very low germination (<20 %) was recorded in Mysore raspberry, molshree and Macadamia nut. The Ceylon olive and *Cantheum parviflorum* seeds failed to germinated (Table 1). The data of day to start germination showed that some the fruit species took longer time to germinate. The macadamia nut seed started germination after 153 days and germination was very low (1 %).

There was very low germination in macadamia

Table 1. Multiplication of minor wild fruits through seed

Fruit	Botanical name	Seed germi-nation (%)	Day to germinated	Seedlings stand (%) after 90days	Seedling height (cm) after 6 months
Yellow Raspberry	*Rubus ellipticus*	22.3	63.2	0	0
Mysore Raspberry	*Rubus neveus*	10.6	53.4	0	0
Karonda	*Carrisa carandas*	90.3	22.6	85.6	29.5
Avocado	*Persea americana*	80.3	21.3	75.3	47.4
Governors' plum	*Flacourtia indica*	30.3	42.2	12.3	63.3
Noni	*Morinda citrifolia*	80.6	24.2	78.3	46.3
Lasoda	*Cordia myxa*	30.3	29.5	26.6	23.6
Molshree	*Momusops elengi*	15.3	47.3	12.3	27.2
Kokum	*Garcinia indica*	70.0	93.3	53.6	16.5
Kachampuli	*Garcinia gummigutta*	85.0	72.6	53.6	15.4
Beenakepuli	*Garcinia xanthochymus*	78.3	36.6	75.3	15.4
Wild Jamun	*Syzygiumcumini*	89.0	23.3	85.0	26.6
Egg fruit	*Pouteria campechiana*	45.3	28.2	32.0	36.3
Manila Tamarind	*Pithecellobium dulce*,	53.3	39.3	35.6	47.7
Ceylon olive	*Elaeocarpus serratus*	0	0	0	0
Carambola	*Averhoa carambola*	75.6	27.6	65.3	57.2
Bilimbi	*Averhoa bilimbi*	53.3	21.3	51.3	31.3
West Indian Cherry	*Malpighia emarginata*	35.6	26.3	34.6	32.5
Surinam Cherry	*Eugenia uniflora*	25.3	16.3	22.6	46.4
Jamaica plum	*Spondiasmombin*	25.6	32.3	21.3	43.0
Macadamia nut	*Macadamia integrifolia*	1.0	153.0	1.0	31.2
Alangium	*Alangium salvifolium*	76.0	34	72	36.6
Canito	*Chrysophyllum cainito*	72.0	32.0	70.3	35.0
Star goose berry	*Phyllanthus acidus*	71.0	25.6	68.3	35.8
Wood apple (Kaith)	*Feronia limonia syn. Limonia acidissima*	81.3	19.0	53.6	16.2
Bael	*Aegle marmelos*	76.3	23.6	51.5	21.5
Soursop	*Annona muricata*	53.3	27.3	49.6	39.7
Kare hannu	*Canthemun parviflorum*	0	0	0	0
CD (0.05)		7.93	6.55	6.94	5.42

nut and Ceylon olive. The low germination in these two species was due to presence of hard seed coat which does not allow imbibition of water and seed remain dormant for long period. The hard seed coat remains intact even after 5-6 months of sowing (Andrade *et al*.,2002). The seeds of yellow raspberry and Mysore raspberry took almost two months to germinate. Although there was no hard seed coat. But internal seed dormancy may be reason for delayed germination. The seed dormancy in Raspberry seed is earlier also reported by Rawat *et al*(2011). Similarly, the fresh seeds of kokum also sown dormancy and seed took almost 3 months to germinate. The seeds of *Garcinia gummigutta* also took longer period for germination.

The late germination in Kokum and gamboge may be due to rudimentary embryo (Richards, 2003). The seed of most of the other species started gemination within one month. Avocado, kaith, bilimbi, karonda were among first to initiate germination indicating not dormancy and physical barrier to hinder the seed germination process. Multiple seedling production from single seeds was observed in *Garcinia xanthochymus* and jamun which may be due to polyembryony and somatic embryony in these species (Richards, 2003). The final plant stand after 90 days of sowing was highest in Karonda (85.6 %) followed by jamun (85.0 %). The final stand was also higher in noni (78.2 %), *Garcinia xanthochymus* (75.3 %), star goose berry (68.3%).

There was lower stand in Molshree and Governor' splum. There was no plant stand in raspberries and all died before attending maturity. The higher seedling mortality in these species can be correlated with the seed size. The seeds of raspberries were very small and could not provide sufficient food to sustain the growth in initial stages (Table 1). The seedling height after six months of sowing was highest in carambola (57.7 cm). This was followed by Manila tamarind (47.7 cm), avocado (47.4 cm), noni(46.3 cm) and Surinam cherry(46.4 cm). Lowest seedling growth was recorded in *Garcinia xanthochymus* (15.2 cm), *Garcinia gummigutta* (16.4 cm) and *Garcinia indica* (16.5 cm). Feronia (16.2 cm) , Beal (21.5 cm) lasoda (23.4 cm) also recorded slow growth (Table 1).

The *Garcinia* species slow growth in general but it has been noticed that their growth and vigour in less humid region is slower than their natural habitat. Avocado, noni, manila tamarind and carambola are faster growing species and their seedling shows similar trends. Banik *et al* (2015) reported 26.67% germination in karonda while present result showed higher germination of Karonda. This may be due to the fact that fresh seeds were sown in present study. The germination percent in kokum and Other Garcinia species was higher as the fresh seed are sown. It is known that most of tropical trees species are recalcitrant type seed and they loose their viable rapidly (Malik *et al*., 2011). Sundriyal and Sundriyal (2001) found that all the species used in study had fairly good seed germination (70-100%) except for *Baccaurea sapida* (34-50%).

The shoot emergence in stem cutting was highest in mulberry (83.3 %). It was lowest in Yellow raspberry and Mysore raspberry with no shoot emergence. The shoot emergence was between 20 to 40 percent in other species. The time taken for shoot emergence ranged from 12.3 to 27.6 days. Governors plum's cutting took minimum 12.3 days to produce new shoot and carambola took highest (27.6 days). The survival of cutting after 90 days was highest (80 %) in mulberry. In other species, the survival was low as there was little root formation and growth and cuttings died after producing shoots. It was noticed more in Governors plum, carambola and Surinam cherry. The plant height after six months was highest in mulberry (57.2 cm) followed by Surinam cherry and West Indian. It was lowest in wax apple (27.2 cm; Table 2). Sundriyal and Sundriyal (2001) observed that stem sprouting and rooting varied significantly among species. They reported that there was no sprouting in *Machilus edulis* and *Baccaurea sapida* in any treatment as well as in control.

The raspberries and bael were multiplied through root suckers. The shoot emergence was highest in yellow raspberry. The shoot emergence was 30 percent in bael while there was no shoot emergence in Mysore raspberry. The final stand was higher (75 %) in yellow raspberry as compared to Bael (15 %; Table 3). The higher success rate in yellow raspberry be may due to production of vigourous and robust sucker. While the sucker of Mysore raspberry was smaller and less vigourous. This reflected in their success and survival. The bael roots produced lot of root suckers. The root suckers were vigourous. The plants with more number of roots survive better.

The day taken for emergence of roots were minimum in *Citrus hindsi* (23 days) and highest in natal plum (35 days). Carambola, bilimbi and canito failed to produce roots. Final rooted layers after 90 days were highest (80 %) in Governor's plum, Karonda, natal plum and *Citrus hindsi.* Surinam cherry and Barbados cherry showed 75 % and 60 % survival, respectively. The final stand of rooted layers after two months of planting in bags was highest in *Citrus hindsi* (65%), followed by natal plum (60%) and Surinam cherry (65 %). Lower final stand was recorded in Barbados cherry, Governor's plum and cherry (Table 4).The

Table 2.Multiplication of minor wild fruits through cuttings

Fruit	Botanical name	Shoot emergence (%)	Day to shoot emergence (day)	Survival (%) after 90 days	Plant height (cm) after 6 months
Himalayan yellow Raspberry	*Rubus ellipticus*	0	0	0	nil
Mysore Raspberry	*Rubus neveus*	0	0	0	nil
Karonda	*Carrisa carandas*	30.3	16.0	0	0
Governors' plum	*Flacourtia india*	30.6	12.3	1.0	34.5
Carambola	*Averhoa carambola*	35.3	27.6	0	0
West Indian Cherry	*Malpighia emarginata*	35.2	17.3	34.3	32.4
Surinam Cherry	*Eugenia uniflora*	25.0	16.0	2.0	46.4
Jamaica plum	*Spondias mombin*	25.2	17.3	21.5	43.5
Mulberry	*Moris alba*	83.3	14.1	80.0	57.2
Wax apple	*Syzygium samarangense*	41.0	24.0	16.3	27.2
CD (0.05)		4.33	3.32	2.85	4.53

Table 3.Multiplication of minor wild fruits through root suckers

Fruit	Botanical name	Shoot emergence (%)	Day to emergence	Final stand after 90days	Plant height (cm) after 6 months
Himalayan yellow Raspberry	*Rubus ellipticus*	75.0	29.0	75.0	34
Mysore Raspberry	*Rubusneveus*	0.0	0.0	0	0
Bael	*Aegle marmelos*	30.0	16.0	15.0	29

Table 4. Multiplication of minor wild fruits by air- layering

Fruit	Botanical name	Day to root emergence	Final rooted layers and after 90days	Final survival 2 month after planting	Plant height (cm) after 6 months
Governor's plum	*Flacourtia indica*	25	80.0	40.0	36.5
Karonda	*Carrissa carandas*	27	80.0	45.0	32.0
Natal plum	*Carrissa macrocarpa*	35	80.0	60.0	24.5
Surinam Cherry	*Eugenia uniflora*	24	75.0	55.0	36.8
Carambola	*Averhoa carambola*	0	0	0	0
Bilimbi	*Averhoa blimbi*	0	0	0	0
Canito	*Chrysophyllum cainito*	0	0	0	0
Barbados cherry	*Malpighia emarginata*	28	60.0	40.0	28.5
Kumquat	*Citrus hindsi*	23	80.0	65.0	34.5
CD (0.05)		2.73	7.15	6.97	4.54

lower establishment in some fruits may be due to less numbers of roots in layers. Ghosh *et al* (2010) found more success in layering in star gooseberry.

Cleft grafting was used to multiply avocado and. The day to start new bud was less (21 days) in avocado as compared to Feronia (31 days). The initial success was 90 percent in both the species while final stand was higher in Feronia (80 %) as compared to avocado (60%; Table 5).Cleft grafting is found successful in several fruit crops. Tripathi and Karunakaran (2020) found that the cleft grafting of avocado in September was most successful.

The study concluded that freshly harvested seeds of some species germinated rapidly. Seed germination took more time in some species due to presence of hard seed coat. The seedling growth was slow in some species when they were multiplied out of their

Table 5. Multiplication of minor wild fruits by grafting

Fruit	Botanical name	Success (%)	Day to emergence of new leaves	Final stand after 90 days	Plant height (cm) after 6 months
Avocado	*Persia americana*	90	21	60	36
Feronia	*Feronia limonia*	90	31	80	16

native climatic zones. The vegetative propagation in some species was found successful. Air layering was found successful in more number of species than other methods. The multiplication by stem cutting was found successful in some species but the shoot formation indicated that use of plant growth regulator may be helpful in the root formation and root growth. Thus more research works on vegetative propagation of these fruit species may be helpful in popularization of elite lines of these fruits.

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In-vitro regeneration in long-day garlic (*Allium sativum*)

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ABSTRACT

The cloves of garlic (*Allium sativum* L.) cultivar Mukteshwar Local, after disinfection, were sprouted under *in-vitro* condition (85.00 % sprouting) on MS medium containing 2 mg/l GA^3. The cloves were soaked in 100 ppm GA^3 solution for 24 hr. Maximum number of shoot buds (7.0) was recorded in treatment containing MS + 4.0 ppm BAP + 1.0 ppm NAA. Among different treatments for shoot multiplication, treatment MS+5.0 ppm BAP+ 1.0 ppm KIN + 0.5 ppm GA^3 was the best. The number of shoots also varied with the level of sugar, light intensity and, light and dark cycle on shoot multiplication. They multiplied best in 30 g/l sucrose, 5000 lux light intensity and 16:8 hr of light and dark cycle. The developed protocol may be used for mass multiplication of garlic cultivars as well as regeneration of genetically transformed cell/ tissue.

Cultivated garlic (*Allium sativum* L.) is a sexually sterile crop and exclusively propagated vegetatively. The propagation rate of garlic in field is approximately 5-10% per year. Thus, it takes many years to build up the required material for commercial cultivation of a new variety. There is no denying in the fact that after traditional method of propagation, micropropagation is next step for rapid multiplication of desired genotype. Therefore, *in-vitro* technique, micropropagation, offers great potential to deliver a large quantity of disease-free and true- to- type, healthy stock in a short time.

MATERIALS AND METHODS

The garlic cultivar, Mukteshwar Local, was taken for study at the Central Institute of Temperate Horticulture (ICAR), Regional Station Mukteshwar, Nainital, Uttarakhand, India. Cloves were taken as a source of explants. These were washed with tween-20 and then surface sterilized with 0.1 % $HgCl_2$ for 2 min. After that explant were washed thoroughly with sterile distilled water. The sterilized explants were soaked in distilled water/various concentration of GA_3 for different time period. Then explants were inoculated on MS basal medium containing 3% sucrose supplemented with or without different concentration of GA_3 for *in-vitro* sprouting of cloves. The medium is gelled with 8 g/l agar and pH was adjusted to 5.8 prior to autoclaving at 121°C for 15 min. Observations were recorded on percentage sprouting and days taken to sprout.

The sprouted cloves were inoculated in MS medium supplemented with different concentration of BAP and NAA. Observations were recorded for number of shoot-bud induction and regeneration frequency. The regenerated shoots were then subcultured onto multiplication medium supplemented with different growth regulators. Observations on average number of shoots per culture and mean shoot length were recorded after four weeks of culture. Effect of sucrose level, light intensity and photoperiod on shoot multiplication were recorded.

The factorial completely randomized design (CRD) with three replications was followed. Fifteen samples were maintained in each replication. Percentage data were subjected to Arc Sin transformation before analysis. The analyses of data were done by using SPSS 13.0 software.

RESULTS AND DISCUSSION

Based on sprouting per cent and days required for sprouting, medium and pre-sterilization treatments

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were standardized. The sprouting per cent was higher (85.00%) on MS medium containing 2 mg/l GA3 (M2) when cloves were soaked in 100 mg/l GA3 solution for 24 hr than on MS medium devoid of GA^3 which had 65% sprouting (Table 1). Days required for sprouting was lower in medium containing 2 mg/l GA3 (M2) for all the cultivars than in medium which was devoid of GA3. Days taken for sprouting were minimum (30.0) in medium MS+ 2 ppm GA3 + soaking of clove for 24 hr in 100 ppm GA^3 solution. With the increase/addition of GA^3 either in medium or in solution for pre-treatment increased sprouting considerably.

The findings indicate that gibberellic acid promotes seed germination/sprouting (Salisbury and Ross, 1995) through one or several possible steps, viz. activation of vegetative growth of the embryo, weakening of a growth constraining endosperm layer surrounding embryos and the mobilization of stored food reserve of the endosperm (Taiz and Zeiger, 2002). Enhanced sprouting by GA^3 treatment might also be due to hydrolysation of reserved food material and activation of enzymes which help in germination (Salisbury and Ross, 1995).

Difference was observed among treatments for number of shoot buds per explant. With the increase in concentration of BAP, number of shoot buds increased significantly but at higher concentration (above 4.0ppm BAP), it decreased. Maximum number of shoot bud (7.0) was recorded in treatment containing MS+4.0 ppm BAP+1.0ppm NAA (T^2) and minimum (1.75) was recorded in medium containing MS+7.0 ppm BAP+1.0ppm NAA (T^5). In MS medium containing 4.0 ppm BAP+1.0 ppm NAA, number of days required for shoot bud induction was low, regeneration frequency was maximum and more number of shoot buds was recorded (Table 2, Fig 1). BAP is reported to be the most responsive cytokinin in shoot bud induction in garlic (Haque *et al.* (2003). Cytokinin such as BAP is

Table: 1 Effect of different treatments on sprouting of garlic clove under *in-vitro* conditions

Treatment	Treatment details	Sprouting (%)	Days taken to sprouting
T_1	MS + soaking of clove for 24 hr in distilled water	50.00 (45.00)^a	48.22^d
T_2	MS + soaking of clove for 24 hr in 50 ppm GA_3 solution	62.50 (52.24)^{ab}	42.33^{bc}
T_3	MS + soaking of clove for 24 hr in 100 ppm GA_3 solution	65.00 (53.73)^{ab}	37.45^b
T_4	MS+ 2 ppm GA_3 + soaking of clove for 24 hr in distilled water	58.00 (49.60)^{ab}	45.32^{cd}
T_5	MS+ 2 ppm GA_3 + soaking of clove for 24 hr in 50 ppm GA_3 solution	68.00 (55.55)^b	38.51^b
T_6	MS+ 2 ppm GA_3 + soaking of clove for 24 hr in 100 ppm GA_3 solution	85.00 (67.21)^c	30.24^a
		SEm± : 2.68	1.68
		SEd : 3.79	2.37
		$CD_{0.05}$: 8.26	5.17

Data within parentheses are ArcSign transformed value. Means for groups in homogeneous subsets are displayed with same alphabets i.e. treatments denoted with same alphabets are not significant at 5% probability using DMRT.

Table: 2 Effect of different treatments on *in vitro* shoot bud induction on clove explant of garlic

Treatment	Treatment details	Number of shoot buds per explant	Number of days taken for shoot bud induction
T_1	MS+3.0 ppm BAP+1.0ppm NAA	2.00^a	58.25^{cd}
T_2	MS+4.0 ppm BAP+1.0ppm NAA	7.00^d	45.20^a
T_3	MS+5.0 ppm BAP+1.0ppm NAA	6.00^c	50.15^{ab}
T_4	MS+6.0 ppm BAP+1.0ppm NAA	4.50^b	55.33^{bc}
T_5	MS+7.0 ppm BAP+1.0ppm NAA	1.75^a	62.25^d
		SEm± : 0.19	2.05
		SEd : 0.26	2.90
		$CD_{0.05}$: 0.58	6.44

Means for groups in homogeneous subsets are displayed with same alphabets, i.e. treatments denoted with same alphabets are not significant at 5% probability using DMRT.

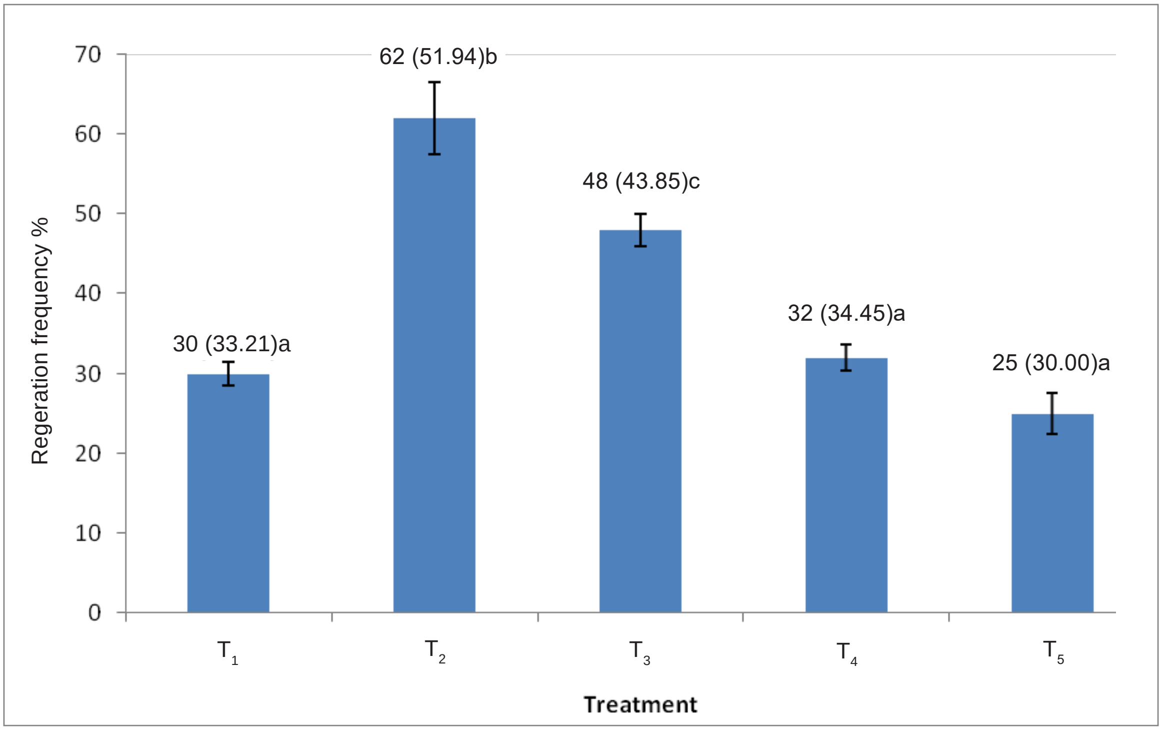

Fig 1. Regeneration frequency of explant in different treatments (T_1: MS+3.0 ppm BAP+1.0ppm NAA; T_2: MS+4.0 ppm BAP+1.0ppm NAA; T_3: MS+5.0 ppm BAP+1.0ppm NAA; T_4: MS+6.0 ppm BAP+1.0ppm NAA; T_5: MS+7.0 ppm BAP+1.0ppm NAA). (Data within parenthesis are ArcSign transformed value. Means for groups in homogeneous subsets are displayed with same alphabets i.e. treatments denoted with same alphabets are not significant at 5% probability using DMRT. $CD_{0.05}$: 4.86; Error bar shows Standard deviation)

concerned with cell division, modification of apical dominance and shoot bud differentiation. In tissue culture media BAP is incorporated mainly for cell division and differentiation of shoot bud from organ or tissue (Bhojwani and Razdan, 1996). The role of cytokinin in in vitro establishment and multilplication of onion explant is also been reported (Passi *et al.*, 2018).

Number of shoots varied in different treatments with maximum (7.0) in MS+5.0 ppm BAP+1.0ppm KIN+0.5ppm GA3 where shoot length was also maximum (6.5 cm) (Fig. 2). No shoot bud was developed in medium containing 1.0 or 2.0 ppm BAP (T_1 and T_2). Addition of GA3 increased number of shoots. This may be due to elongation of small buds, which were not able to elongate without GA3. Increase in BAP concentration from 5.0 mg/l onward decreased the number of shoots. It was also observed that with the increase in the cytokinin concentration the shoot elongation was not affected as it was induced by the increase in GA3 level. Gibberellins are known to increase shoot length by inducing cell elongation and division (Rizza et al., 2017; Camara *et al.*, 2018; Suarez Padrón *et al.*, 2020).

The number of shoots varied with level of sucrose added to medium. With the increase in sucrose level from 30 to 40 g/l, number of shoots/cultures increased significantly but decreased thereafter. The maximum number of shoots (7.5) was recorded in medium containing 40 g/l of sucrose and minimum number of shoots (6.0) was found in treatment containing 60 g/l of sucrose. In tissue culture experiments, generally 2-4% sucrose (w/v) is usually optimum (George, 1993). Varying sucrose level have often given either increase or decrease in shoot multiplication rate and accordingly, it can be seen that the *in vitro* requirement of sucrose varies greatly with morphogenetic stage (Damino *et al.*, 1987).

The maximum number of shoots (7.0) were recorded at 5000 lux light intensity level and minimum (4.0) at 3000 lux. Shoot proliferation is generally influenced by light intensity. The optimum light intensity varies with plant species. Different morphogenetic processes require specific light intensity and both axillary and adventitious shoot bud proliferation are higher with increased light intensity (Lazzeri and Dunwell, 1986). There was difference between treatments with regard to number of shoots.

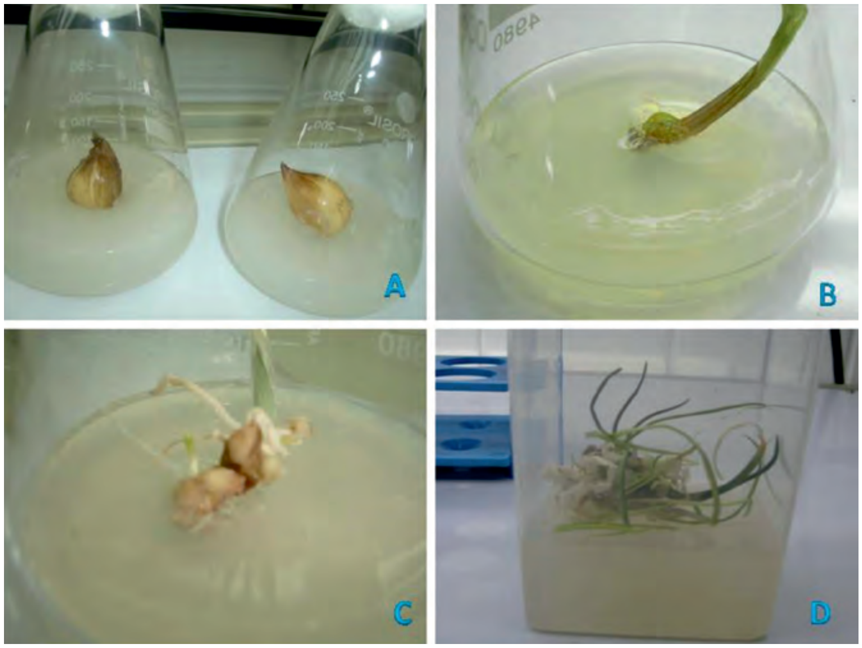

Fig. 2. A: *In vitro* culture establishment of garlic clove explant after treatment with s 0.1 % $HgCl_2$ for 2.0 minutes. B: sprouting of garlic clove on MS medium containing 2 mg/l GA3 and cloves were soaked in 100 mg/l GA3 solution for 24 hr. C: *In vitro* shoot bud induction on MS+4.0 ppm BAP+1.0ppm NAA. D: *In vitro* shoot multiplication on MS+5.0 ppm BAP+1.0ppm KIN+0.5ppm GA_3

Maximum number of shoots (7.0) were recorded when cultures were provided with 16:8 hr light and dark cycle and minimum (2.5) in 24:0 hr of light and dark cycle.

With increase or decrease in light period, number of shoots decreased. Shoot morphogenesis is generally stimulated by light and photoperiod coupled with total irradiance which has profound effect. In some plants, shoot proliferation is enhanced by high irradiation during stage-II (Hammerschag, 1978). Earlier, Haramaki (1971) suggested the use of light maintained at 3000-1000 lux for higher shoot proliferation in *Sinniongia*. Optimum light is also known to improve the quality of microshoots (Mcgranachau *et al*., 1987).

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Contrast analysis recommends flame sterilization for surface depuration in coconut (*Cocos nucifera*) meristem culture

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ABSTRACT

Five different surface sterilization treatments were carried out along with the control treatment for obtaining sterile explants in coconut (*Cocos nucifera* L.) at ICAR-CPCRI, Kasaragod, Kerala, during 2019-20. The treatments included different combinations of mercuric chloride, sodium hypochoride, tween-20 and flame sterilization. While 100% of the meristem got contaminated in the control treatment which was surface sterilization with 0.1% mercuric chloride (HgCl2) treatment for 3 minutes, followed by 20% sodium hypochlorite (NaOCl) treatment for 10 minutes, only 26.67% contamination was found in the treatment five which included 20% sodium hypochlorite with 250 μL tween 20 treatment for 10 minutes followed by tap water wash for 30 minutes, 0.1% mercuric chloride treatment for 3 minutes, 20% sodium hypochlorite treatment for 5 minutes and finally flame sterilization before chopping and inoculating the meristem. Contrast analysis was carried out for flame sterilization and difference between the means of two groups was statistically significant in both bacteria and fungi contamination revealing that flame sterilization has resulted in reduction of contamination.

Key Words: Surface sterilization, Meristematic shoot, Contamination, Flame sterilization

Coconut (*Cocos nucifera* L.) is an important perennial plantation crop of tropics providing livelihood security for millions of people round the worldwide. India's vegetable oil demand is growing and by 2030 it is expected to be around 34 million tonnes (Manorama *et al.*, 2019) and furthermore the demand for coconut oil is also increasing. Standardization of micro propagation methods is very important in coconut as no true-to-type vegetative means of propagation is available. Obtaining quality and uniform planting material in bulk quantities is not possible with currently used conventional method of seed propagation. Initial attempts were made for micropropagation of coconut from 1980s. Since then, different explant tissues such as meristems, endosperm, leaves, roots, zygotic embryos, ovary, immature inflorescence and plumule were used (Nguyen *et al*., 2015). Recently meristems are used as explants in many crops (Murkute, 2020). Surface sterilization removes bacteria and other contaminants from surfaces, but those inhabiting inner tissues and organs are usually not affected by these sterilants (Orlikowska *et al*., 2017). However, *in vitro* culture establishment from field grown plant are more prone to contamination and also is the most important reason for losses during *in vitro* culture of plant (Tiwari *et al*., 2012). Microbial contaminants, viz. viruses, bacteria, yeast and fungi are found on surface as well as inside the plant body (Omamor *et al*., 2007). Since coconut is a recalcitrant crop culture requires a long duration of time for regeneration. The cultures are maintained in a sterile environment throughout and thorough surface sterilization is done. Compared to the plumular and inflorescence explant, meristem explants are more susceptible to contamination as the seedlings were collected from open field condition. Hence different surface sterilization methods were tried to obtain sterile explant for meristem culture in coconut.

MATERIALS AND METHODS

Germinated coconuts with 20-25 cm long shoots, with or without leaves were collected from ICAR-CPCRI, Kasaragod, during November 2019 - February 2020 to carry out the experiment. All these coconuts had emerged roots attached to the husk. Initially all the shoots were

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separated from the husk and shell. The outer leaves were removed and the shoots were cut short to a height of 15 cm. The basal portion along with roots was trimmed off. Before initiating the treatments, all the shoots were washed thoroughly under running tap water for 20 minutes and then material was treated with a fungicide solution containing Bavistin 2 g/L for 1 hour followed by sterile distilled water wash for three times.

The experiment was laid out in a completely randomised design with 6 treatments including the control replicated thrice. Each experimental unit comprised five shoots (Table 1). The control treatment was surface sterilization with 0.1% mercuric chloride treatment for 3 minutes followed by 20% sodium hypochlorite treatment for 10 minutes (this is the usual procedure followed for decontamination of coconut embryonic and plumular explant material).

The five different treatments were as follows: (1) 20% sodium hypochlorite treatment for 10 minutes + 0.1% mercuric chloride treatment for 3 minutes + 20% sodium hypochlorite treatment for 5 minutes; (2) 20% sodium hypochlorite with 250 μL tween-20 treatment for 10 minutes + open tap water wash for 30 minutes + 0.1% mercuric chloride treatment for 3 minutes + 20% sodium hypochlorite treatment for 5 minutes; (3) 0.1% mercuric chloride treatment for 3 minutes, followed by 20% sodium hypochlorite treatment for 10 minutes + flame sterilization before chopping the meristem; (4) 20% sodium hypochlorite treatment for 10 minutes + 0.1% mercuric chloride treatment for 3 minutes + 20% sodium hypochlorite treatment for 5 minutes + flame sterilization before chopping the meristem and (5) 20% sodium hypochlorite with 250 μL tween-20 treatment for 10 minutes + tap water wash for 30 minutes + 0.1% mercuric chloride treatment for 3 minutes + 20% sodium hypochlorite treatment for 5 minutes + flame sterilization before chopping the meristem. The initial hypochlorite treatment as well as mercuric chloride treatment was done in normal room condition, while second hypochlorite treatment and flame sterilization were carried out inside Laminar Air Flow Chamber.

Flame sterilization was carried out by dipping the meristem in 70% ethyl alcohol and swiftly moving the meristem along the flames 3-4 times till the flame subsides. The outer sheaths were removed after flame sterilization, meristem was chopped to 1mm sized bits and inoculated in meristem culture media. Observations on presence of contamination due to bacteria and fungi were noted and percentage of contamination for each treatment was computed. As the explant is subjected to physical and chemical stress, viability of explants after inoculation was confirmed by Tetrazolium test.

The test is based on the principal that living tissues, which respire, are capable of reducing a colourless chemical 2,3,5 triphenyl tetrazolium chloride or bromide) into a red coloured compound formazen by H transfer reactions catalysed by the enzyme debydrogenases. Formazan being non-diffusable stains the living tissues red. Thus, the living parts of a viable seed should be stained red when incubated in the solution of this chemical (Lopez Del Egido *et al.*, 2017). Analysis was carried out for observed treatments after arc sine transformation of percentage data using SAS Ver. 9.3.

RESULTS AND DISCUSSION

All the treated coconut meristem were chopped and inoculated to Petri plates with meristem culture media. Observations on bacterial and fungal contaminations were taken daily for one month till the next subculture. Here the explants are collected from field conditions stringent sanitation treatments were implemented (Orlikowska *et al.*, 2017). Surface sterilization of the explants involves the use of fungicides, bactericides, as well as heat treatment followed by the isolation and culture of true meristems (Cassells, 2012). Analysis of variance of

Table 1. Different sterilization procedural steps followed for treatments (T_1 to T_5) to reduce the contamination in coconut meristem cultures under *in vitro*

Treatment	Running tap water wash (20 min)	Immersion in fungicide Bavistin 2 g/L (1hour)	Initial 20% NaOCl treatment (10 min)	Tween-20 (250μL)	0.1% $HgCl_2$ (3 min)	Second 20% NaOCl wash (5 min)	Flame sterilization
T_1	+	+	+	-	+	+	-
T_2	+	+	+	+	+	+	-
T_3	+	+	+	-	+	-	+
T_4	+	+	+	-	+	+	+
T_5	+	+	+	+	+	+	+
Control	+	+		-	+	-	-

arc sine transformed data on per cent contamination was carried out separately for bacteria and fungi. F-statistics and corresponding probability values indicates that at least one treatment is significantly different from others in case of both bacteria (F= 10.7, p=<0.001) and fungi (F= 16.78, p= <0.001). Results of ANOVA and post hoc tests are presented in Table 2.

Table 2. Comparison of treatment means using ANOVA and post hoc tests

Treatment	Treatment of 'bacteria	Treatment of fungus'
T^1	50.75^{AB}	63.74^{AB}
T^2	46.90^{BC}	38.84^{CD}
T^3	51.12^{AB}	50.75^{BC}
T^4	30.07^{BC}	35.00^{CD}
T^5	22.01^{C}	22.01^{D}
Mean	46.32	47.90
C	77.05^{A}	77.05^{A}
CV (%)	21.94	17.78
SE(d)	8.299	6.951
Tukey's HSD at 5%	27.876	23.349

Results reveal that T_2, T_4 and T_5 have significantly lower bacterial contamination as compared to the control whereas fungal contamination was significantly lower in T_2, T_3, T_4 and T_5 as compared to the control. Overall, treatment T_5, the least contaminated is significantly different from T_1 and T_3. However, there is no evidence of significant difference from T_2 and T_4. Subsequently, the hypothesis of non-significant difference among treatments with flame sterilization as compared to treatments 'without it' was tested employing contrast analysis. Here, the null hypothesis: [Mean of (C, T_1, T_2) – Mean of (T_3, T_4, T_5)] = 0 was tested.

Difference between the means of two groups is statistically significant in both bacterial and fungal contamination revealing that the flame sterilization has resulted in reduction in contamination. Usually, significantly lower explant or initial contamination is found in donor plants growing in the greenhouse (Leifert *et al*., 1994), but here the seedlings are collected from field condition and that may be the reason why the control treatment could not prevent the contamination in the cultures. Similarly, Nurul *et al.* (2012) has stated that combination of fungicide and mercuric chloride reduced contamination in leaf and seed explants but in our experiment since the explants are plantlets collected from field condition; additional treatments are necessary for obtaining a contamination free explant. Calcium chloride, mercuric chloride and detergents have been reported to be efficient surface sterilants in shoot meristems in many of the plant species (Jan *et al*., 2013; Sharuti *et al*., 2011; Tyagi *et al*., 2011).

In our trials, a second treatment of the explants with sodium hypochlorite gave a higher success rate (T_4 and T_5) when compared to treatment with initial sodium hypochlorite treatment followed by mercuric chloride treatment. These results are in agreement with that of Leifert *et al.,* (1994, which may be attributed to the better penetration of sodium hypochlorite. Flame sterilization was used for surface sterilization for immature leaf and inflorescence explants in arecanut. Even though heat treatment can sometimes kill the cells of the explant, the treatment is done with swift motion of the flamed explant, where the time may not be enough to kill the plant cells. Again, the inoculated meristem portion is obtained after removing the outer surface sterilized leaf axils of the shoot, where the heat is not yet penetrated. The Tetrazolium Chloride test has shown that the meristems were viable as the meristem colour changed to red when the meristem pieces were kept overnight in Tetrazolium Chloride solution.

CONCLUSION

Surface sterilization of explants is important because the cultures are to be maintained contamination free for years to obtain the plantlets. Apart from

Table 3. Contrast analysis for flame sterilization

Parameter	Variance	Contrast	Value of contrast	Std. Error	t	df	Sig. (2-tailed)
Bacteria	Assume equal variances	1	-71.49	14.37	-4.97	12	.000
	Does not assume equal variances	1	-71.49	14.37	-4.97	4.74	.005
Fungus	Assume equal variances	1	-71.87	12.04	-5.97	12	.000
	Does not assume equal variances	1	-71.87	12.04	-5.97	6.51	.001

fungicide and mercuric chloride treatments, initial and final treatment with sodium hypochlorite as well as flame sterilization can reduce the surface contaminants considerably in meristematic explants of coconut.

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Evaluation of gladiolus (*Gladiolus grandiflorus*) cultivars for performance and correlation in vegetative, floral and multiplication characters under paired- row system

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ABSTRACT

The vegetative, floral and corm characters of seven gladiolus cultivars (Friendship, Candyman, White Prosperity, Novalux, Priscilla, Summer Sunshine and Dull Queen) were evaluated under paired-row system to study the performance of cultivars and to find suitable cultivar for cut flower production. The vegetative performance of cultivars Novalux, White Prosperity and Candyman were comparatively better with early shoot emergence in 5.566 days (White Prosperity), maximum plant height of 160.62 cm (White Prosperity), maximum shoots per corm of 1.867 (Novalux) and highest number of leaves (8.33) in cultivar Candyman. The cultivar Priscilla performed superiorly in some major floral characters such as spikes per corm (1.733), early spiking (65.33 days) and vase life (10.73 days). While cultivar White Prosperity was also better performer in some critical floral characters such as florets per spike (16.400), rachis (81.827 cm), florets open at once (6.733), spike length (103.587 cm) and size of florets (10.673 cm). In case of multiplication property, cultivar Dull Queen produced highest number of corms (2.400) and cormels (47.267) while corm size (9.060 cm) and weight (212.133 g) was highest in Novalux. The outcome of the experiment indicated that cultivars White Prosperity, Priscilla and Novalux were best suited under paired-row system for cut flower production and corm and cormel production.

Key Words: Correlation, Paired-row, Floral , Corms, Cormels, Multiplication

Gladiolus (*Gladiolus grandiflorus* L.), is a remunerative crop to farmers due to its easy cultivation practices and short life cycle (Rashmi and Chandrashekhar, 2016). It belongs to Iridaceae family and sub-family Ixoidaceae with around 300 species. The chromosome number is 2n=30-120 with basic chromosome number, n=15 (Kumar, 2018). It prefers temperate and subtropical climate which makes it advantageous for cultivation in Assam. Varieties with novel colours and new adaptive characters are developed every year. These varieties might show varied responses in paired-row system. Hence varietal evaluation under paired-row system was necessary to identify suitable varieties under paired-row system. Therefore an experiment was conducted to identify suitable cultivars for cut flower and corm production under paired-row system. The correlation between different characters and yield of corm and spike was also studied.

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MATERIALS AND METHODS

The experiment was conducted at Assam Agricultural University, during 2019-2020. The experimental site is located at 26°45′ N latitude and 94°12′ E longitude with an altitude of 87 m above sea-level. Randomised block design (RBD) was used for designing the experiment with seven treatments and three replications. Twenty-one plots of size 1.5m x 1.2m were laid to randomly, accommodating seven treatments. Seven cultivars, namely Friendship, Candyman, White Prosperity, Novalux, Priscilla, Summer Sunshine and Dull Queen, were examined under paired-row system. Spacing is the major factor in paired-row system which was taken as 10cm within the pairs while between two paired-rows 40cm spacing was taken to accommodate thirty corms.

Recommended package of practices was followed. The spikes were harvested with the opening of basal floret and recorded the vase-life in 4% sucrose solution. Data on several vegetative, floral and corm characters were recorded from five representative plants from each plot at 15 days interval and subjected to statistical analysis to test the significance of treatments using ANOVA (Panse and Sukhatme, 1985). Correlation studies were carried out to estimate the effect of vegetative and floral characters on yield of spikes and corms by using the method suggested by Karim *et al*. (2014). The significance of correlation was tested against 'r' value from Fisher and Yates table.

RESULTS AND DISCUSSION

There was wide variation among treatments. The days for shoot emergence spread from 5.566 days in White Prosperity to 7.162 days in Summer Sunshine. While number of shoots/corm ranged from 1.200 in Summer Sunshine to 1.867 in Novalux. With uniform climatic condition and package of practices, these variations might have arisen due to variation in genetic constitution of cultivars and endogenous promoters and inhibitors of growth. Such variations were also reported by Kadam *et al.* (2014) and Naresh *et al*. (2015). Cultivar White Prosperity recorded maximum height of 160.62 cm at maturity, while Dull Queen showed minimum height (130.077cm).

The number of leaves also differed significantly among cultivars with Candyman showing highest number of leaves (8.33). The trend in leaf length ranged from 57.993 cm (Priscilla) to 50.013 cm (Summer Sunshine). The variations in those characters were mostly due to divergent genetic constitution and also might have interdependence on each other. White Prosperity and Candyman which produced good number of leaves with better length also recorded superior plant height. This might be due to increase in overall photosynthetic production in those cultivars which lead to higher growth. Similar trend of variations were also experienced by Chourasia *et al*. (2015) and Kumar (2017).

The early spike emergence was recorded from 65.33 days in Priscilla to 82.80 days in Summer Sunshine. Cultivars, White Prosperity and Friendship, also recorded as early spiking variety with 71.700 days and 71.600 days respectively. Cultivars, White Prosperity, Friendship and Priscilla recording better vegetative growth might have facilitated early completion of vegetative phase to enter reproductive stage (Table 1). Shaukat *et al*. (2012) and Singh *et al*. (2018) observed similar duration in spike emergence. Spikes/corm might have a direct relationship with shoots/corm, ranging from 1.733 in Priscilla to 1.067 in Summer Sunshine.

However production of blind shoots might have also created variation in spikes/corm. White Prosperity recorded superiority in spike length (103.587 cm) and rachis length (81.827 cm), while Candyman (72.607 cm) and Friendship (51.260 cm) recorded lowest spike length and rachis length respectively (Chourasia *et al*., 2015 and Swaroop *et al*., 2019). The positive correlation between spike length and various vegetative characters such as plant height, rachis length and florets/spike was shown by Kumar *et al*. (2015) and Choudhury *et al*. (2011). Cultivars White Prosperity, Priscilla producing higher rachis length also produced higher number of florets of 16.400 and 16.000 respectively and also larger size florets of 10.673 cm and 9.640 cm respectively.

Inter nodal length of spikes might had also played role in variation of floret number. Similar findings were confirmed by Sankari *et al*. (2012) and Choudhury *et al*. (2011). Vase-life ranged from 9.067 days in Friendship cultivar to 13 days in Priscilla cultivar and such differences might had resulted from unique genetic make-up of each cultivars and their ability to accumulate carbohydrate. The variation was in agreement with Lepcha *et al*. (2007) and Kumar (2017). Higher marketable yield was recorded from Novalux (38.333), Priscilla (36.667) and Candyman (36.000) which might had correlated with spikes/corm. However, weak spikes with less market acceptance had also contributed towards variation in the character.

The corm and cormel characters showed significant variance among cultivars. Weight of individual corm spanned from 29.600 g in Dull Queen to 212.133 g in Novalux cultivar. The cultivars Novalux and Candyman producing higher weight corms might have supplemented towards bigger size corms of 9.060 cm and 7.340 cm respectively (Table 1). Similar variations in weight and size of corms were confirmed by Bhatt *et al.* (2015). Number of corms and cormels were influenced by size of mother corms, food reserve partitioning, genetic make-up and initial growth performance (Chourasia *et al*., 2015). Cultivar Dull Queen exhibited highest number of corms (2.400) which was at par with Priscilla (2.133) and Summer Sunshine (1.933). The range of cormel production was from 14.600 in Friendship cultivar to 47.267 in Dull Queen cultivar. The results confirm to those of Bhatt *et al*. (2015) and Kadam *et al*. (2014).

Correlation studies depicts the inter dependability or association of various parameters and helps in selecting genotypes with better quality and high yield characters. The plant height showed significant positive correlation with important floral characters such as spike length (r_p =0.868, r_g =0.915), rachis length (r_p =0.736, r_g =0.758), size of florets (r_p = 0.773, r_g =0.799) and corm characters such as size of corms (r_p = 0.445, r_g =0.462) at both phenotypic and genotypic level. Length of leaves also showed significant positive correlation with marketable yield (r_g =0.576), spikes per corm (r_g =0.913), rachis length (r_g =0.566), spike length (r_g

Table 1. Performance of gladiolus cultivars on floral characteristics

Treatment	Emergence of spike (days)	Spikes per corm planted	Spike length (cm)	Rachis length (cm)	Florets per spike	Size of florets (cm)	Vase life in sucrose (days)	Marketable Yield of spikes per plot
Friendship	71.600	1.133	78.813	51.260	15.067	8.860	9.067	29.333
Candyman	79.733	1.533	72.607	53.893	13.400	8.813	10.333	36.000
White Prosperity	71.700	1.133	103.587	81.827	16.400	10.673	10.733	29.333
Novalux	77.400	1.467	90.740	67.787	13.467	9.473	12.000	38.333
Priscilla	65.333	1.733	81.067	63.293	16.000	9.640	13.00	36.667
Summer Sunshine	82.800	1.067	74.953	56.580	11.400	8.793	9.667	28.000
Dull Queen	76.433	1.200	68.373	53.187	13.067	8.373	10.733	29.333
S. Ed. (±)	1.433	0.103	2.060	1.449	0.182	0.072	0.122	1.361
CD (0.05)	3.156	0.227	4.538	3.192	0.400	0.158	0.268	2.998

=0.565), florets per spike (r_g =0.954), size of florets (r_g =0.812). The results indicated that cultivar with better vegetative performance resulted in high yield and quality flowers.

The days to spike emergence negatively correlated with parameters like size of florets (r_p = -0.487, r_g = -0.504) and number of florets (r_p = -0.866, r_g = -0.920) which indicated early spike emergence resulted in higher floret number and larger size floret. Spike and rachis length have recorded significant positive correlation with florets per spike (r_p = 0.598, r_g =0.618 and r_p = 0.540, r_g =0.548) and size of florets (r_p = 0.932, r_g =0.955 and r_p = 0.942, r_g = 0.958). Marketable yield exhibited positive association with spikes per corm (r_p = 0.833, r_g =0.955), shoots per corm (r_p = 0.608, r_g=0.768), weight of corms (r_p = 0.645, r_g =0.693) and size of corms (r_p = 0.650, r_g=0.773). The size of corms showed significant positive association with plant height (r_p = 0.445, r_g =0.462), marketable yield (r_p = 0.650, r_g =0.773) and weight of corms (r_p =0.780, r_g =0.798).

However negative association was found between size of corm and number of corms per corm planted (r_p = -0.584, r_g = -0.715) indicating high partitioning of food reserve in corms lead to smaller size corms. Similar associations were recorded by Amrutha (2012) and Verty *et al*. (2017). Thus, Priscilla, White Prosperity and Novalux could be selected as suitable cultivars for cut flower and corm production under paired-row system.

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Effect of foliar spraying of micronutrients on growth and yield of potato (*Solanum tuberosum*)

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ABSTRACT

The experiment was conducted to find out the effect of foliar spraying of micronutrient on growth and yield of potato (*Solanum tuberosum* L.) during 2019-20 at Vegetable Research Farm, Department of Horticulture, BHU, Varanasi. The experiment was laid out in a randomised block design with 3 replications having 9 treatments. The treatments were T_1 (control), T_2 (B-20 (boron) @ 0.06%), T_3(B-20 (boron) @ 0.09%), T_4(zinc sulphate @ 0.03%), T_5 (zinc sulphate @ 0.05%), T_6 (B-20 (boron) @ 0.06% + zinc sulphate @ 0.03%) T_7 (B-20 (boron) @ 0.06% + zinc sulphate @ 0.05%), T_8 (B-20 (boron) @ 0.09% + zinc sulphate @ 0.03%) and T_9 (B-20 (boron) @ 0.09% + zinc sulphate @ 0.05%). T_9 (B-20 (boron) @ 0.09% + zinc sulphate @ 0.05%) was found to be the best for all the growth and yield traits except for number of leaves in that T_3 (B-20 (boron) @ 0.09%) was recorded with highest value, for the rest trait followed by T_7 (B-20 (boron) @ 0.06% + zinc sulphate @ 0.05%) and T_8 (B-20 (boron) @ 0.09% + zinc sulphate @ 0.03%), while the least value was observed in T_1 (control) that was sprayed with water.

Key Words: Boron, Growth, Zinc sulphate, Micronutrients, Treatment, Yield

Potato (*Solanum tuberosum* L.) is an annual plant of nightshade family (Solanaceae). Potato cultivated in intensive condition has huge demand of micronutrients. The B application with essential major nutrients plays a good role in improving its yield (EI-Dissoky and Abdel-Kadar, 2013). Zinc plays a very crucial part in improving quality and production of potato tubers. Deficiency symptoms of boron in potatoes are mostly observed on shoot, with stunted growth with shorter internodes and curling of leaves are found. Deficiency of Zn is seen as a chlorosis, in the interveinal place of new leaves. Keeping in view, an experiment was conducted.

MATERIALS AND METHODS

The experiment was conducted at Department of Horticulture, Institute of Agricultural Sciences, BHU, Varanasi, during 2019 -20. The experiment was laid out in the randomized block design with nine treatment replicated thrice. Planting was done on 16 November 2019. Row- to-row distance of 60 cm and plant - to- plant distance of 15 cm were kept. There were 20 plants/ row in 5 rows. Potato Kufri Jyoti was used. The treatment were T_1 (control), T_2 (B-20 (boron) @ 0.06%), T_3 (B-20 (boron) @ 0.09%), T_4 (zinc sulphate @ 0.03%), T_5 (zinc sulphate @ 0.05%), T_6 (B-20 (boron) @ 0.06% + zinc sulphate @ 0.03%) T_7 (B-20 (boron) @ 0.06% + zinc sulphate @ 0.05%), T_8 (B-20 (boron) @ 0.09% + zinc sulphate @ 0.03%) and T_9 (B-20 (boron) @ 0.09% + zinc sulphate @ 0.05%). Foliar application of micronutrient was done at 30and 45 DAS. The data were record on height of plants , number of leaves, plant stand count, number of haulms, number of tubers/plants, weight of tubers/plant, length and width of tubers, tuber yield/plot(kg), tuber yield(q/ha), marketable tuber yield (q/ha) and it was statisacally analysed.

RESULTS AND DISCUSSION

The maximum height (94.64 cm) was in treatment T_9 foliar application of B- 20 (boron) @ 0.09% + zinc sulphate @ 0.05%, followed by T_7 (94.47 cm) and T_8 (93.62 cm), while the lowest height (88.63 cm) was recorded in treatment T_1 - untreated control. Zn and B enhance the cell division and also endol acetic acid which increases the height. These results are in conformity with the finding of Islam *et al*. (2014); El-Dissoky and Abdel -Kader (2013); Uikey *et al*. (2017)

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Significant effect of foliar application was observed. The maximum number of leaves (77.66) was recorded in treatment T_3 foliar application of B- 20 (boron) @ 0.09%, followed by T_2 (76.00) and T_9 (75.66), whereas minimum number of leaves (70.00) / plant was observed in treatment T_1- untreated control. The increment in number of leaves is due to enhancing the level of cytokinin content that leads to the emergence of new leaves.

Zinc and boron did not affect the germination percentage. So, there was no statistically significant effect of foliar spray. This result is in accordance with the finding of Bannerji *et al.* (2016); Sarkar *et al*. (2018) and Magdi and Mousa (2009).

The maximum number of haulms / plant (7.33) recorded in treatment T_9 - foliar spray of B -20 (boron) @ 0.09% + zinc sulphate @ 0.05%, followed by T_7 (6.00) and T_8 (5.33), whereas minimum number of haulms / plant (1.66) was observed in treatment T_1 - untreated control. Zn and B enhanced the activity of meristematic tissue, increasing number of haulms. These findings are in accordance with finding of Bari *et al.* (2001) Basavarajeswari *et al.* (2008) and Hatwar *et al*.(2003)

The maximum number of tubers / plant (13.00) was observed in treatment T_9 foliar application of B -20 (boron) @ 0.09% + zinc sulphate @ 0.05%, followed by T_7 (11.66), and T_8(11.00), Whereas minimum number of tubers / plant (6.66) was observed in treatment T_1 - untreated control . Higher uptake of zinc and boron by foliar application resulted in larger uptake by reproductive tissue that ultimately increased number of tubers. This result are in accordance these of Sarkar *et al.* (2018); Banerjee *et al.* (2016); Al- Jobori and AL-Hadithy (2014).

Table 1. Effect of foliar spraying of micronutrients on growth and yield parameter of potato

Treatment	Plant height (cm)	Number of leaves/ plant	Plant stand count	Number of haulms/ plant	Number of tubers/ plant	Length of tubers (cm)	Width of tubers (cm)	Weight of tubers (g)	Tuber yield (kg/plot)	Tuber yield (q/ha)	Market-able yield (q/ha)
Control (untreated)	88.63	70.00	100	1.66	6.66	5.57	2.66	109.00	11.13	123.73	118.66
B-20 (boron) @ 0.06%	90.63	76.00	100	2.33	8.00	6.61	3.41	119.00	14.48	160.92	154.33
B-20 (boron) @ 0.09%	92.24	77.66	100	3.66	8.66	7.36	4.17	174.00	15.61	173.48	168.00
zinc sulphate @ 0.03%	92.84	72.33	100	4.00	9.66	7.39	4.61	218.66	15.81	175.70	169.66
zinc sulphate @ 0.05%	93.38	73.00	100	4.66	10.00	7.68	4.62	226.00	16.37	181.92	176.33
B-20 (boron) @ 0.06% + zinc sulphate @ 0.03%	93.51	73.33	100	5.00	10.33	7.88	4.77	241.00	17.58	195.40	190.00
B-20 (boron) @ 0.06% + zinc sulphate @ 0.05%	94.47	73.66	100	6.00	11.66	8.52	5.01	289.33	18.76	208.48	202.66
B-20 (boron) @ 0.09% + zinc sulphate @ 0.03%	93.62	74.00	100	5.33	11.00	8.21	5.00	269.00	17.96	199.59	193.33
B-20 (boron) @ 0.09% + zinc sulphate @ 0.05%	94.64	75.66	100	7.33	13.00	8.64	5.19	377.33	19.99	221.77	216.00
SE (d)	1.03	1.19	0	0.68	1.20	0.55	0.36	2.68	1.52	15.43	16.82
CD at 5%	2.19	2.52	0	1.44	2.56	1.81	0.77	5.69	3.22	32.71	35.66

The maximum weight of tubers / plant (377.33 g) was recorded in treatment T_9 foliar application of B - 20 (boron) @ 0.09% + zinc sulphate @ 0.05%, followed by T_7 (289.33 g) and T_8 (269.00 g). While minimum weight of tubers / plant (109.00 g) was observed in treatment T_1 - untreated control. Due to metabolic activity of micronutrients like zinc and boron in formation of proteins, enzyme activation and carbohydrate metabolism, increases utilization of other fertilizer, hence increases the weight of tubers. These results are in agreement with Al-Jabori and Al-Hadithy (2014).

The maximum tuber length (8.64 cm) was observed in treatment T_9 foliar application of B-20 (boron) @0.09% + zinc sulphate @ 0.05%, followed by T_7 (8.52 cm) and T_8 (8.21 cm), whereas minimum length of tubers (5.57cm) was recorded in treatment T_1 – untreated control. Micronutrients helps in water and nutrient transportation from root to shoot more efficiently, that leads to increment in length. These results are in accordance with Weerahewa and David (2015) .

The maximum tuber width (5.19 cm) was observed in treatment T_9 foliar application of B -20 (boron) @ 0.09% + zinc sulphate @ 0.05%, followed by T_7 (5.01 cm) and T_8 (5.00 cm), whereas minimum width of tuber (2.66 cm) was recorded in treatment T_1 - untreated control. Combined effect of various micronutrients help in efficient photosynthesis, protein synthesis which results in increase in width. This findings in accordance with Singh *et al*. (2018).

The maximum tuber yield (221.77 q/ha) was observed in treatment T_9 foliar spray of B -20 (boron) @ 0.09% + zinc sulphate @ 0.05%, followed by T_7 (208.48 q/ha) and T_8 (199.59 q/ha), whereas the minimum yield (123.73 q/ha) was observed for treatment T_1 - untreated control. Increased efficiency of metabolic function results in higher protein assimilation and carbohydrates resulting in higher yield. These findings are in accordance with Sandeep *et al*. (2014); Parmer *et al*. (2016) and Javanmardi and Rasuli (2017).

The maximum marketable tuber yield (216.00 q/ha) was observed in treatment T_9 foliar spray of B-20 (boron) @ 0.09% + zinc sulphate @ 0.05%, followed by T_7 (202.66 q/ha) and T_8 (193.33 q/ha), whereas minimum marketable yield (118.66 q/ha) was observed for treatment T_1 - untreated control. This result is in accordance with Sarkar *et al*. (2018) and Kalroo *et al*. (2014).

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Enhancing shelf-life of carrot *(Daucus carota)* during post-harvest processing

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ABSTRACT

The study was carried to find out the effect of physical, chemical and biological treatments on carrot (*Daucus carota* L.) for enhancing shelf-life during post-harvest processing at Department . of Food Process Engineering, Agricultural Engineering College & Research Institute, Tamil Nadu Agricultural University, Coimbatore. The most significant changes in post-harvest quality were weight loss, bitterness, bacterial deterioration, rotating and sprouting. Losses in carrots are due to *Sclerotinia* rot, *Botrytis* rot, bacterial soft rot (*Erwinia* sp.) and sour rot (*Geotrichum* sp.). The physical, chemical, biological and combination of these methods were studied. Among the different methods, combination of chlorination and ozonization during washing followed by application of *Lactobacillus plantarum 020* at the rate of 10 ml / litre of wash water was more effective. Carrots processed with the treatment had a shelf-life of six days under normal room temperature, whereas shelf-life of untreated carrots was two days under normal room temperature.

Key Words: Post-harvest processing, Spoilage, Shelf-life, Disorder, Biological, Chemical

In India, carrot (*Daucus carota* L.) is cultivated in 30,000 ha per annum. Tamil Nadu is the second largest producer of carrot. However, carrots are susceptible to a number of post-harvest diseases and disorders. Mechanical injuries, bruising and cracking, caused during processing render them more prone to attack by organisms. About 20 - 30% of the total carrot is lost due to post-harvest spoilage and water loss (Shibairo *et al*., 2002). The losses in vegetables are much higher due to inadequate post-harvest handling, transportation and storage facility (Susheel Kumar Sarkar *et al*, 2020). The major constraint in its processing is post–harvest losses caused due to microbial spoilage. Processed carrots have less than 48 hours of shelf-life. Therefor study was undertaken to find out post-harvest microbial management techniques that could reduce post-harvest losses through physical/chemical/ biological or combination of all methods, whichever is effective and practically feasible.

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MATERIALS AND METHODS

The probiotic culture, *Lactobacillus plantarum* 020, (source: NDRI, Karnal, India) was cultured in De Man, Rogosa and Sharpe (MRS) broth for 24 h at 37°C. The culture was harvested, centrifuged and prepared for further study. Harvested cells were mixed in sterile distilled water to get 109 CFU per ml and used for different treatments. The starter culture prepared as above was used to treat carrots at the rate of 10 ml culture per 1000 ml of wash water during post-harvest processing. Ten ml of prepared starter culture of *Lactobacillus plantarum* 020 was introduced into 1000 ml wash water to get 1% inoculum. Prepared wash water was kept at room temperature for one hour and used to treat carrots.

The treatments were:

T_0, Control

T_1, Chlorination (200 ppm) + Ozonization (30 min)

T_2, Chlorination (200 ppm)+*Lactobacillus plantarum* 020

T_3, Ozonization (30 min) + *Lactobacillus plantarum* 020

T_4, Chlorination (200 ppm) + Ozonization (30 min) + *Lactobacillus plantarum* 020

The population density of bacteria, fungi, actinomycetes and viability of probiotic culture was enumerated by serial dilution plate technique (Parkinson *et al.*, 1971). A known quantity of whole carrot sample was transferred to peptone water to get 10^{-1} dilution. After thoroughly mixing it, one ml of this dilution was transferred to 9 ml peptone water to get 10^{-2} dilution. Likewise, sample was diluted serially with 9 ml peptone water till appropriate dilution was obtained.

Carotene content in carrot was estimated following the procedure as described by Lee (1986). The carotene content was measured on days 0, 2, 4 and 6. Measured quantity of sample was homogenized in a pestle and mortar using acetone and extracted repeatedly using acetone until the residue is colourless. This mixture is then added to a separating funnel containing petroleum ether. Five per cent sodium sulfate solution was then added to the solution. The petroleum ether extract was removed from the funnel and added to anhydrous sodium sulfate. Carotene content was estimated using spectrophotometry method, in which yellowish colour formed is measured against spectrophotometer at the wavelength of 453 nm. Total quantity of carotene content in 100 g of carrot sample is calculated using the formula:

$$\text{Total carotene} = \frac{\text{Absorbance of sample} \times \text{Total volume} \times 100}{0.2592 \times \text{weight of sample} \times 1000}$$

Weight loss in carrots during storage was found using an analytical balance with a precision of 1×10^{-4}g.

The loss of colour during storage was estimated with a spectrophotometer (HunterLab's MiniScan EZ) which provides a 31.8 mm port size that has a 25 mm viewed area. The relative intensities of light at different wavelength along visible spectrum (400-700 nm) are then analyzed to produce numeric results, indicating the colour of sample. The results were expressed as Hunter colour values of L*, a* and b*, where L* value denotes lightness (+) and darkness (-), a* value is used to indicate the redness (+) and greenness (-) and the b* value is used to denote the yellowness (+) and blueness (-) of the sample.

The changes in hardness of carrots during storage were measured using a texture analyser (Brookfield, CT3 Texture Analyzer, India). The following specifications were loaded. The Brookfield texture analyser had load cell of 50 kg capacity, the probe was chosen TA44, an aluminium cylinder with 4 mm diameter, compression was the selected test type. The target value was fixed to 5 mm distance and no hold time was fixed. The trigger load was fixed to 10 g with a test speed 1 mm/s. These parameters once set, will automatically run the data for remaining samples. The hardness of a carrot is measured by maximum force required to compress the sample.

The carrot sample was placed in sample holder and distance between sample and probe was adjusted. After placing all required parameter, the texture analyser was run. A probe of 4 mm diameter was made to pass 5 mm deep into the carrot samples. The required parameters were automatically recorded before the probe withdraws from the sample. The hardness was measured on 0th and 6th day of carrot storage.

The statistical analysis was carried out using AGRES software. Differences were considered to be significant at $p<0.05$. The data were subjected to analysis of variance (ANOVA) with a mean comparison performed using two factorial completely randomized design.

RESULTS AND DISCUSSION

The carotene content was significantly affected by the storage period, storage temperature and treatments used ($p<0.05$) (Fig. 1). During storage, there was a sharp decline in the total carotene content in carrots. However, carotene content was maintained in samples treated with probiotic culture. The carotene content of carrots ranged from 5.9625 ± 0.76 to 13.35 ±0.37 during storage. The carotene content in carrots having the presence of probiotics was found higher during storage compared to samples without probiotics. The carotene content of samples treated with T_0, T_1, T_2, T_3 and T_4 on 0th day were 13.3, 11.68, 10.12, 10.70 and 12.14 mg/100g on 0th day respectively.

On storage there was a minimal degradation in total carotene content in samples. Since, untreated carrot sample had a maximum spoilage on 6th day, carotene content of to samples were not recorded. The carotene content of samples treated with T_1, T_2, T_3 and T_4 on the 6th day were 7.99, 7.02, 6.86, 7.65 mg/100g. Among treatments used, T_1 and T_4 had minimal degradation in carotene content compared with other treated samples. Abitha *et al.* (2019) studied the impact of probiotics in preserving the microbiological property and nutritional quality in carrot and found similar results.

The study showed the ability of probiotic cultures in reduced carotene content degradation during storage under room temperature among other treated samples. The degradation in carotene content of untreated sample was observed mainly due to spoilage. On the 6th day of storage, there was a maximum spoilage in untreated samples degrading the total carotene content, whereas a minimum degradation in carotene was observed in treated samples.

Similar finding were reported by Kun *et al.* (2008) on *Bifidobacterium* strains like *B. lactis* Bb-12, *B. bifidum* B7.1 and B3.2. These strains could preserve the biochemical changes in fermented carrot juice with minimal degradation of carotenoids and nutritional value of the product without any nutrient supplementations. Several *Bacillus* sp. known as endophytes can prevent deleterious effects of pathogenic microorganisms (Bora *et al.,* 2019). The probiotic strains of *L. casei, L. acidophilus, L. plantarum,* and *L. delbrueckiiare* are resistant to low pH, did not influence the lycopene content and its chemical properties (Ferdousi *et al.*, 2013).

The weight loss was influenced by the storage condition, the treatments used and the initial microbial load (Fig. 2). There was a steady increase in per cent weight loss in all samples during the storage period. The percent weight loss among samples ranged between 7.9 ± 0.85 to 35.996 ± 0.65. The highest weight loss was observed in untreated samples. At the end of storage, probiotics treated samples retained the weight in samples, as probiotics cells in surface reduced microbial load causing spoilage. Spoilage microbes soften the tissues and cells of carrots, ultimately reducing the weight and poor moisture retention in roots was observed. The treated samples had a reduced spoilage compared to untreated samples. Among treated samples, carrots coated with *Lactobacillus plantarum* 020 maintained weight during storage at room temperature. The per cent weight loss in samples treated with T_0, T_1, T_2, T_3, T_4 were 36.99, 27.79, 23.24, 25.16 and 22% respectively. Among the treated samples, T_4 and T_2 had a reduced weight loss percentage among other treated samples with 23.24 and 22 % weight loss per cent.

Similar results were reported when *Lactobacillus acidophilus* was incorporated in beet root juice was better in terms of pigments, vitamins and minerals. The microorganism also maintained a good cell vitality during storage preserving its moisture. Probiotic used as an edible coating to improve the quality factor of minimally processed carrots showed a reduced effect in colour and showed a greater retention in moisture content of carrots (Shigematsu *et al.*, 2018). The use of probiotics as an edible coating demonstrated a slowdown in moisture loss from food products (Soukoulis *et al.*, 2014).

The L* value of carrots ranged from 51.26 to 54.57 during storage. The L* value indicates lightness of the sample. The a* value ranged between 24.09 to 32.86 during storage indicating redness of sample. The b* value ranged from 27.77 to 34.38 during storage indicating the yellowness of the sample. Colour value was measured immediately after treatment and on the 6th day of storage. Carrots showed more changes in colour after treatments. Luminosity was significantly different in all samples compared to the control. There was an increase in lightness in all treated carrots. Similarly a decrease in intensity of redness and yellowness of treated carrots was observed, compared to the control. On the 6th day of storage, T_4 treated samples had a minimum change in lightness L* compared to the 0th day of T_4 treated carrots. T_1 treated carrots had higher intensity in reddness (a*value) and yellowness (b*value) than other treated samples by the 6th day of storage. The L* value, (Fig 1), a* value (Fig 2) and b* value of carrots during storage (Fig 3) also given.

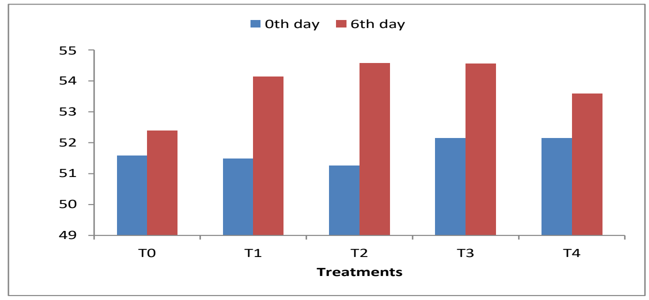

Fig 1. The L* value of carrots during storage

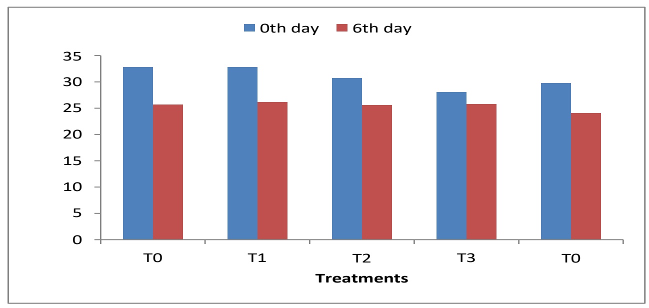

Fig 2. The a* value of carrots during storage

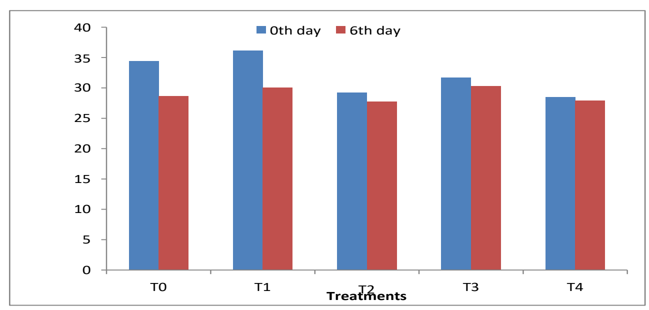

Fig 3. The b* value of carrots during storage

Different treatment methods used along with the processing conditions largely affects the colour value of the carrots. This change in colour may be due to various chemical and enzymatic changes that occur during various treatments used.

Hardness of carrots varies according to the change in moisture content and spoilage occurred during storage. Since the carrots were stored under room condition, there was increased loss of moisture to the surroundings, which increased the hardness of carrots. Similarly, presence of spoilage in roots also greatly affected the hardness of carrots. Spoilage in carrots softens the tissue of carrots making it fragile, thus less force is required. The hardness varied according to microbial load and moisture content present on the 6^{th} day of storage. The untreated sample had an increased microbial load, softening the tissues as most of the roots were spoiled. Hence, T_0 samples were excluded in hardness determination.

Carrots treated with chlorine, ozone and *Lactobacillus plantarum* 020 had minimum degradation in firmness than other combination treated samples. Chlorine, ozone and *Lactobacillus plantarum* 020 treated carrots required 47.697 N, deformation at hardness were on 2.08 mm distance, adhesiveness of 1.6 mJ and 5 fractures in carrots on the 6th day of storage. Carrots processed with the above treatment had a shelf-life of six days under normal room temperature, whereas the shelf-life of untreated carrots was two days under normal room temperature. The finding could be adopted well in real field conditions to improve carrot shelf-life.

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Characterization of peach (*Prunus persica*) genotypes for physico-chemical and yield attributes grown under temperate environment

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ABSTRACT

Forty peach (*Prunus persica L.*) genotypes were studied for physico-chemical and yield attributes grown under temperate environment using Mahalanobis D^2 statistics at ICAR-Central Institute of Temperate Horticulture, Srinagar (Jammu & Kashmir) during 2016-2018. Most of the genotypes differed significantly for fruit colour, physico-chemical and yield attributes when subjected to multivariate analysis. The maximum standard deviation was observed for fruit weight, followed by firmness index, fruit width and least for fruit shape index and titratable acidity. The cluster analysis classified genotypes into two major groups. The first group possessed superior attributes in terms of highest fruit length, weight, width and diameter, while second group had maximum fruit weight, TSS, titratable acidity and highest yield. Principal component analysis (PCA) revealed that first PC, which is the most important component, explained 39.8% of total variation and was positively related to leaf length and leaf length: width ratio, leaf thickness, oil content (fresh and dry-weight basis), stone weight and yield. Among genotypes, most diverse genotypes were Nimla, Summer Glo, Mayfire, Red Globe, Fantasia, Crest Heaven, CITH-P-5, Syria and Punjab Nectarine superior diverse genotypes could be utilized as donor parents to commence crossing in peaches and breeding programmes and may result in genotypes having desired for fruit colour, fruit size, TSS and yield.

Key Words: Genetic variability, Fruit quality, Yield, Temperate environment, Physico-chemical attributes.

The peach (*Prunus persica* L.) is highly remunerative and nutritionally rich fruit crop. In India, a number of varieties/genotypes/cultivars are grown in different agro-ecological regions (Lal *et al*., 2016). The genetic diversity can be used in breeding to increase genetic variation in base populations by crossing cultivars with a high level of genetic distance as well as for introgression of exotic genotypes (Sharma *et al*., 2015; Tripathi *et al*., 2018). These morphological traits are primary markers utilized in germplasm management (Kumar *et al*., 2016; Lal *et al*., 2016 and Mir *et al*., 2019). Although newly developed molecular markers are valuable techniques in gene-based diversity studies, however these procedures have disadvantage of high cost (Ahmad *et al*., 2014; Matias *et al*., 2016). The potential of existing genetic variability is vast and need to be explored for genetic enhancement of peach genotypes. Keeping in view, studies were carried out to find out extent of genetic diversity in 40 peach genotypes.

MATERIALS AND METHODS

The studies were carried out at ICAR-Central Institute of Temperate Horticulture, Srinagar, Jammu & Kashmir, India, during 2016-2018. Recommended uniform package of practices were followed. The average maximum temperature 22.11°C, minimum 6.15°C, rainfall 901 mm, relative humidity 64.5% and evaporation 2.65/day and soil characteristics, *viz*. pH= 6.91, EC = 0.35dS/m were recorded during the study. Forty peach genotypes (Mayfire, Early Glo, Early Red June, Stark Early, Fertilia, Silver King, Early Grande, Florida Prince, Shan-e-Punjab, Snow Queen, Syria, Punjab Nectarine, CITH-P-1, CITH-P-2, CITH-P-3, Nimla, South Land P-1, Peshwari, Gloheaven, Vance Marble, Elberta, Red Globe, Vance Missouri,

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Summer Glo, CITH-P-6, July Elberta, South Land P-2, Sun Heaven, Snowcrest, K-209011, Red Heaven, Flavorcrest, CITH-P-4, CITH-P-9, CITH-P-5, CITH-P-7, Crest Heaven, Fantasia, Quetta and CITH-P-8) conserved at peach germplasm block of ICAR-CITH, Srinagar, were studied. The peach genotypes were sourced from UC-DAVIS, California, and from various R& D organizations of India, via NBPGR, New Delhi.

The trees were planted at a spacing of 3.0 m × 3.0 m. The average age of trees was 9 years. The primary selection criterion was based on fruits and yield attributes. Individual genotypes were marked in the field. The data were recorded at the time of fruit maturity during summer (June-August) seasons of year and data were pooled for analysis. Twenty fruits from each genotype were randomly collected and observations on fruit length (mm), fruit weight (g), fruit diameter (mm) and fruit yield (kg/plant) were recorded. The length and diameter of fruits were measured with the help of digital Vernier calipers. The peel colour of each genotype at ripening was measured using calibrated Hunter Lab UltraScan PRO colorimeter attached with Easy Match QC software (Hunter Associate Laboratory, Inc., Reston, USA) and expressed as L^* (lightness; 0 = black, 100 = white), a^* ($^-$a = greenness, $^+$a = redness), and b^* ($^-$b = blueness, $^+$b = yellowness) values. Based on L^*, a^*, b^* data the Hue and chroma value was calculated.

Fruit shape was determined by calculating fruit shape index as the ratio of fruit length and diameter, whereas fruit weight was measured using Sartorius balance with accuracy of 0.001 g. Total soluble solids (TSS), titratable acidity and TSS/titratable acidity were determined as per the standard procedures (AOAC, 1994). The experiment was conducted under a randomized block design with three replications and pooled data of three years were analyzed as per the method suggested by Gomez *et al.* (1984). Biometrical descriptive analysis was performed as grouping or classification of genotypes based on suitable scale is quite imperative to understand the usable variability existing among them.

To explore the diversity and relationship among genotypes, their vital horticultural characteristics were studied by multivariate factor analysis. To find out extent of similarity among selected genotypes, clustering of genotypes into similarity groups was performed using the method tree procedure PROC CLUSTER based on average distance. In order to identify the patterns of variation in fruit colour, physico-chemical and yield attributes, principal component analysis (PCA) was conducted as PROC PRINCOP SAS 9.3 software SAS Institute, Cary, NC and Jackson(1991).

RESULTS AND DISCUSSION

Among genotypes, brightness(L*) value of fruit skin color was recorded highest in K-209011, followed by Vance Missouri (72.78), Summer Glo (70.64), Red Heaven (70.25) and lowest in CITH-P-5 (43.86) followed by Peshawari (45.11), Quetta (45.7) and Mayfire (47.87). The maximum a* value was measured in Mayfire (39.16), followed by Fantasia (29.16), Flavorcrest (27.57), Early Red June (27.22) and CITH-P-7 (26.73) and lowest in CITH-P-3 (1.77) followed by CITH-P-4 (2.75), South Land P-1 (4.01) and Stark Early (6.13). The a* value represents high blush colour which make fruit more visually attractive hence these varieties were considered as most attractive and suitable for domestic as well as international market.

The b* value indicates yellowness of fruits, also preferred by consumers was maximum in Vance Missouri (57.7), followed by Red Heaven (52.5), K-209011 (52.12) and Summer Glo (47.86) and lowest in Peshawari (16.62), CITH-P-5 (21.18), Quetta (22.53) and Snow Queen (24.27). Similarly, fruit pulp colour was also estimated and maximum L* value was estimated in Summer Glo (77.39), followed by K-209011 (76.56), Crest Heaven 75.62 and CITH-P-2 (74.92) and lowest in CITH-P-7 (41.99), followed by CITH-P- (43.26), Vance Marble (52.07) and Gloheaven (55.13); however, a* value was measured highest in Shan-e-Punjab (41.74), followed by Elberta (23.64), Vance Missouri (23.09) and Snowcrest (22.16) and lowest in Silver King (5.68) followed by Peshawari (4.37), Stark Early (2.46) and South Land P-2 (2.41).The b* value was recorded highest in genotype Elberta (66.8) followed by CITH-P-1 (62.09), Flavor Crest (60.62) and Sun heaven (59.97) and lowest in CITH-P-7 (21.24) followed by Vance Marble (22.74), CITH-P-9 (22.74) and South Land Peach-1 (29.55).

The variability in fruit skin and pulp colour of individual genotypes would certainly provide an idea, which could be utilized for selection of desirable parents in peach breeding programme for the development of attractive and higher acceptable fruit peel and pulp colour genotypes.

The fruit physical traits are not only governed genetically but are also influenced by environmental factors (Lal *et al*., 2013). These traits were investigated in all genotypes. The CITH-P-8 (69.19) produced longest fruits followed by Summer Glo (68.83), Nimla (68.55) and Red Heaven (63.73). However lowest in Syria (35.91) followed by Punjab Nectarine (37.3), Quetta (40.48) and South Land Peach (42.45). Similarly maximum fruit width was also in Summer Glo (68.62), followed by Nimla (65.42), Vance Missouri (64.28) and Snowcrest (62.82), whereas minimum in Mayfire (31.51) followed by Punjab Nectar (31.91) and Syria (34.11). The fruit diameter was highest in Summer Glo (71.85), followed by Nimla (66.95), Snowcrest (64.16) and Early Grande (63.45) and lowest in Punjab Nectarine (37.21) followed by Mayfire (37.66), Syria (38.73), Quetta (41.36) and Vance Marble (42.75).

Fruit shape was maximum in Silver King (1.16), followed by Stark Early (1.17), CITH-P-8 (1.15) and Fantasia (1.11) and lowest in South Land P-1 (0.9) followed by Snowcrest (0.92), Early Glo (0.92) and Syria (0.93), whereas maximum fruit weight was recorded in Summer Glo (180.2), followed by Nimla (176.07), Snowcrest (142.11) and Vance Missouri (135.72) and lowest in Mayfire (27.75), followed by Punjab Nectarine (28.39), Syria (28.73) and Shan-e-Punjab (40.29). Considerable variability was observed for all the traits indicating diversity in genotypes and their amenability to selection. Similar kind of variability among horticultural traits and yield were also reported by Saran *et al*. (2010) Milatovic *et al*. (2012); Kumar *et al*. (2015); Pandey *et al*. (2021).

The maximum total soluble solids (°B) was recorded in genotype CITH-P-5 (18.45), followed by CITH-P-7 (18.20), South Land Peach-1 (17.63), Florida Prince (16.83) and least in Mayfire (6.70) followed by CITH-P-3 (8.5), Snow Queen (9.17) and Early Glo (9.47). The maximum value for sugar acid ratio was recorded in South Land P-2 (28.44) followed by CITH-P-7 (28.00), CITH-P-5 (24.57) and Sunheaven (24.51) however, lowest in Mayfire (6.63) followed by Snow Queen (8.73), Silver King (9.57) and Early Glo (9.68).The titratable acidity was recorded highest in Snow Queen (1.05%) followed by Early Grande (1.02%), Summer Glo (1.02%), Silver King and least in South Land P-2 (0.62%) followed by CITH-P- (0.65%), July Elberta (0.65%) and Quetta (0.66%). The firmness index was recorded highest in Silver King (67.57), followed by Early Glo (63.77), Early Red June (63.50) and Vance Marble (59.1) and lowest in Summer Glo (24.72), and followed by CITH-P-9 (24.83), CITH-P-6 (27.76) and Sunheaven (31.38). Yield was highest in Red Globe (29.56 kg/plant), followed by Nimla (29.36 kg/plant), Fantasia (28.35 kg/plant) and Crest Heaven (26.65 kg/plant) and lowest in Syria (1.89 kg/plant) followed by South Land Peach-1 (3.36 kg/plant), Red Heaven (3.56 kg/plant), South Land Peach-2 (3.68 kg/plant) and Punjab Nectarine (4.35 kg/plant). Similar results were also reported by Lal *et al*. (2013) in peaches.

The maximum standard deviation was observed for fruit weight (38.31), followed by firmness index (11.43), fruit width (9.23) and least for fruit shape index (0.068) followed by titratable acidity (0.120) (Table 1). Similarly, coefficient of variation (%) was found maximum for fruit yield (60.59) followed by fruit weight (45.85) and TSS-titratable acidity ratio (30.37) and lowest for fruit shape index (6.74) followed by titratable acidity (15.06). Skewness describes the symmetrical distribution pattern with respect to its dispersion from the mean. The skewness values showed that the data were normally skewed which was less than ±2. However, positive skewness was recorded for fruit length, fruit width, fruit diameter, fruit shape index, fruit weight, titratable acidity, TSS/titratable acidity, firmness index and yield and negative for TSS. For distribution of quantitative traits which provides information about nature of gene action and number of genes controlling the traits respectively.

The skewed distribution of a trait in general suggests that trait is under the control of non-additive gene action and is influenced by environmental variables. Positive skewness is associated with complementary gene interactions while negative skewness is associated with duplicate (additive ×additive) gene interactions (Table-1). The genes controlling the trait with skewed distribution tend to be predominantly dominant irrespective of whether they have increasing or decreasing effect on the trait. It was recorded platykurtic distribution pattern for

Table 1. Descriptive statistics for ten important horticultural traits of 40 peach genotypes

Variable	Range	Mean	Standard deviation	CV (%)	Skewness	Kurtosis	Bimodality
Fruit length (mm)	35.91- 69.19	52.69	8.73	16.57	0.02	-0.79	0.41
Fruit width (mm)	31.61-68.62	49.65	9.24	18.61	0.10	-0.54	0.37
Fruit diameter (mm)	37.21-71.85	51.92	8.32	16.02	0.30	-0.44	0.39
Fruit shape index	0.9-1.17	1.02	0.07	6.74	0.51	-0.35	0.43
Fruit weight (g)	27.75-180.2	83.58	38.32	45.85	0.76	0.06	0.48
TSS (°B)	6.7-18.43	13.12	2.91	22.20	-0.09	-0.84	0.42
Titratable acidity (%)	0.62-1.05	0.80	0.12	15.06	0.63	-0.64	0.54
TSS/Titratable Acidity	6.63-28.44	17.00	5.22	30.73	0.21	-0.42	0.37
Firmness Index	24.72-67.57	44.58	11.43	25.65	0.15	-0.70	0.40
Yield/plant (kg)	1.89-29.56	13.26	8.04	60.59	0.52	-0.82	0.52

fruit weight however, leptokurtic distribution fruit length, fruit width, fruit diameter, fruit shape index, TSS, titratable acidity, TSS/titratable acidity, firmness index and yield. Kurtosis is negative or close to zero in the absence of gene interaction and is positive in the presence of gene interactions.

The traits with leptokurtic and platykurtic distribution are controlled by fewer and large number of genes, respectively. Bimodality of genetic admixture values provides evidence of strong isolation between two morphological and genetic clusters, supporting the existence of asympatric genotypes pair within the gene pool. The values are nearer to zero, explains the closeness among the genotypes.

The dendrogram classified all genotypes into two major groups at normalized root mean square (NRMS) distance of 1.81 at (Fig. 1). The first group formed, which included only two genotype (Nimla and Summer Glo) contributing 5% of total genotypes studied. These genotypes were characterized by highest fruit length, width and diameter. The second group was comprised of 38 genotype and contributed 95% of the total genotypes. The second group further categorized into two major clusters at 1.12 NRMS. The first major cluster was consisted of 24 genotypes contributing 60% and second major cluster included

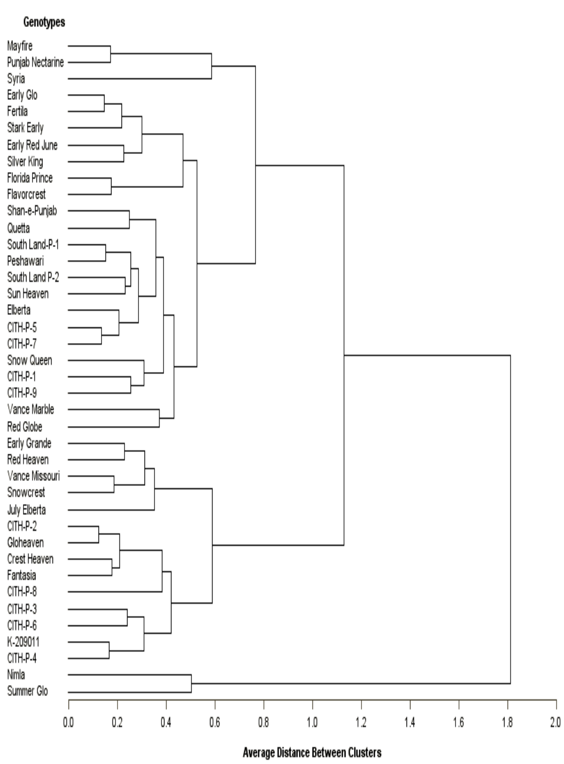

Fig 1. Dendrogram of 40 peach genotypes obtained by average distance between clusters based on 10 fruit quality and yield traits

32.50%. At 0.76 NRMS second major cluster divided in to two sub-clusters.

The first sub cluster included three genotypes (Mayfire, Punjab Nectarine and Syria) characterized for lowest fruit diameter, length, and weight however, second sub cluster consisted 21 genotypes namely Early Glo, Fertilia, Stark Early, Early Red June, Silver King, Florida Prince, Flavorcrest, Shan-e-Punjab, Quetta, South Land Peach-1, Peshawari, South Land-P-2, Sun Heaven, Elberta, CITH-P-5, CITH-P-7, Snow Queen, CITH-P-1, CITH-P-9, Vance Marble and Red Globe. At 0.0.589 NRMS the second major cluster was also divided in to two sub clusters.

The first sub-cluster included five genotypes (Early Grande, Red Heaven, Vance Missouri, Snowcrest and July Elberta).The second sub cluster consisted of nine genotypes namely CITH-P-2, Gloheaven, Crest Heaven, Fantasia, CITH-P-8, CITH-P-3, CITH-P-6, K-20901 and CITH-P-4. The dissimilarity level in terms of genetic distance ranged from 0.20-1.18, indicating a high degree of dissimilarity between genotypes and high genetic distance between genotypes and if chosen for hybridization program, may give high heterotic F_1s and broad spectrum of variability in segregating generations.

Principal components analysis is a way of identifying patterns in data, which expresses data in such a way as to highlight their similarities and differences (Lal *et al*., 2016). Therefore, it was carried out to determine the characters more strongly contributed to principal components and which traits were the major sources of variation within the genotype collections. It reduced the 10 original characters in experiment to four principal components (Table 2). The first four principal components with Eigen values >1 explained 90.00% of variation among 40 genotypes. Other PCs had Eigen values ≤1 and excluded in interpretation. The first PC, which is the most important component, explained 39.8% of total variation and was positively related fruit length, fruit width, fruit diameter, fruit and weight.

The PC2 accounted for 27.0% of the total variation and the characters with the greatest weight on this component were titratable acidity and firmness index. The PC3 accounted for 13.31% and positively related to fruit shape index TSS/titratable acidity, TSS/ titratable acidity and yield per plant, however PC4 accounted only for TSS suggesting that these principal component score might be used to summarize the 10 variables in any further analysis of data. The traits with largest absolute value closer to unity within the first component influence the clustering than those to lower absolute value closer to zero. Thus, in present

Table 2. Principal component analysis of 40 peach genotypes showing the eigen vectors, eigen values and percentage total variance accounted for by 10 principal component axes

Character	PRIN1	PRIN2	PRIN3	PRIN4
Fruit length (mm)	0.454	0.175	0.221	0.134
Fruit width (mm)	0.493	0.031	-0.066	0.060
Fruit diameter (mm)	0.491	0.098	-0.071	0.030
Fruit shape index	-0.037	0.214	0.702	0.296
Fruit weight (g)	0.487	0.087	-0.057	0.050
TSS (˚B)	0.113	-0.510	0.065	0.303
Titratable Acidity (%)	-0.049	0.447	-0.387	0.224
TSS/Titratable Acidity	0.080	-0.572	0.203	0.122
Firmness Index	-0.141	0.344	0.443	0.031
Yield/plant (kg)	0.172	-0.021	0.235	-0.854
Eigen value	3.977	2.696	1.331	1.002
Difference	1.282	1.365	0.329	0.484
Proportion	0.398	0.270	0.133	0.100
Cumulative	0.398	0.667	0.800	0.901

study differentiation of genotypes into different components was because of high contribution of few traits rather than small contribution of each trait. The positive and negative loadings show positive and negative correlation trends between the component and variable.

Thus, these characters which load high positively or negatively contributed to more diversity. This situation confirms the suitability of using horticultural traits as a basis for selecting parental sources; nevertheless, studies for several years must be conducted before parental selection for a possible plant breeding. The PC analysis provided a simplified classification of the peach genotypes for conservation and breeding.

CONCLUSION

Thus, Nimla, Summer Glo, Mayfire, Red Globe, Fantasia, Crest Heaven, CITH-P-5, Syria and Punjab Nectarine were found promising for yield and fruit quality traits and therefore could be multiplied and distributed for performance evaluation under different temperate regions of India for productivity enhancement besides utilization as parents for peach breeding programme for enhancing desirable horticultural traits.

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Short Communication

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Effect of defoliation and storage of scion stick on growth of softwood graft of mango (*Mangifera indica*)

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Mango (*Mangifera indica* L.) is vegetatively propagated by inarching, veneer grafting, epicotyl grafting, softwood grafting, *etc*. In softwood grafting, it is easy to handle and quite efficient as well as grafts can normally raised within a year, thus reducing cost of raising grafts considerably. The vegetative propagation technique through softwood grafting is much influenced by climatic condition of the region and is mostly carried out on the onset of monsoon, thereby restricting the availability of planting material for a particular season (Uchoi *et al.*, 2012). Therefore, an experiment was conducted to test possibility of propagation of mango by softwood grafting.

The experiment was conducted at Regional Horticultural Research Station, ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari, Gujarat, India, during 2018-2019 The experiment was laid out in a completely randomized design with factorial concept and repeated thrice with 12 treatment combinations. The experiment comprised two factors: (1) effect of defoliation (6, 9 and 12 days before detachment from mother plant) and (2) effect of storage of scion stick (0,1, 2, and 3 days). The effect of this treatments on incremental girth at union (mm), incremental length of sprouted scion shoot (cm), incremental height of graft (cm) and number of shoots were studied.

There was significantly maximum incremental girth at union observed in 12 days prior defoliated and fresh scion stick (without storage) at 60, 120 and 180 DAG (Table 1). This might be due to presence of more nutrient that caused early bud sprouting and early leaf production, causing accumulation of photosynthates in shoot which leads to increased girth of stem (Shama, 2013).

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Maximum girth was obtained in fresh scion stick (without storage), whiles, minimum girth was noted in 3 day storage treatment. As storage period increased it was adversely affect on girth of scion stick, decreasing trend of girth might be due to rapid decaying tissue of scion at the cut end as storage period increased (Thakar and Shah, 2013).

Incremental length of sprouted scion shoot had significant effect due to defoliation and storage of scion stick at 60, 120 and 180 DAG (Table 1). Significantly the maximum incremental length of sprouted scion shoot was observed in defoliated scion shoots. It might be due to defoliated scion shoot contained more carbohydrates and other food substances (Thakar and Shah, 2013) which cause rapid increased in length of sprouted scion. Among different storage period maximum length of sprouted scion shoot was observed in fresh scion stick (without storage), while minimum length of sprouted scion shoot was obtained in 3 day stored scion stick.

This might be due to early sprouting and better union which lead to higher length of scion, whereas longer storage period of scion resulted in late union and delayed sprouting which might here resulted in poor growth of graft. The storage period increased rapid decaying of tissue from cut end of scion stick causing less successful graft union leading to minimum length of scion (Thakar and Shah, 2013). Similar findings were obtained by Chavda *et al.* (2018).

The height of graft showed significant effect on defoliation and storage of scion stick at 60, 120 and 180 DAG (Table 1). Significantly the maximum height of graft was observed in 12 days prior defoliated scion shoots. It might be due to the storage of humidity and food material in the scion stick which reflects on growth stages (Mane and Nalage, 2017). Also might be due to defoliated scion shoot contained more carbohydrates

Table 1 Effect of defoliation and storage of scion sticks on growth of softwood graft of mango

Treatment	Incremental girth at union (mm)			Incremental length of sprouted scion shoot (cm)			Incremental height of graft (cm)			Number of shoots
	60 DAG	120 DAG	180 DAG	60 DAG	120 DAG	180 DAG	60 DAG	120 DAG	180 DAG	180 DAG
Defoliation (D)										
D_1 : 6 days	2.59	3.01	3.22	2.37	4.82	8.96	2.87	5.22	9.36	1.77
D_2 : 9 days	2.67	3.09	3.33	2.51	5.03	9.19	3.01	5.43	9.59	1.99
D_3 : 12 days	2.75	3.17	3.46	2.70	5.34	9.47	3.20	5.74	9.86	2.13
S.Em.±	0.04	0.04	0.06	0.05	0.06	0.09	0.05	0.07	0.10	0.04
CD (5%)	0.12	0.12	0.18	0.15	0.19	0.28	0.15	0.18	0.27	0.13
Storage periods (S)										
S_1 : 0 day	2.83	3.22	3.49	2.84	5.54	9.70	3.34	5.94	10.10	2.31
S_2 : 1 day	2.77	3.20	3.48	2.75	5.39	9.55	3.25	5.80	9.95	2.20
S_3 : 2 days	2.60	3.03	3.29	2.34	4.77	8.98	2.84	5.17	9.38	1.77
S_4 : 3 days	2.48	2.91	3.09	2.18	4.55	8.58	2.68	4.95	8.98	1.57
S.Em.±	0.05	0.05	0.07	0.06	0.07	0.11	0.06	0.08	0.11	0.05
CD (5%)	0.14	0.14	0.20	0.17	0.22	0.32	0.17	0.21	0.32	0.15
Interaction effect (D X S)										
S.Em.±	0.09	0.08	0.12	0.10	0.13	0.19	0.11	0.13	0.19	0.08
CD (5%)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)	5.54	4.79	6.25	7.22	4.44	3.62	6.02	4.11	3.47	7.65

and other food substances (Thakar and Shah, 2013) which cause rapid increased in length of sprouted scion which ultimately increased the height of graft of mango var. Sonpari.

Among different storage period maximum height of graft was observed in fresh scion stick (without storage), while minimum height of graft was obtained in 3 day stored scion stick. This might be due to early sprouting and better union which led to higher length of scion whereas longer storage period of scion resulted in late union and delayed sprouting which might here resulted in poor growth of graft. Also as storage period increased rapid decaying of tissue from cut end of scion stick causing less successful graft union leading to minimum length of scion ultimately minimum height of graft (Thakar and Shah, 2013).

The number of shoots/graft was significantly affected by defoliation and storage of scion stick. Maximum number of shoots were obtained in 12 days prior defoliated scion stick which might be due to more number of active swallow bud which accumulate food material were present in defoliated scion shoot which cause more number of shoots (Adjei and Mante, 2007). In jackfruit, it was found that more number of shoots is due to activate both the terminal and axillary dormant buds which swallowed through stimulation of parenchymatous cells. Significant effect of storage of scion stick observed on number of shoots. Maximum number of shoots found in fresh scion stick (without storage) while, minimum number of shoots were observed in 3 day storage of scion stick. In present investigation early sprouting and more number of leaves were noted in same treatment which leads to photosynthesis and produced more carbohydrates which ultimately increased number of shoots per graft.

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Current Horticulture **10** (1) 62-63, January–June 2022

Evaluation of yield of small-fruited bitter gourd (*Momordica charantia*) under saline soil

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Small-fruited bitter gourd [*Momordica charantia* L. var. *muricata* (Willd.) Chakrav.] grows well in tropical and subtropical climates. This species needs to be conserved (Bano and Sharma, 2017). *Momordica charantia* var. *charantia* is crossable with *Momordica charantia* var. *charantia* (Vijayakumar *et al*.,2019). It is an herbaceous vine and does not require pandal (support). It grows up to a length of 1.5 m on the ground. The vines have deeply lobed leaves, yellow flowers and very small fruits without grooves. It is cultivated in Tamil Nadu for its excellent taste and texture after cooking. It fetches price of 25-40 % more than large type bitter gourd. It performs well in soil with a good drainage facility. Keeping in view, an experiment was conducted to find out its cultivation under saline soil.

The experiment was conducted at Horticultural College and Research Institute for Women, Tiruchirappalli, during 2018-20. Fifty genotypes of small-fruited bitter gourd were collected from different districts of Tamil Nadu. The experiment was laid out in a randomized block design with three replications. The seeds were sown in July and January at the spacing of 2 m x 1.5 m. Vine were allowed to creep on the ground. The data on germination percentage, number of days taken for germination, days to first male and female flower opening and node of first male and female flower appearance, fruit length, individual fruit weight, number of fruits/plant and number of seeds/fruit was recorded. The data were subjected to statistical analysis (Panse and Sukhatme, 1985).

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There was variation in foliage, flowers, size and weight of the individual fruits. The vines have deeply lobed leaves on long petioles, herbaceous pentangular stem with ridges and furrows. Male and female flowers were pentamerous with a range of yellow colour on long pedicel. Fruits were very small, oval in shape with bulged centre and without grooves. The immature fruits have seeds without hollow. The ripe fruits were orange in colour with bright red pulp enclosed seeds and split longitudinally. The wide variation in the size and wartyness of the fruits was recorded.

The germination percentage ranged from 46.33 to 100. The number of days taken for germination ranged from 5.34 to 6.93. The number of days for germination was significantly lower (5.34) in MCM 3, followed by MCM 50 (5.45).

In pooled data analysis, number of days taken for first male flower opening ranged from 33.81 to 47.96. The number of days for first male flower opening was significantly lower (33.81) in MCM 25. In pooled data analysis, node of first male flower appearance ranged from 7.48 to 18.22. The significantly lower value (7.48) for first male flower appearance was recorded in MCM 25, followed by MCM 24 (7.91).

The number of days taken for first female flower opening ranged from 38.67 to 57.63. The number of days for first female flower opening was significantly lower (38.67) in MCM 25, followed by MCM 24 (41.85). The node of first female flower appearance ranged from 13.08 to 21.76. The significantly lower value (13.08) for first female flower appearance was recorded in MCM 28, followed by MCM 24 (13.81). The results are in conformity with the findings of Saranyadevi *et al*., 2017.

Table 1. Fruit length, individual fruit weight, number of fruits/plant and number of seeds/fruit

Accession Number	Fruit length (cm)	Individual fruit weight (g)	No. of fruits/ plant	Number of seeds/fruit
MCM 1	4.39	6.15	44.59	5.37
MCM 2	2.46	3.39	35.59	5.74
MCM 3	3.35	4.66	36.88	6.83
MCM 4	3.96	5.90	32.85	6.52
MCM 5	3.20	8.03	34.44	6.26
MCM 6	2.50	3.40	34.22	7.22
MCM 7	2.47	2.40	36.55	5.78
MCM 8	4.28	3.69	35.92	6.15
MCM 9	3.32	2.66	36.56	7.04
MCM 10	3.47	2.80	42.45	9.22
MCM 11	4.51	4.51	37.11	10.55
MCM 12	3.06	4.42	43.26	7.15
MCM 13	3.09	2.63	42.56	6.67
MCM 14	2.77	5.89	43.72	7.50
MCM 15	3.24	2.63	40.26	5.26
MCM 16	4.22	4.74	44.37	6.70
MCM 17	3.46	3.44	41.93	7.29
MCM 18	4.14	4.65	38.15	5.59
MCM 19	3.38	3.69	40.85	6.92
MCM 20	3.31	4.23	36.67	6.15
MCM 21	3.39	2.63	41.74	4.63
MCM 22	3.36	2.17	35.11	4.22
MCM 23	2.80	2.48	36.59	6.03
MCM 24	2.81	2.14	28.89	7.33
MCM 25	3.18	5.89	33.92	7.33
MCM 26	2.91	5.79	38.04	6.26
MCM 27	2.71	3.20	38.55	5.45
MCM 28	4.56	3.76	40.11	3.37
MCM 29	2.64	3.33	31.07	4.41
MCM 30	4.79	3.70	35.70	6.59
MCM 31	4.29	5.99	38.67	7.41
MCM 32	3.42	2.38	41.33	4.96
MCM 33	3.32	2.43	44.00	6.85
MCM 34	3.80	3.89	42.07	6.22
MCM 35	3.46	3.00	35.70	7.19
MCM 36	3.47	5.57	36.70	9.30
MCM 37	2.16	4.52	39.04	6.55
MCM 38	2.75	2.75	37.83	6.50
MCM 39	5.37	8.46	29.55	10.78
MCM 40	2.52	2.54	33.74	4.74
MCM 41	5.41	8.50	33.96	5.74
MCM 42	4.21	4.55	36.22	5.96
MCM 43	2.36	1.65	36.71	3.67
MCM 44	2.47	2.03	38.15	5.37
MCM 45	5.46	9.70	39.85	3.41
MCM 46	2.39	2.28	36.52	4.67
MCM 47	3.73	2.75	40.59	13.74
MCM 48	2.51	1.80	38.44	4.45
MCM 49	2.60	2.92	38.81	3.37
MCM 50	3.75	3.76	38.50	4.56
MCM 51	4.52	4.31	35.22	4.22
Mean	3.45	4.05	37.85	6.30
SEd	0.17	0.26	2.07	0.62
CD (0.05)	0.33	0.52	4.07	1.22

The fruit length ranged from 2.16 cm to 5.46 cm (Table 1). The significantly higher value (5.46 cm) for fruit length was recorded in MCM 45, followed by MCM 41 (5.41). In pooled data analysis, individual fruit weight was significantly higher (9.70 g) in MCM 45, followed by MCM 41 (8.50). The results are in conformity with those of Neelavathi *et al*., 2015.

In pooled data analysis, the number of fruits per plant ranged from 28.99 to 44.59 (Table 1). The significantly higher number (44.59) of fruits/plant was recorded in MCM 1, followed by MCM 16 (44.37). The number of seeds/fruit ranged from 3.37 to 13.74. A significantly higher number (13.74) of seeds/fruit was recorded in MCM 47, followed by MCM 39 (10.78). The results are in conformity with those of Priyadharshini *et al*. (2018). Thus, among accessions, MCM 1 (44.59) and MCM 16 (44.37) were found to have better yield performance. All the accessions showed field tolerance to fruit flies.

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Current Horticulture **10** (1) 64-65, January–June 2022

Evaluation of garlic (*Allium sativum*) varieties for better growth and yield for Madhya Pradesh

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Garlic (*Allium sativum* L.) is grown as a winter crop in Madhya Pradesh, Gujarat, Rajasthan, Maharashtra and Uttar Pradesh. Madhya Pradesh is the largest producer of garlic in India, occupying 81.17 thousand ha with a total production of 424.50 thousand tonnes. In India, garlic is cultivated in 134.9 thousand hectare. Lack of high-yielding varieties is one of the main constraints in limiting the production and productivity. Keeping in view, Krishi Vigyan Kendra, Burhanpur, conducted on-farm trial to assess the performance of different varieties in Nimar region: a) to identify high-yielding and environmentally-suitable varieties/cultivars and b) to test their suitability and productivity.

The on- farm trial was conducted during *rabi* seasons 2016-17, 2017-18 and 2018-19 in a randomized block design with five replications. Five farmers' fields of the same village treated as five replications. The seeds were sown at a spacing of 20cm x 10 cm. Cloves were detached carefully from the composite bulbs and used for planting. Only sound, bold unbroken and healthy cloves were selected and used. The time of sowing was from 15 October-15 November. Yamuna Safed-1,Yamuna Safed - 3, Yamuna Safed - 2 and local variety were tested.

Organic manure (FYM) and fertilizers were applied according to recommended doses, i.e. 15 t/ha FYM along with fertilizers N : P_2O_5 : K_2O @ 100 : 50 : 50 kg/ha. nitrogen (N) was applied in three splits. FYM was mixed along with half of the dose of nitrogen, total phosphorus and potash were applied as basal dressing before planting. Balanced quantity of N was top -dressed in two split doses of one-fourth each 45 and 75 days after planting. Observations were recorded on 10 randomly selected plants in each replication for all the characters, viz.- plant height (cm), number of cloves per bulb , weight of individual clove (g), fresh weight of bulb (g), and yield (t /ha).

The maximum plant height (16.85cm) was recorded in Yamuna Safed 3 (G-282), followed by Yamuna Safed-1 (G-1) 16.12cm 20 days after germination. The lowest plant height was recorded (13.16cm) in local. At 120 days after germination of garlic cloves, the plant height was highest in G-282 (62.58cm), followed by G-1 (60.04 cm) respectively. The minimum plant height was recorded in local (57.47). These results are in agreement with findings of Tiwari *et al.* (2002), Futane *et al*. (2006), Memane *et al*.(2008), and Lawande *et al*.(2009).

The same trend as observed in plant height was found in number of cloves/bulb. The maximum number of cloves/ bulb was recorded by Yamuna Safed 3 (G-282) (21.31), followed by Yamuna Safed -1 (G-1) 21.01 and the minimum by local variety (15.80). The variety Yamuna Safed 3 was significantly superior than Yamuna Safed 1 (G-1). The findings are supported by Sankar *et al.* (2008), Chala and Quraishi (2015) and Gupta *et al.* (2017).

The maximum fresh weight of 39.96 g of garlic bulb was recorded with Yamuna Safed 3 and found significantly superior than all other varieties, whereas Yamuna Safed 1 was found at par. The minimum bulb weight was recorded the local variety (18.79 g). Yamuna Safed-3 (G-282) seems to be better in position in utilizing the input and in enhancing bulb weight, compared to other varieties.

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Significant differences were recorded among the varieties with respect to weight of individual cloves. The maximum weight of individual cloves was recorded by Yamuna Safed-3 (1.80g), showing significant response over all variety. The minimum weight of individual cloves was recorded by local varieties (1.17 g). These results are in agreement with finding of Mishra *et al* (2017) .

The maximum yield of bulb was (112.21 q/ha) by G-282, followed by G-1 (100.58 q/.ha) and minimum yield (91.45 q/ha) were found under local variety. Yamuna Safsed 3 was significantly superior for bulb yield comprised to all variety. This type of varietal difference in onion was also reported by Kumar *et al.,* (2017); Verma and Thakre (2018). The variation in yield might be due to genetic factors of varieties and differences in fertility level of fields. Thus, Yamuna Safed 3 emerged as a superior overall all other varieties, followed by Yamuna Safed in relation to growth and yield.

Thus, Yamuna Safed-3 could be recommended for garlic growers in the district Burhanpur as it shows best results among the tested varieties farmers.

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Current Horticulture **10**(1) 66-68, January–June 2022

Effect of foliar feeding of micronutrients on growth and yield of bitter gourd (*Momordica charantia*)

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Bitter gourd (*Momordica charantia* L.) is important vegetable crop. It is a cross-pollinated crop and can be grown in both *kharif* and *rabi* seasons. Micronutrients such as iron, zinc, boron, manganese etc. play a vital role in modifying its growth and development. The deficiency of micronutrients adversely affects the production of vegetable besides quality. Therefore, an experiment was conducted on foliar feeding of micronutrients to evaluate its effect on growth parameters and fruit yield of bitter gourd.

The field experiment was conduct in *kharif* season of 2019 at Vegetable Research Farm, Kalyanpur of Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, Uttar Pradesh. The soil is sandy loam in texture and soil pH was 7.7, which showed slightly alkaline reaction. The soil was low in organic carbon 0.37%, low in available N 152.0 kg/ha, medium in available P 14.4 kg/ha and low in available K 181.0 kg/ha at initiation of experiment.

The experiment was laid out in randomized block design with three replications. There were 14 different treatments, *viz*., boric acid @ 100 ppm, zinc sulphate @ 100 ppm, ammonium molybdate @ 50 ppm, copper sulphate @ 100 ppm, ferrous sulphate @ 100 ppm, manganese sulphate @ 100 ppm, mixture of all, mixture of all without B, mixture of all without Zn, mixture of all without Mo, mixture of all without Cu, mixture of all without Fe, mixture of all without Mn and commercial formulation (multiplex @ 4 ml/litre of water) were tested against the control (only water spray).

The bitter gourd variety 'Kalyanpur Barahmasi' was used. The crop was sown on 3 July with a spacing of 1.50m X 0.60m. Seeds were treated with Carbendazim systemic fungicide containing 50% WP @ 2.5 g/kg seed before sowing. Recommended dose of fertilizers (NPK) was applied @ 60, 80 and 60 kg/ha. The entire quantities of phosphorus and potassium and half of nitrogen were applied as basal and rest amount of nitrogen was applied in two split doses at 25 and 45 DAS as top. Total three foliar sprays were given at an interval of 10 days starting from 40 days after sowing. Other package of practices were adopted.

The observations were taken on growth and fruit yield and subjected to analysis of variance with mean comparison of 5% level of significance. Five competitive plants were selected randomly from each plot to record the data on various characters. The average value of each character was calculated on the basis of five plants from each replication.

Growth parameters were influenced significantly by different treatment. The foliar application of mixture of all micronutrients (boric acid @ 100 ppm + zinc sulphate @ 100 ppm + ammonium molybdate @ 50 ppm + copper sulphate @ 100 ppm + ferrous sulphate @ 100 ppm + manganese sulphate @ 100 ppm) recorded significantly highest vine length of 3.52m. It was followed by multiplex @ 4ml/litre of water with 3.15m and boric acid @ 100 ppm with 2.92m. However, foliar feeding of multiplex @ 4ml/litre of water and boric acid @ 100 ppm were found statistically at par with each other. The minimum vine length of 1.86 m was found under the control (only water spray). It might be attributed to availability of micronutrients for crop use. Only water spray (control) could not meet the micronutrients need of crop. The results are in confirmation with the findings of Kumar *et al.*, (2012).

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Similar trend was also observed in number of branches/vine and plants sprayed with mixture of all micronutrients (boric acid @ 100 ppm + zinc sulphate @ 100 ppm + ammonium molybdate @ 50 ppm + copper sulphate @ 100 ppm + ferrous sulphate @ 100 ppm + manganese sulphate @ 100 ppm) produced significantly maximum number of branches/vine (13.58), followed by multiplex @ 4ml/litre of water (12.24) and boric acid @ 100 ppm (11.30). Improvement in growth characters as a result of foliar application of micronutrients might be due to enhanced photosynthetic and other metabolic activities which lead to increase in various plant metabolites responsible for cell division and elongation (Hatwar *et al.,*2003). The minimum number of branches / vine (7.40) was obtained in plants grown without micronutrients application (control). The results are similar to findings documented by Singh *et al.,* (2003). Hatwar *et al.* (2003) reported that number of branches plant was significantly higher with combined foliar application of Zn, Fe and B in chilli cv. Jayanti.

Yield was influenced significantly by different treatments. The foliar application of mixture of all micronutrients (boric acid @ 100 ppm + zinc sulphate @ 100 ppm + ammonium molybdate @ 50 ppm + copper sulphate @ 100 ppm + ferrous sulphate @ 100 ppm + manganese sulphate @ 100 ppm) produced significantly highest yield attributes like number of fruits / vine (23.14), fruit length (23.94 cm), fruit girth (9.26 cm), average fruit weight (66.38 g) and fruit weight (1.51 kg/vine). It was followed by multiplex @ 4ml/litre of water and boric acid @ 100ppm. However, foliar application of mixture of all micronutrients, multiplex @ 4ml/litre and boric acid @ 100ppm were found statistically at par with each other in terms of yield attributes (Table 1).

Pawar and Tambe (2016) reported that vegetative growth, curd weight, yield and curd physio-chemical

Table 1. Effect of micronutrients on growth and yield parameters of bitter gourd

Treatment	Vine lengh (m)	No. of branches/ vine	No. of fruits/vine	Fruit length(cm)	Fruit girth (cm)	Avg. fruit weight (g)	Fruit weight/ vine (kg)	Fruit yield (q/ha)	Increase in yield over control (%)	
Control (only water spray)	1.86	7.40	20.28	18.32	6.96	54.10	1.20	80.68	-	-
Boric acid @100 ppm	2.92	11.30	22.98	22.48	8.88	62.12	1.41	94.24	13.56	16.81
Zinc sulphate @100 ppm	2.52	9.76	22.70	21.03	7.92	58.28	1.32	89.12	8.44	10.46
Ammonium molybdate @50 ppm	2.12	8.26	21.94	20.10	7.48	55.72	1.26	84.88	4.20	5.20
Copper sulphate @100 ppm	2.34	9.08	22.38	20.38	7.72	56.57	1.28	86.32	5.64	6.99
Ferrous sulphate @100 ppm	2.48	9.62	22.65	20.92	7.86	57.85	1.31	88.58	7.90	9.79
Manganese sulphate @100 ppm	2.26	8.82	22.18	20.26	7.64	56.15	1.27	85.26	4.58	5.68
Mixture of all (B+Zn+Mo+Cu+Fe+Mn)	3.52	13.58	23.14	23.94	9.26	66.38	1.51	99.68	19.00	23.55
Mixture of all without B	1.98	7.84	20.98	19.62	7.18	54.44	1.23	83.28	2.60	3.22
Mixture of all without Zn	2.02	7.98	21.43	19.78	7.26	54.87	1.24	83.84	3.16	3.92
Mixture of all without Mo	2.84	11.00	22.92	22.18	8.46	61.26	1.39	93.48	12.80	15.86
Mixture of all without Cu	2.68	10.38	22.76	21.53	8.00	59.56	1.35	91.03	10.35	12.83
Mixture of all without Fe	2.06	8.12	21.82	19.94	7.32	55.29	1.25	84.02	3.34	4.14
Mixture of all without Mn	2.78	10.75	22.84	21.66	8.14	59.98	1.36	92.12	11.44	14.18
Multiplex @ 4 ml/litre of water	3.15	12.24	23.04	23.32	9.06	64.23	1.46	97.32	16.64	20.62
SEm±	0.09	0.37	0.58	0.74	0.32	2.22	0.05	3.19	-	-
CD (P=0.05)	0.27	1.07	1.68	2.16	0.93	6.42	0.14	9.26	-	-
CV	6.36	6.56	4.52	6.14	7.00	6.57	6.31	6.22	-	-

qualities were improved with application of boron and molybdenum in addition with RDF in broccoli. Agarwal and Ahmed (2007), Rab and Haq (2012) and Chaudhuri *et al.* (2017) also reported the effect of different micronutrient mixture on average fruit weight in different vegetable crops.

The foliar application of mixture of all micronutrients (boric acid @ 100 ppm + zinc sulphate @ 100 ppm + ammonium molybdate @ 50 ppm + copper sulphate @ 100 ppm + ferrous sulphate @ 100 ppm + manganese sulphate @ 100 ppm) produced significantly highest fruit yield of 99.68 q/ha, followed by multiplex @ 4ml/litre of water with 97.32 q/ha and boric acid @ 100 ppm with 94.24 q/ha. However, these three treatments were found statistically at par with each other in terms of fruit yield. In the absence of foliar application of micronutrients (control treatment) observed lowest fruit yield of 80.68 q/ha.

Similar results were also reported by Raj *et al.*, (2001). In treatment of mixture of all micronutrients, the higher values of yield attributing parameters were observed which are directly associated with fruit yield enhancement. This appreciation in fruit yield might be due to higher micro nutrient availability to bitter gourd crop. The results are similar to Patil *et al.* (2013).

CONCLUSION

It may be concluded that foliar feeding of micronutrients (boric acid @ 100 ppm + zinc sulphate @ 100 ppm + ammonium molybdate @ 50 ppm + copper sulphate @ 100 ppm + ferrous sulphate @ 100 ppm + manganese sulphate @ 100 ppm) produced highest growth and fruit yield of bitter gourd cv. Kalyanpur Barahmasi. Hence, it may be recommended for farmers of Kanpur.

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Current Horticulture **10** (1) 69-70, January–June 2022

Studies on changes in physical characters during development of ber (*Zizyphus mauritiana*) fruits

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An experiment was conducted to study the pattern of physical changes at 15 days interval after fruit setting till maturity in ber (*Zizyphus mauritiana* Lamk.) fruits of cv. Narendra Ber Selection-2 during 2019-20 at college of Horticulture and Forestry, Kumarganj, Ayodhya, Uttar Pradesh. The fruits on tagged current season shoots were harvested 21, 36, 51, 66, 81, 96, 111, 126, 141, 156, 171 and 186 days after fruit setting. Samples were collected from main experiment station. The fruit length increased from 0.38 to 3.75 cm and fruit breadth from 0.23 to 3.32cm during 186 days of fruit growth and development. Increase in weight was observed during all stages and maximum weight was 21.02g at harvesting stage.

Fruit volume increased continuously (from 0.70 to 37.55 cm^3) during entire phase of growth. Pulp and seed weight increased gradually and were traceable only 111 days after fruit setting. Pulp and seed ratio continued to increase from fruit setting till maturity. Specific gravity increased till 51 days after fruit setting (last week of October), thereafter markedly decreased when fruits proceeded towards maturity. Shape of fruits was ovate during entire period of growth and development.

The experiment was conducted at Main Experiment Station, Department of Fruit Science, Acharya Narendra Deva University of Agriculture and Technology, Narendra Nagar, Kumarganj, Ayodhya, Uttar Pradesh, India, during 2019-20. The 27 years old uniform vigorous ber trees of Narendra Ber Selection-2 were selected. The trees received uniform cultural operation throughout the experiment. The trial was laid out in a completely randomized design with four replications. The four fruits from each replication were randomly selected for analysis at 15 days interval. Length and diameter of fruits were measured with help of Vernier caliper. Length was measured across the polar axis fruits, i.e. between apex and stem-end, while fruit diameter at the point of maximum width in the direction perpendicular to axis and expressed in centimeter. The fruit weight was recorded using electronic balances and average weight of fruit was calculated by dividing the total weight of fruits with the number of fruits weighed. The water displacement method was applied to record the volume of fruits and the average fruit volume was expressed as cubic centimeters (cc).

The fresh weight of fruits was divided by volume of fruits to get average specific gravity of fruits. Stone of four fruits, already subjected to measurement of weight, were seperated, and weighed on electronic balance. Average weight per stone was calculated and expressed in gram. The stone weight was subtracted from fruit weight to calculate the pulp weight. The average pulp weight was divided by average stone weight to record the pulp to stone ratio. The shapes of fruits were observed visually. The data on physical characters of fruits were analyzed statistically as per applying the (Panse and Sukhatme, 1967).

Among different stages, maximum fruit length (3.75 cm) was recorded 186 days after fruit setting, followed by 3.62 cm on 171 DAFS and minimum 0.38 cm on 21 DAFS, while marginal increase in length was more up to 66 DAFS. The gradual increase in fruit length was observed during fruit growth from fruit setting to full maturity. Fruit length might increases due to accumulation of water and foods into fruits and more cell division and cell elongation of fruits. Sahu *et al*. (2019) reported that length in ber cvs Gola, Banarasi, Karaka, Umran , Jawahar Ber-1, Jawahar Ber -2, Jawahar Ber-3 fruits increased with advancement of growth and development period. The width of fruit was 2.10 cm on 96th day and reached the maximum (3.32 cm) 186^{th} day and minimum (0.23cm) 21 days of fruit settings (Table 1).

The cell division, cell elongation and accumulation of carbohydrates increased the fruit breadth. This trend

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Table 1. Changes in physical characters during growth and development of ber

Interval (days)	Month	Fruit length(cm)	Fruit breadth(cm)	Fruit weight(g)	FruitVolume(cm³)	Specific gravity	Pulpweight(g)	Seedweight(g)	Pulp and Seed ratio	Fruit shape
21	October	0.38	0.23	0.75	0.70	1.07	-	-	-	ovate
36		1.03	0.61	1.20	0.81	1.48	-	-	-	ovate
51		1.66	1.11	2.01	0.82	2.45	-	-	-	ovate
66	November	2.31	1.59	3.30	2.78	1.18	-	-	-	ovate
81		2.56	1.84	5.23	4.50	1.16	-	-	-	ovate
96	December	2.82	2.10	5.60	5.34	1.04	-	-	-	ovate
111		3.03	2.14	8.92	8.28	1.01	7.86	1.06	7.41	ovate
126	January	3.14	2.38	11.30	14.16	1.03	10.18	1.12	9.08	ovate
141		3.31	2.50	14.41	16.78	1.02	13.28	1.13	11.75	ovate
156	February	3.46	3.03	17.33	22.16	1.02	16.16	1.17	13.81	ovate
171		3.62	3.15	19.71	29.70	0.95	18.54	1.17	15.84	ovate
186	March	3.75	3.32	21.02	37.55	0.92	19.84	1.18	16.81	ovate
SEm±		0.05	0.04	0.09	0.09	0.23	0.3	0.02	0.41	-
CD (5%)		0.14	0.12	0.25	0.25	0.67	0.88	0.05	1.2	-

of fruit breadth increase is in conformity with those of Kumari *et al*. (2015). There was minimum 0.75g fruit weight at 21 days and maximum (34.98g) 186 DAFS. The accumulation of metabolites and water in fruits during growing period at rapid rate results in increased weight. The similar trend in weight of ber fruits is reported by Jat *et al*. (2004). The volume of fruits increased continuously from 0.70cm³ to 37.55 cm³ to 186 DAFS. The increase in volume was statistically significant up till 186 DAFS. The accumulation of metabolites and cell elongation in fruits during the growing period at rapid rate results in increase in volume. The continuous increase in volume of fruits was also reported by Pandey *et al*. (2019). The specific gravity of fruits continuously increased during growth and development up till 51 DAFS.

The maximum specific gravity in fruits was 2.45 at 51 days that was gradually decreased (0.92) 186 days after fruit setting. The increase in specific gravity might be due to accumulation in more metabolites, gaining of higher weight at faster rate than increase in volume. The pulp weight at various stages of fruit growth was non- significant, whereas it was significant at end stage. The minimum weight 5.36g of pulp was found 96 DAFS and maximum (33.01g) 186 DAFS. It is clear that pulp content of the fruit increased continuously during growth and development. The pulp content could not be separated from seed before 111 days of fruit setting. The results are in line of Sahu *et al.* (2019). The seed content increased continuously in ber fruits. The maximum seed weight was 1.97g in 186 days and (0.21g) 96th DAFS. This is consistent with those of Pandey *et al*. (2019). The pulp:stone weight ratio increased from fruit setting till maturity. The results were in line with the findings of (Sahu *et al*., 2019). It is clear that the shape of ber fruit cv. NBS-2 was ovate at all the stages during fruit growth from fruit setting to full maturity. Similar observation was recorded by Godi *et al*.(2016).

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Effect of frontline demonstrations on yield and economics of tomato (*Lycopersicon esculentum*) in Rajasthan, India

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The study was carried out to find out the effect of frontline demonstrations on yield of tomato (*Lycopersicon esculentum* Mill.) at Krishi Vigyan Kendra, Banswara, MPUAT, Udaipur, during 2013-14 to 2016-17 at farmers' fields in different locations of Banswara district. A total 40 demonstrations were conducted at 40 farmers' fields on 8.0 ha lands. Each frontline demonstration was laid out on 0.2 ha area, while adjacent 0.2 ha was considered as the control (farmers' practices). The selection of farmers was done on basis of survey by KVK and special training was organized for selected farmers on tomato cultivation. For the demonstration plot all the recommended package of practices like the use of biocontrol agents (Trichoderma and Pseudomonas) enriched FYM, recommended dose of fertilizers and integrated pest management practices, use of quality seed of improved variety etc. were followed.

The traditional practices were taken as the control. Field days were also conducted to show the results of front-line demonstration to farmers of the same village and neighbouring villages. The district has sub-humid agroclimatic condition with average temperature of 21.3 – 40.6^{0}C in summer and 9.5 – 34.9^{0}C in winter and annual rainfall of 900 mm. Soil of the area is medium red loamy soil. The data on yield, pest management, production cost and returns were collected with frequent field visits from frontline demonstration plots and farmers practice plot (control plot) and finally extension gap, technology gap, and technology index were calculated as per formula.

$$\text{Increase yield (\%)} = \frac{\text{Demonstration yield} - \text{farmers, yield}}{\text{Farmers yield}} \times 100$$

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Technology gap = potential yield—demonstration yield
Extension gap—demonstration yield—yield under existing Farmers' practice

$$\text{Technology index (\%)} = \frac{\text{Potential yield} - \text{demonstration yield}}{\text{potential yield}} \times 100$$

The yield potential due to frontline demonstration ranged from 618.5 to 643.8 q/ha in demonstration plots and from 482.5 to 496.7 q/ha at farmers' fields during all the years. The average yield of 633.03 q/ha was obtained under demonstration plots as compared to 489.40 q/ha at farmers fields. Higher yield in demonstration plots due to knowledge and adoption of biofertilizer enriched FYM, recommended dose of fertilizers, preparation of raised beds and timely application of plant protection chemicals. The average yield of tomato increased by 29.36 %. The yield of tomato could be increased over the yield obtained under farmers, practices (lack of knowledge on use of bio fertilizers, no use of balanced dose of fertilizer, no IPM practices) of tomato cultivation.

The above findings are in similarity with the findings of Kumar *et al.* (2017). Similarly yield enhancement in different crops in frontline demonstrations were documented by Kumar *et al.* (2014). The increment in yield ranged from 26.17 to 31.87 per cent. The per cent increase in yield over farmers, practice was highest (31.87) during 2016-17. However variations in yield of tomato in different years might be due to the variations in soil moisture availability, rainfall, and change in location of demonstrations every year.

Extension gap of 128.3, 140.5, 150.1 and 155.6 q/ha was observed during all the years. On an average extension gap was 143.63 q/ha (Table 1). This

Table 1: Productivity, technology gap, technology index and extension gap in tomato under FLD

Years	Area (ha)	No. of farmers	Yield (q/ha)			increase in yield (%)	Extension gap (q/ha)	Technology gap (q/ha)	Technology index (%)
			Potential	Demo	Farmers practice				
2013-14	2.0	10	750	618.5	490.2	26.17	128.3	131.50	17.53
2014-15	2.0	10	750	637.2	496.7	28.29	140.5	112.80	15.04
2015-16	2.0	10	750	632.6	482.5	31.11	150.1	117.40	15.65
2016-17	2.0	10	750	643.8	488.2	31.87	155.6	106.20	14.16
Average	-	-	750	633.03	489.40	29.36	143.63	116.98	15.60

Table 2: Comparative B:C analysis of tomato under FLD and farmers 'practice

Year	Cost of cultivation		Gross return (Rs./ha)		Net return (Rs./ha)		B:C ratio	
	Demo	Local check	Demo	Local check	Demo	Local check	Demo	Local check
2013-14	81,000	75,000	3,09,000	2,45,000	2,28,000	1,70,000	3.81	3.27
2014-15	84,000	75,000	3,19,000	2,48,000	2,35,000	1,73,000	3.80	3.31
2015-16	84,900	75,500	316300	2,41,300	2,31,400	1,65,800	3.73	3.20
2016-17	90,000	80,000	321900	2,44,100	2,31,900	1,64,100	3.58	3.05
Average	84,975	76,375	3,19,067	2,45,000	2,31,575	1,68,225	3.73	3.21

emphasized the need to educate the farmers through various techniques for adoption. On an average, technology gap was 116.98 q/ha. This may be due to the soil fertility, managerial skills of individual farmers' and climatic condition of area. Hence, location-specific recommendations are necessary to bridge these gaps. These findings are similar to Singh *et al.* (2011) .The technology index shows feasibility of demonstrated technology at the farmers' fields. The technology index varied from 14.16 to 17.53 % (Table 1). On an average technology index of 15.60 % was observed during the four years.

The cost of production of tomato under demonstration varied from ₹ 81,000 to ₹ 90,000 /ha with an average of ₹ 84,975 as against ₹ 75,000 to ₹ 80,000 with an average ₹ 76,375 under control. The additional cost increased in demonstration was mainly due to more cost involved in balanced fertilizer, procurement of improved hybrid seed and IPM practices. The cultivation of tomato under improved technologies gave higher net return of ₹ 2,28,000, ₹ 2,35,000, ₹ 2,31,400 and ₹ 2,31,900 /ha during 2013-14, 2014-15, 2015-16 and 2016-17 respectively with an average net return of ₹ 2,31,575 /ha which was lower ₹ 1,68,225 at farmers' fields. The benefit: cost ratio of tomato ranged from 3.58 to 3.81 in demonstration plots and from 3.05 to 3.31 at farmers' fields (Table 2). This may be due to higher yield obtained under improved technologies compared to the control.

This finding is similar with the findings of Singh *et al.* (2011), Choudhary *et al.* (2017). Similar findings are also reported by Chapke (2012) in case of jute. The B:C ratio was recorded to be higher under demonstration against control during all the years.

The study concludes that FLDs conducted by KVK, Banswara, made significant impact on horizontal spread of this technology. The productivity gain under FLD over existing practices of tomato cultivation has created greater awareness and motivated other farmers to adopt the demonstrated technologies for tomato production in the district which helps to enhance the vegetable production, consumption, nutritional security and overall livelihood security of Banswara.

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