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# *Current Horticulture*

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# CURRENT HORTICULTURE

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Mini Research Review

*Current Horticulture* **8**(1): 3–6, January–June 2020

# Role of arbuscular mycorrhizas in citrus (*Citrus* spp.) crop production—a review

Ying-Ning Zou, Bo Shu and Qiang-Sheng Wu*

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**Received:** Januaryy 2017; **Revised:** March 2019

**ABSTRACT**

Arbuscular mycorrhizal fungi (AMF) are found in rhizosphere of citrus (*Citrus* spp.) crops to form mutualistic symbiosis with roots, arbuscular mycorrhizas. The AMF have been confirmed to increase plant growth, enhance nutrient acquisition and stress tolerance, improve fruit quality, and stabilize soil aggregation. Such roles of mycorrhizal symbiosis are an important part of the normal growth of citrus trees. However, low mycorrhizal colonization of roots is found in citrus grown in open field. The growth of AMF needs a good soil environment and supply of plant carbohydrates. On the other hand, some technologies of citriculture can also affect mycorrhizal growth and activity. The present mini review simply outlined mycorrhizal growth in roots, and paid attention to horizontal roots. Mycorrhizal roots of citrus require the characteristics of loose aeration, water-repellent, moist and slightly acidic soils. In addition, proper pruning and thinning of flowers and fruits, mulch, no tillage, enough sunlight, appropriate soil moisture and nutrient content, and mycorrhized seedlings at transplanting are collectively conducive to the growth and activity of arbuscular mycorrhizas. Some highlights regarding AMF management in citriculture are also briefly proposed.

**Key Words**: Arbuscular mycorrhizal fungi, Citrus, Mycorrhiza, Rhizosphere, Symbiosis, Tree management

Citrus crops are perennial evergreens and endophytic mycorrhizal plants (Srivastava, 2014). In general, root hairs of citrus plants are generally absent, thus, strongly relying on its symbiotic fungi, arbuscular mycorrhizal fungi (AMF), to partly replace nutrient acquisition of root hairs (Qrtas, 2017; Wu *et al.*, 2013, 2017b). The AMF can form arbuscular mycorrhizas (AMs) with roots of citrus, in which AMF provides the mineral nutrients and water needed by the plant and increases the ability of plants to tolerate abiotic stress, including salt stress, drought stress, high temperature stress, and diseases and insect pests (Liu *et al.*, 2019). In field, if citrus trees are associated with the lack of mycorrhizal fungi, there are the symptoms of stunting and nutrient deficiency in citrus (Menge, 1977; Gao *et al.*, 2018). Through photosynthesis and a series of complex physiological and biochemical changes, plants form a variety of complex organic compounds, some of which are transported down to their roots and feed the symbiotic fungi for life (Jiang *et al.*, 2017). However, the nature populations of AMF in citrus orchard have been seriously destroyed by plenty of fertilizer and fungicides (Menge, 1983), resulting in low mycorrhizal colonization of citrus roots (Wu *et al.*, 2004). People have tried to produce commercial AMF to increase agricultural output and reduce fertilizer use in field. AMF use for mycorrhizal formation on citrus seedlings is proposed and subsequently transplanted to the open field.

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## Mycorrhizal growth in roots

Citrus roots are important for tree anchorage and support, as well as the collection and transport of water and nutrients (Junior *et al.*, 2012). Citrus plants possess vertical roots and horizontal roots. Among them, horizontal roots have a great influence on development of above ground parts. The horizontal roots are well developed, with fine meristematic roots, many lateral roots and dense distribution of absorbent roots (Testezlaf *et al.*, 2007). The water and mineral nutrients needed by citrus plants during each growth period must be provided by arbuscular mycorrhizal symbiosis from the soil. It has a strong ability to absorb water and mineral nutrients from the soil to the fungal partner, which is beneficial to the smooth transformation of citrus above ground parts from vegetative growth to reproductive growth. As a result, the growth of citrus root systems, especially horizontal roots and mycorrhizal status, directly affects the whole metabolism and various life activities. Hence, mycorrhizal growth in citrus roots is closely related with tree growth, flowering and fruit-bearing characteristics.

In China, Wu *et al.* (2004) observed 12.94 - 27.42% of root mycorrhizal colonization in citrus plants grown in the three gorge reservoir region. In the Citrus unshiu 'Guoqing No. 1' grafted on trifoliate orange, vesicles, arbuscules, entry points, internal hyphae, external hyphae and internal chlamydospores were observed (Wu and Xia, 2010). In addition, few vesicles and many arbuscules were found in mycorrhizal roots. Mycorrhizal colonization by native AMF was found in root elongation zone and maturation zone, as well as root tip and meristematic zone. Rodríguez-Morán *et al.* (2015) reported that in Citrus macrophylla seedlings colonized by a mixture of two AMF, arbuscules were scattered through the cells of medium and inner cortex, with the outer cortical cell layers relatively free of intracellular fungal structures. On the other hand, vesicles were also located in intercellular spaces of the same cortical cell layers.

## Mycorrhizal roles in citrus

As outlined by Wu *et al.* (2017a), mycorrhizal functionings on citrus plants are as follows :

- Enhancement of nutrients;
- Improvement of fruit quality and plant growth;
- Optimization of root system architecture;
- Enhancement of tolerance in response to drought stress, salt stress, high temperature stress, flooding, and plant diseases;
- Improvement of soil structure by mycorrhizal extraradical hyphae and glomalin (a mycorrhiza-related metabolite);
- Increase of soil fertility through hydrolases, and glomalin contribution of soil organic carbon.

## Growth environment of mycorrhizas in citrus

Although AMF are heterotrophic fungi, AMF can adapt to various unfavorable environmental conditions, including high salinity, low soil water content, waterlogging, deserts, beaches, *etc.* (Miransari, 2010). In rhizosphere, AMF was confirmed to release organic acids (*e.g.* acid phosphatase) and hydrolases (*e.g.* chitinase and chitosanase) in the surroundings of roots to form a relative acid mycorrhizosphere or hyphosphere (Bestel-Corre *et al.*, 2002). On the other hand, mycorrhizal hyphae have a dramatically higher osmotic pressure than root hairs, which is beneficial for the absorption of soil water and nutrients by mycorrhized roots. Furthermore, AMs also ingest carbohydrates and fatty acids from citrus for its growth and development (Jiang *et al.*, 2017).

As a result, when the accumulation of carbohydrates and other organic compounds in roots is relatively abundant, it can stimulate the growth and reproduction of mycorrhizal fungi, which benefit for growth, physiological and metabolic activities of citrus trees. However, sometimes things do not work out that way. The vigorous growth of AMF sometimes leads to excessive consumption of carbohydrates and fatty acids, which is not good for citrus growth. Mycorrhizal fungi are limited in their ability to adapt to unfavorable conditions.

Junior *et al*. (2012) recommended the ideal environment for citrus roots that grew in a porous, medium-textured, well-drained soil, where water is easily available but not in excess. In general, when AMs are found in roots, citrus roots require the characteristics of loose aeration, water-repellent, moist and slightly acidic soils. Hence, Li (1997) proposed the relevant boundary conditions needed by mycorrhizal growth and activity:

**Soil temperature :** In general, 15-25? is suitable for the growth of mycorrhizas and roots. Too high or too low is not conducive to the normal activities of mycorrhizal fungi, and even causes the death of mycorrhizal fungi.

**Soil moisture and aeration status :** The annual precipitation of 1200-2000 m is appropriate. Soil relative water content ranges from 60 to 80% of the maximum field water capacity, and the oxygen content of soil voidage is more than 8%. Long-term waterlogging will form soil plate formation, oxygen content decreased, so that mycorrhizas cannot be normal activities, even death.

**Soil pH :** Soil pH can change the physical and chemical properties of soil. It also directly affects microbial activity and the decomposition of nutrient elements. Thus, it affects the soluble levels of nutrients in soil and the absorption and utilization of nutrients by trees. The soil pH value is 6 ~ 6.5, and it should not be lower than 5 or higher than 8, otherwise the growth of AMF is disadvantageous. If the soil pH value in citrus orchard is low, mycorrhizal formation of citrus trees is less. So, it is necessary to apply magnesium oxide ash to raise the soil pH value.

**Light and tree nutrition:** If citrus plants are grown in a sunny environment, citrus can synthesize more photosynthates, resulting in more carbon compounds transferred from sources to pools (*e.g.* roots) to support the activity of mycorrhizal fungi. When tree bears too many fruits or leaves are damaged, carbon compounds in the root are not enough, and the mycorrhizal fungi do not grow well, thus affecting its absorption of mineral nutrients and water from soil to plant.

**Fertilization and soil nutrition :** Under the conditions of nutrient-rich soils and fertilization, roots are well developed and the fine roots are dense. Such roots can absorb a larger number of soil nutrients. This results in inhibition of mycorrhizal growth and functions. As reviewed by Zou *et al.* (2019), mycorrhizal functions depend on growth of roots and root hairs and soil nutrient status. To keep high capacity of AMF activity, less fertilization and relative nutrient-deficiency are necessary.

### Mycorrhizal requirements on citri-culture technology

According to the characteristics of mycorrhizal activities, following points should be paid attention to citrus cultivation process:

**Soil management :** The soil layer needs to be deep, the soil structure is loose, the groundwater level is low, the soil permeability, water retention and drainage ability are good, and soil is slightly acidic (pH 6~6.5), which collectively promote root growth and mycorrhizal fungal activity.

Mulch in tree crown can improve soil structure and ventilation conditions. Mycorrhizal activity also stimulates the decomposition of mulch to promote soil fertility. Ploughing and weeding must be reduced to prevent the damage of mycorrhizal extraradical hyphae or mycorrhizal hyphal network between adjacent citrus trees or between citrus and intercrop.

Use of herbicides in citrus orchards strongly reduces mycorrhizal colonization of citrus. As reported by Carrenho *et al.* (1998), metalaxyl at higher concentration tended to reduce the number of spores of AMF in rhizosphere of *Citrus sinensis/C. limon*. However, no tillage in citrus orchard is beneficial for mycorrhizal formation, because the grass itself has some mycorrhizal formation, which can increase mycorrhizal growth of citrus (Hu, 1993). Although grass and citrus trees have the problem of competing for nutrients and water, the growth of grass in orchard in mountainous area can also prevent the loss of water and soil.

The addition of exotic soil to citrus rhizosphere not only increases the root domain, but also increases the density of mycorrhizal fungi in soil, due to large amount of AMF in exotic soil (Hu, 1993). The citrus roots with low mycorrhizal density can be infected by adding exotic soil containing native mycorrhizal community.

**Sites of citrus planting in mountain:** Many of citrus plants are planted in mountain. We propose that in the low-temperate zone, south slope facing the sun should be chosen; in high temperature zone, it is advisable to choose the north slope with small amount of light to build gardens, so as to ensure a reasonable light intensity for photosynthesis. Adequate photosynthesis will provide energy for growth of roots and mycorrhizas.

**Nutrient and water management :** Organic fertilizers such as decayed farm manure, cake fertilizer, compost, soil manure, manure, *etc.* are appropriately applied to outer canopy of trees in an appropriate depth. Such nutrient management can strengthen the activity of AMF. It is well documented that AMF effectively absorb nitrogen, phosphorus, and other elements from the soil, thus reducing the demand for fertilizer (Bagyaraj *et al.*, 2015). Mycorrhizal fungi are microorganisms that require oxygen for its growth. Appropriate soil moisture content is conducive to the growth of AMF. In addition, the water-use efficiency of citrus is relatively higher than other crops, and water use of citrus in mid-summer is 0.4 - 0.5 cm / day (Parsons and Wheaton, 2000). Too much or too little soil moisture is bad for mycorrhizal activity.

**Transplanting :** We propose the use of mycorrhized citrus seedlings before citrus transplanting. At seedlings stage, the trees have established good mycorrhizal growth. Wu *et al.* (2019) also developed a technique to propagate indigenous AMF. The fresh root segments with the diameter of < 2 mm as the source was propagated with white clover in pots. Such propagated mycorrhizal inoculums can be used in tree transplanting. Citrus plants infected with exotic mycorrhizal fungi can promote the absorption of phosphorus and other mineral elements in the root system, increase the growth of the plant, and improve the resistance.

**Pruning and fruit management :** During tree management, proper pruning and thinning of flowers and fruits should be carried out to reduce nutrient and carbohydrate consumption in the aboveground part, so that more nutrients and carbohydrates can transfer into the root for mycorrhizal growth.

### Future outlook

Mycorrhizal roles in citrus plants have been widely recognized, while the information regarding mycorrhizal management in citriculture is scarce. In fact, many citrus growers do not know much about mycorrhiza, which requires more publicity by researchers. In developing and developed countries, one or two standard model gardens of mycorrhizal management in citrus should be established to promote the benefits of mycorrhizale in citrus orchards and also popularize mycorrhizal fungi. Mycorrhizal roles are related with soil nutrient status and tree photosynthesis, the role of which needs to be concerned in citrus orchards.

Although there are some difficulties in propagating AMF, great efforts are needed. In the future, growth and reproduction of indigenous mycorrhizal fungi should be more considered, because exotic mycorrhizal fungal application has possibly the biological invasion risk.

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**Research Review**

*Current Horticulture* **8**(1): 7–11, January–June 2020

# Evaluation of genetic resource of Chinese potato *(Plectranthus rotundifolius)* for abiotic stress management — a review

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**ABSTRACT**

Tropical tuber crops are mainly grown in limited scales even in the areas where they are consumed as staple foods. Due to change in the feeding habits tuber crops are gradually disappearing from the human diet. There is a necessary to promote the tuber crops cultivation by realizing their nutritional value and adaptability to harsh weather conditions. Chinese potato is one of the important minor tuber crops of nutritional and commercial value in tropical regions of the world. Chinese potato *(Plectranthus rotundifolius)* belongs to the family Lamiaceae *(Labiatae)* of order Lamiales with a chromosome number of 2n= 64. It has several medicinal properties due to the presence of flavanoids that help to lower the cholesterol level of blood. It is facing several production problems like photosensitivity, low yield and poor tuberization. Moreover, very less genetic variation is available in the country. As germplasm serves as an invaluable source of variation, there is a necessity to collect, conserve and make utilisation of it.

**Key Words**: *Abiotic stress, Chinese potato, Genetic resource, Tuber crops, Value-addition*

Tropical tuber crops are climate resilient crops as they have enormous potential to feed millions in tropical and subtropical regions of the world. Among these crops, tapioca, sweet potato, yams, taro and elephant foot yam are cultivated on moderate to large scale in India. The other tropical tuber crops namely, Chinese potato (*Plectranthus rotundifolius* (syn.) *Solenostemon rotundifolius*), West Indian Arrowroot *(Maranta arundinacea)*, Queensland Arrowroot *(Canna edulis)*, East Indian arrowroot - Tuikhur *(Curcuma angustifolia)*, Insulin plant *(Costus igneus)*, Yam Bean *(Pachyrrhizus erosus)*, Tvphorrium species, Typhonium flagelliforme, Tacca pinnatifida, Aisaema sp, Vigna Vexillata etc. are known widely (Singh and Arora, 1978), but their cultivation is very much limited in India. Tuber crops over past many years have created a niche in food security of millions of people, especially in tropical and subtropical regions of the world, as they form the third most important food crop after cereals and legumes (Remya Remesh *et al.*, 2019).

However, several minor tubers are mostly known by local languages and they are not fully domesticated for commercial cultivation. Majority of the minor tuber crops are under-exploited mainly due to their lack of adaptability and other physiological constraints. The minor tuber crops have very good potential for exploitation for food, nutrition and other uses. Since food and nutritional security is very important nowadays, its requirement can be met through traditionally known and sustainability feasible minor tubers (Kana *et al.*, 2012).

It is to be noted that many parts of wild plants especially, tubers and starchy rhizomes are consumed as staple and main foods. Several wild tubers are utilized as traditional starchy source and ayurvedic medicines by the tribal's and other communities living nearer to forest regions. Due to the alarming loss of genetic resources; nutrient deficiency often prevails in the underdeveloped tribal areas. Due to the rapid increase in human population and consequent shortages of grain crops, collection, improvement and utilization of underutilized tuber crops such as Chinese potato are of paramount importance (Vimala and Nambisan, 2005). Although many of the minor tuber crops produce flower, almost most of them are not found to produce seeds which affect breeding and improvement strategies (Prematilake, 2005). The tuber crops are predominantly propagated utilizing tubers

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of varying shapes and sizes. Genetic improvement and variety development of various minor tuber crops are still scanty (Nkansah, 2004). These crops have been neglected for years (Enyiukwu *et al.*, 2014). Neglected species are considered important in developing countries as they play the important role in meeting food and nutrition and income generation to farmers (Padulosi *et al.*, 2013). There is the need for a renovated concerted effort for collection, conservation, evaluation and cataloguing of genetic resources of minor tuber crops (Olojede *et al.*, 2005). The application of improved breeding techniques will help to increase yield coupled with tolerance to abiotic and biotic stresses (Achigan-Dako *et al.*, 2015). Therefore, studies were undertaken on the genetic resources, their constraints and strategies of conservation of Chinese potato *(Plectranthus rotundifolius)* have been presented with an objective to promote its effective utilization and varietal development.

## CHINESE POTATO

Chinese potato (*Plectranthus rotundifolius* Syn. *Solenostemon rotundifolius*, *Coleus rotundifolius*, *Plectranthus tuberosus*, *Coleus parviflorus*) belongs to the family Lamiaceae (Labiatae) of order Lamiales with a chromosome number of 2n= 64. Chinese potato is a very important crop in several countries of Africa and Asia (Aculey *et al.*, 2011). It is reported to be originated from East Africa then it spread to tropical West Africa and then to Southeast Asia including India, Sri Lanka, Malaysia and Indonesia (Harlan *et al.*, 1976). In Asia, Chinese potato is reported to be cultivated in Sri Lanka, South India and Java (Jayakody *et al.*, 2005). They occur wild in grassland in East Africa region and even at high altitude (2200 m) in Kenya (Nkansah, 2004). It grows over a wide range of climatic and edaphic conditions, consequently, morphological characters also vary among populations (Agyeno *et al.*, 2014). It has an aromatic flavour and delicious taste on cooking. These tubers are rich in minerals like calcium, iron and certain vitamins including thiamine, riboflavin, niacin and ascorbic acid (Jayapal *et al.*, 2015). The aromatic flavor of the tuber makes it a sought vegetable and is reported to have medicinal properties due to the presence of flavanoids that help to lower the cholesterol level of blood (Horvath *et al.*, 2004; Abraham and Radhakrishnan, 2005; Sandhya and Vijayalakshmi, 2005) and enzyme inhibitors (Prathiba *et al.*, 1995).

It has simple leaves with serrate margins, oppositely attached to a succulent, square-shaped stem. Some plants have a central purple marking on the lamina (NRC, 2006). Leaves are green, light-green and olive-green with toothed margins in leaves (Opoku-Agyeman *et al.*, 2004). Three landraces of P. esculentus are known on the basis of their variability, namely 'Bebot', Riyom'and Longat' while *S. rotundifolius* consists of *S. rotundifolius* var. nigra and S. rotundifolius var. alba (Agyeno *et al.*, 2014). Clusters of starchy and brown or black tubers are present at the base of the primary stem. According to Opoku-Agyeman *et al.* (2004), the leaves of Chinese potato are predominantly (over 90%) green with the following variations; green, light-green and olive-green colours. The most negative characteristic of S. rotundifolius is the small tubers (Prematilake, 2005). Large size tubers are also reported (Opoku-Agyeman *et al.*, 2004) in India and Sri Lanka where productivity is high when compared to African conditions. Tubers of Chinese potato are reported to have variation in shapes, sizes and colours. Tuber skin colour can be red, white or black (Dittoh *et al.*, 1998). According to Tindall (1983), *Solenostemon rotundifolius* has three varieties with respect to skin colour: var. nigra A. Chev. (black in colour), var. rubra A. Chev. (reddish-grey or reddish yellow in colour) and var. alba A. Chev (white in colour). Even though tubers of Chinese potato are of different colours, the tuber flesh in all three varieties is white (Opoku-Agyeman *et al.*, 2004). However, dark-brown, reddish-yellow and light-grey flesh colours have also been documented (Burkill 1985). Nanema *et al.* (2018), reported significant variability in young plant colour, leaves morphology, colour and form of inflorescence as well as tuber skin and flesh colour in three accessions (E02, E35 and E20) collected in Burkina Faso. The yield is very low and owing to the poor seed setting and no appreciable variability is present in the population for genetic improvement. Currently, a spacing of 90 cm × 20 cm with seed tuber weight of 7-10g is reported to be ideal for higher yields (Bayorbor and Gumah, 2007). However, spacing recommended for cultivation in Kerala is 45 cm × 30 cm (Ravindran *et al.*, 2013).

The important national and international institutions that maintain and conserve genetic resources of Chinese potato are discussed here (list is not exhaustive). Outside Africa, collections are maintained at the Plant Genetic Resources Centre, Gannoruwa, ICAR-Central Tuber Crops Research Institute, Kerala Agricultural University and several South East Asian countries.

In Ghana, Chinese potato is extensively cultivated in the northern part of the country (Aculey *et al.*, 2011). It is also popular in the border country of Nigeria where it is cultivated in the middle and North Eastern regions (Enyiukwu *et al.*, 2014). Chinese potato genetic resources are maintained and conserved through cryopreservation (Bennett-Lartey *et al.*, 2008) in the Botany Department (BD) of the University of Ghana (Kwarteng *et al.*, 2018).

At the Plant Genetic Resources Research Institute (PGRRI), Ghana, the research works done during 1990 to 2000 under Root and Tuber Improvement Project (RTIP) on Chinese potato and genetic resources are mostly conserved. These genetic resources collected through RTIP project of PGRRI are also duplicated in the other institutes under National Research Agricultural System. The institute's names are 1.Crops Research Institute (CRI), 2. Savanna Agricultural Research Institute (SARI), 3. Agricultural Research Center (ARC) at Kade in the Eastern Region, 4. Directorate of Crop Services (DCS) and 5. University of Cape Coast Ghana (Bennett-Lartey *et al.*, 2008).

Vegetable and Ornamental Plant Institute, Pretoria, South Africa conserves germplasm of *S. rotundifolius* collected in Malawi, Zambia and South Africa (Kwarteng *et al.*, 2018) Accessions of *Plectranthus*, *Manihot*, *Solenostemon* and amadumbe (*Xanthosoma* and *Colocasia*) are maintained as field collections in the glasshouse and *in vitro*. They have established genebanks for the conservation of their precious plant genetic resources. (http://www.arc.agric.za/arc-vopi/Pages/Plant%20Breeding/Indigenous-Vegetables-Genebank.aspx).

Pant genetic resources centre (PGRC) was established under the grant of Japan international cooperation (JICA) in 1988 at Gannoruwa Agriculture Complex. The PGRC has national responsibility for conservation of all the crop varieties and their wild relatives in Sri Lanka (https://www.doa.gov.lk/SCPPC/index.php/en/institute/35-pgrc-2). Chinese potato accessions also maintained in the station (Nkansah 2004) and tissue culture technique has been followed to induce somaclonal variants to broaden the genetic base of the crop for future. Callus culture regeneration of *S. rotundifolius* has been reported by Prematilake (2005) and media protocols were developed to regenerate plants from leaf explants and variants (plant structure, leaf colour and tuber size). Experimental *in vitro* multiplication by tissue culture was successful, using stem meristems, apices and nodes.

A total of 155 accessions of *S. rotundifolius* representing the major geographical sites in Burkina Faso were characterized for assessing the genetic variability at University of Ouagadougou, Unit of Training and Research in Science of Life and Earth, Laboratory of Genetics and Plant Biotechnology, Burkina Faso. Except for tuber size, variation was reported for vegetative and tuber yield (Nanema et al., 2009).

There are eighty-seven collected accessions of Chinese potato conserved in the field gene bank of ICAR- Central Tuber Crops Research Institute, Thiruvananthapuram, India (Mukherjee *et al.*, 2015) and it is reported that significant difference existed in tuber size within the accessions and not between the accessions. Chinese potato is easily be propagated through tuber sprouts and cuttings and *S. rotundifolius* was regenerated either via axillary shoot proliferation, organogenesis or somatic embryogenesis and when the plants are transplanted in the field after they have been regenerated through callusing and somatic embryogenesis, they produce bigger tubers as well as higher yield in the range of 100-220 g/plant. The average starch content and dry matter values 16.5-20% and 26.4-35.6%, respectively were obtained (Mukherjee *et al.* (2015). A promising selection (CP-58) was released as for cultivation in the state of Kerala. This variety Sree Dhara has a yield potential of 25-28t/ha and its tuber is dark brownish and with aromatic flavour (http://www.ctcri.org/varieties/dhara.php).

Sixty coleus genotypes collected from different ecogeographical regions are conserved at College of Horticulture, Vellanikkara and Vellayani, Kerala Agricultural University, India. They showed genetic diversity in terms of high heritability for tuber yield, harvest index, biological yield/plant, and tuber volume and tuber weight. Ethyl methanesulphonate had induced genetic variability in coleus (Abraham and Radhskrishna, 2005). An increase in the concentration of mutagens results in delayed sprouting (Abraham and Radhakrishnan 2009).

*In vitro* regeneration and successful establishment ex vitro with 85% survival was achieved using juvenile shoot tips and nodal segments of Chinese potato at Division of Plant Genetic Resources, Indian Institute of Horticultural Research, Bangalore, India. Nodal segments of Coleus species were observed to be the most appropriate ex-plant source for initiation of cultures (Rajasekharan *et al.*, 2010).

The positive Genotype × Environment for tuber characteristics was observed by Karuniawan *et al.* (2016) in Indonesia. The study of black potato germplasm in Java, Indonesia have shown variation for morphological characters (Nuraeni, *et al.*, 2012), but molecular marker study revealed narrow genetic variability (Yulita *et al.*, 2014).

## CONSTRAINTS AND FUTURE STRATEGIES

Chinese potato is an important minor tuber crop. Current problems associated with this crop are low yield, photosensitivity, small size tubers for which great attention is warranted for collection, evaluation, conservation and utilization. Chinese potato is one of the neglected and underutilized crops which exhibit superior performance under extreme soil and climatic conditions of Asia and Africa (Tadele, 2009). Chemical mutagens and tissue culture technologies have been employed to regenerate plantlets with desired variations and broadening the genetic base of the crop. The experiments by researchers utilizing the different cultivars of Chinese potato indicated that this plant produces small size tubers and in some cases 'branched' tubers. The future research programme has to be planned to overcome these problems. Breeders, therefore, need to develop high yielding cultivars with non-tuber branching capacity in addition to withstanding the fluctuations of the weather (Enyiukwu *et al.* 2014). As there are reports of variations for large size tubers in Africa and outside Africa; international exchange of germplasm for mutual benefits also may be attempted. It is easily propagated and disease resistance makes it an interesting tuber crop for the lowland tropics. To further widen the genetic base germplasm with wide variability intensive advance breeding technologies are recommended for achieving high-yielding cultivars even under abiotic stress conditions.

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Research Review

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# Cultivation of underutilized fruit crops in hot semi-arid regions: developments and challenges — a review

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**ABSTRACT**

There are quite a large number of indigenous and underutilized fruit crops, which are used by the local inhabitants. In fact, these fruits are the only source of protective food to meet the need of vitamins and minerals of people living in villages. Owing to curative properties, these fruits are used in Ayurvedic and Unani medicines since time immemorial. Apart from their nutritive and medicinal values, a few underutilized fruits have excellent flavour and very attractive colour.Their cultivation is very restricted and they grow mainly as wild. Being tolerant to biotic and abiotic stresses, these fruit crops are suitable for growing in the drought prone areas.Since India has a rich heritage of indigenous fruit types, some of them have already been recommended for commercial planting. It is apparent that there are more fruit crops that await future exploitation. Semi-arid fruits are the oldest fruit tree crops with wide distribution, reflecting their adaptation to a wide range of edapho-climatic conditions of our country. The understanding of various agro-techniques, propagation methods, canopy management, and biotic and abiotic stresses management are equally important for improving their productivity and quality. These crops are known as underutilized but they are locally abundant, and restricted to their geographical location owing to dearth of scientific knowledge. These crops like bael, jamun, tamarind, chironji, khirni custard apple, etc. are immensely constructive and climate smart by surviving in harsh agroclimatic conditions, and can be established on degraded lands, which are presently being underutilized. Therefore, to review the research work done and exploring lacunae in these potential crops critically has become the need of the hour. Hence, research review paper deals all issues and challenges pertaining to these fruit crops.

**Key Words**: Arid region, Extreme weather, Production potential, Semi-arid fruits, Underutilized fruit crops

The Indian semi-arid regions are characterized by extreme temperature, erratic rainfall, poor soil and water quality, which ultimately limit the productivity of fruit crops. However, these conditions can favourably be utilized to enhance the productivity through advanced fruit technological interventions, resulting in more income by utilizing solar and wind energy, human work force, and developing infrastructural facilities which greatly favour in doubling the income of farmers.

There is a plenty of scope for quantum jump in fruit production in semi-arid areas. The regions have strength to produce high quality bael, lasoda, khirni, karonda, jamun, chironji, tamarind, wood apple, custard apple, fig, phalsa, mulberry, manila tamarind, timru, mahua and palmyra palm (Saroj *et al.* 2018; Singh and Singh, 2012). These fruits are source of income and nutrional security to inhabitants in arid and semi-arid regions (Singh and Singh 2015c, 2015d, 2016a, 2016b and 2016c)

The existing low productivity could be enhanced by following improved new sustainable technologies and inputs with or without irrigation. The amelioration of the extreme conditions is also considered vital for life support to the inhabitants. The recent awareness regarding the potential of these ecologically fragile lands for production of quality produce has not only opened up avenues for providing sustainability in

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livelihood and nutritional security but at the same time for bringing new areas also to increase fruit production. The area expansion and yield potential of semi-arid fruit crops has increased manifold because of development of new varieties and advancement in agro-techniques and processing techniques for development of value-added products.

## Demographic status of hot semi-arid fruits

In India, semi-arid zone occupies nearly 37 per cent of the total geographical area (131 million ha) of the total 329 million ha of the country's geographical area, and spread over in Maharashtra (19%), Karnataka (15%), Andhra Pradesh (15%), Rajasthan (13%), Gujarat (9.5%), Tamil Nadu (10%), Uttar Pradesh (7%) and Madhya Pradesh (6%). Semi-arid region is characterized by moisture stress and poor soil and water quality. The annual average rainfall in the semi-arid regions ranges between 290 and 750 mm, which is 2-3 times lesser than potential evapotranspiration. Therefore, fruit crops selected for the region must be tolerant to abiotic stresses and should have reproduction phase synchronized to maximum moisture availability period.

The prevailing stressed conditions necessitate special technologies relating to suitable cultivars, propagation techniques, cultural practices, plant-protection measures and utilization methods to realize maximum value. In semi-arid region, a number of farming communities have small land holdings and poor resources, and cannot afford the burden of credit with available resources, but they can generate income by using scientific rainfed horticultural technologies. Due to erratic rainfall pattern in this region, appropriate technology is needed to increase productivity. With increasing biotic and abiotic pressure, most of the semi-arid regions are confronted with challenges of low productivity due to uncertain supply of water.

## Medicinal significance

The nutritional values of most of the underutilized fruits are numerous and they are recommended to be included in use of daily diet. They are widely used in formulations of various ayurvedic medicines owing to rich in minerals, vitamins and phytochemicals. These fruits are rich in flavour and aroma. Beside their importance for nutritional, therapeutical and economic value, diversity of these fruits also has cultural and social value, contributing to the stability of ecosystem. Cultivation and consumption of these crops may be helpful in overcoming the nutritional deficiencies predominant in rural / tribal areas. They also improve socio-economic conditions of poor masses of the country.

In addition to socio-economic and ecological advantage, such fruits have numerous medicinal properties as its different plant parts have pharmacological activities. Therefore, these fruits are rich in minerals, vitamins and phyto-chemicals which need to be harvested for commercialization and utilization of wasteland simultaneously. Biological activities of semi-arid fruits are presented in Table 1.

## Morphology, reproductive biology and pollination

At CHES, Godhra, germplasm of bael, jamun, mahua, tamarind, wood apple, custard apple, khirni, karonda, chironji, phalsa and wild noni have been studied for their morphology, flower characters, mode of pollination and pollinating agents. Wide range of variability in leaf morphology, flower characters and phenology has been reported in different germplasm of hot semi-arid fruits under rainfed semi-arid condition (Singh *et al.*, 2013a). Singh *et al.* (2015a) reported intervrietal morphological variability in terms of leaf base margin and apex in bael varieties under rainfed semi-arid conditions. Different pollinating agents (honey bees, beetles, housefly, butterfly, ants *etc*) were found responsible for pollination in different fruit crops. Among them, honey bees were found to be ultimate and legitimate pollinating agents in most of the fruit of semi-arid region.

Morphological, floral, phenological and pollination behaviour in different germplasm of hot semi-arid fruits have been studied in detail, viz. bael (Singh *et al.* 2008, 2011a, 2011b, 2012a 2012b, 2014a, 2019a, 2019e, 2018a and 2018b), jamun (Singh and Singh 2012b, Singh *et al.* 2007a, 2010a, 2011a and 2019d), khirni (Singh and Singh 2005d, Singh *et al.* 2016b and 2019c), tamarind (Singh and Singh 2005b, Singh *et al.* 2006, 2008 and 2010), chironji (Singh et al. 2006 and 2010), phalsa (Singh *et al.* 2019a), karonda (Singh *et al.* 2014), custard apple (Vikas *et al.* 2017 and 2018), wood apple (Yadav *et al.* 2018), mahua (Singh *et al.* 2005 and 2008) and wild noni (Singh and Singh 2018, Singh *et al.* 2013b, 2016b and 2014b) under rainfed hot environment of western India. Morphovariations in the form of vivipary, metaxenia and cauliflory in bael germplasm has been reported by Singh *et al.* (2018b) under dryland conditions of western India.

## Plant genetic resources

Conservation of genetic resources of underutilized fruits is important, because these species are at the verge of extinction and many are threatened and endangered. The diversity of some of the underutilized fruits is well studied while for other underutilized fruits relatively little has been done yet. Gaps in collection are found between the species and regions.

**Table 1. Biological activities of underutilized hot semi-arid fruits**

| Crop | Biological activities |
|---|---|
| Bael | Anticancer, sedative, hypnotic, analgesic, anticonvulsive, hypothermic, antimalarial, antipyretic, antidiuretic, antitumor, cardioactive, antihyperglycemic, antidislipidemic, antiinflammatory, antiulcer, antiseptic, antiallergic, antidirrhoea, astringent, antibacterial, antihelminthic, antispasmodic, artiemicide, cytotoxic anti-diabetic, antidiabetic |
| Jamun | Antidiabetic, antihyperglycemic, antifungal, anti-inflammatory, neuropsycho-pharmacological, antimicrobial, antibacterial, radioprotectiv, gastroprotective, antifertility, anorexigenic, antidiarrheal, ulcerogenic and anti-HIV. |
| Custard apple | Antiviral, antioxidant activity, respiratory stimulant, antimalarial, antihelmintic, antiulcer hepatoprotective, anti-arthritic, antiinflammatory and analgesic, anti-HIV, hypoglycemic |
| Mulberry | Antidiabetes, hypertension, anaemia, and arthritis antioxidant, antimicrobial, and neuro-protective, anti-inflammatory. |
| Wood apple | Antimutagenic, hypoglycemic and hyperlipidemic vomiting and hiccups, dysentry, indigestion and induce bowel boils and amoebiosis, diuretic activity, anti-bacterial, antifungal. |
| Tamarind | Cardioprotective, gastric, jaundice, fever, |
| Khirni | Aphrodisiac, appetizer, arthritis, jaundice, blood purifier |
| Mahua | anti-inflammatory, hematoprotective, antitumor, analgesic, rheumatism, ulcer, tonsillitis ulcers, dyspepsia, opcity of the cornea, bronchitis, urethrorrhea, leprosy |
| Chironji | Antidiarrhoea, intercostals, rheumatic pains and skin diseases |
| Phalsa | Astringent, stomachic, demulcent, rheumatism, antiinflammation, administered in respiratory, cardiac and blood disorders, antimicrobial, anti-platelet, antiemetic, anti-cancer properties anticancer, antioxidant, radioprotective and antihyperglycemic properties |
| Karonda | astringent, appetizer, antipyretic, antidiabetic scabies, intestinal worms, diarrhoea antipyretic, appetizer, antiscorbutic, antihelmintic |
| Manila tamarind | Abortifacient, anodyne, astringent, larvicidal, guamachil is a folk remedy for convulsions, dysentery, dyspepsia, earache, leprosy, peptic ulcers, sores, toothache, and venereal disease eczema, sore throat, acne and pimples |
| Wild noni | Antibacterial, antiviral, antifungal, antitumor, antihelmin, analgesic, hypotensive, anti inflammatory and immune enhancing effects. |
| Fig | Metabolic, cardiovascular, respiratory, antispasmodic, anti-inflammatory, antidiarrhoea, respiratory haemorrhage, diuretic, diabetics, anthelmintic tuberculosis, anticancer, antidiarrheal |
| Timru | Antimicrobial , antiplasmodial, antidiabetic, antimaleria |
| Gonda | Antihelminthic, diuretic,,demulcent |

*Source :* Maity *et al.* 2009, Singh *et al.* 2019, Sharma *et al.* 2007 Singh *et al.* 2001, Yadav *et al.* 2018, Shyam Sunder 2010, Qureshi *et al.* 2010, Mishra 2018, Hoareau, 1999, Chauhan *et al.* 2012 and Maridass *et al.* 2008.

According to IPGRI (Padulosi, 1999) conservation (both *in-situ* and *ex-situ*) of genetic diversity of underutilized fruits are very poor. This fact indicates that furthermore that the vast bulk of genetic resources of underutilized fruits are in the hands of users and local communities.

In this context, intensive crop specific surveys in target variability pockets and explorations were undertaken in arid and semi-arid regions of diversity rich areas of state, *viz.* Gujarat, Madhya Pradesh, Uttar Pradesh, Chhattishgarh, Haryana, Punjab, etc. and and a large number of germplasm of semi-arid fruits were collected over the years for systematic evaluation, characteri-zation and conservation of indigenous germplasm at CHES, Godhra. In past few years, the genetic resource conservation of semi-arid horticultural crops is being maintained in field repository at CIAH, Bikaner, and its regional centre CHES, Godhra, and CAZRI, Jodhpur. The genetic resource conservation of major semi-arid fruit crops is also maintained in field repository of SAUs and other ICAR Institutes.

Germplasm are being evaluated for development of varieties having desirable traits. Some of the varieties like bael (Goma Yashi), jamun (Goma Priyanka, chironji (Thar priya) and tamarind (Goma Pratek) have been planted on commercial scale at farmers field (Singh *et al.*, 2018c, Singh *et al.*, 2010a). An enormous variability with respect to yield, qualitative and quantitative character in different fruit crops, *viz*. jamun (Singh and Singh, 2005a, 2012b and 2019d), bael (Saroj *et al.*, 2004, 2008, Singh *et al.*, 2015, Sharma *et al.*, 2013, Singh *et al.*, 2014f, 2014g, 2016c, 2019b and 2019e), karonda ( Singh *et al.*, 2014 ), khirni (Singh *et al.*, 2016b), tamarind (Saroj and Awasthi 2004, Sharma *et al.*, 2015, Singh *et al.*, 2006), wood apple (Singh *et al.*, 2016f, Yadav *et al.*,

**Table 2. Germplasm conservation of semi-arid fruits at CIAH, Bikaner ( Saroj *et al*., 2018)**

| Crop | Scientific name | No. | Crop | Scientific name | No. |
|---|---|---|---|---|---|
| Bael | *Aegle marmelos* | 21 | Manila tamarind | *Pythocelobium dulcae* | 03 |
| Cactus pear | *Opuntia ficus-indica* | 24 | Jamun | *Syzygigium cuminii* | 2 |
| Phalsa | *Grewia subenaequalis* | 05 | lasoda | *Cordya myxa* | 15 |
| Fig | *Ficus carica* | 02 | Karonda | *Carissa carandus* | 05 |
| Mulberry | *Morus* spp. | 15 | Wood apple | *Feronia limonia* | 03 |

**Table 3. Germplasm conservation of semi-arid fruits at CHES, Godhra**

| Crop | Scientific name | No. | Crop | Scientific name | No. |
|---|---|---|---|---|---|
| Bael | *Aegle marmelos* | 196 | Manila tamarind | *Pythocelubium dulcae* | 25 |
| Capegooseberry | *Physalis peruviana* | 06 | Jamun | *Syzygium cuminii* | 68 |
| Phalsa | *Grewia subanaequalis* | 25 | Palmyra palm | *Borassus flabellifer* | 2 |
| Badhal | *Artocarpus lacucha* | 04 | Karonda | *Carissa carandus* | 40 |
| Mulberry | *Morus* spp. | 15 | Fig | *Ficus carica* | 07 |
| Mahua | *Bassia latifolia* | 30 | Chironji | *Buchanania lanzan* | 30 |
| Tamarind | *Tamarindus indica* | 25 | Wood apple | *Feronia limonia* | 30 |
| Custar apple | *Annona squamosa* | 40 | Khirni | *Monilkara hexendra* | 30 |
| Mulberry | *Morus* spp. | 03 | Lasoda | *Cordia myxa* | 04 |

2018), custard apple (Yadav *et al.*, 2017 and 2018 ), mahua (Bhargava *et al.*, 2017, Dhakar *et al.*, 2015, Singh and Singh 2005c), wild noni (Arya *et al*., 2014, Patel *et al*., 2014, Rathod *et al*., 2016, Singh and Singh 2015e, Singh *et al*., 2013b), chironji (Singh *et al*., 2006 and 2016d), phalsa (Singh *et al*., 2019a and 2019f) and manila tamarind (Awasthi and Saroj 2006) have been reported. At present, ICAR-CIAH (Table 2) and its regional Centre CHES, Godhra are maintaining a large number of diverse germplasm of underutilized semi-arid fruits in field repository (Table 3).

## Varietal wealth

The environmental conditions of hot semi-arid regions are very harsh hence; selection of plant species and their varieties for such region for growth and production is important. The crop must have one or another characters like deep root system, summer dormancy, high 'bound water' in tissues, reduced leaf area, sunken stomata, thick cuticle, wax coating of pubescence, presence of latex, and ability to adopt shallow, rocky, gravelly and undulated wasteland. Keeping these facts in view, the importance of underutilized fruits in changing climatic scenario, research work on collection, characterization, evaluation and conservation of underutilized fruits have been initiated at CIAH, Bikaner, and its regional centre CHES, Godhra, and high-yielding quality varieties were developed. Varietal wealth developed is given in Table 4.

## Propagation

The importance of underutilized fruits is increasing because people are realising the potential of these fruits. Looking into the importance of these fruits, the demand of their genuine planting material is increasing day-by-day. To meet the demand of planting material, vegetative propagation techniques have been standardized for commercial multiplication. The variability has been observed in plants raised through seeds. Except few plant species, vegetative methods of propagation are used for their multiplication. Propagation through vegetative methods, *viz.* stem cutting, layering, stooling and grafting have been described for many semi-arid fruits. Patel *et al.* (2016) reported that the seed priming treatment improves the germination and vigour of seedling in custard apple. Under dryland condition, *in-situ* establishment of jamun orchard has been found successful with better survival (Singh *et al.*, 2009). Vikas *et al.* (2017) reported that $GA_3$ and cow urine enhance germination and growth of custard apple seedlings under rainfed semi-arid conditions.

Treatment of seeds with growth regulators ($GA_3$) enhanced per cent seed germination and growth of seedlings in Pithecelobium dulce under hot arid conditions (Singh *et al.*, 2011). In order to optimize the production of semi-arid fruit crops, propagation techniques of jamun, lasoda, khirni, wood apple, manila tamarind, custard apple, mahua, bael, chironji, *etc.* have been standardized for large scale multiplication of plants (Table 5). For better success and survival of

**Table 4. Different promising varieties of hot semi-arid fruits**

| Crop | Varieties | References |
|---|---|---|
| Bael | Goma Yashi, Thar Divya, Thar Neelkanth, NB-7, NB-9, NB-5, CISHB-1, CISHB-2, Pant Aparna, Pant Shivani, Pant Sujata and Pant Urvashi | Singh *et al.*, 2011a, 2012c, 2015a, 2016e, 2019a, Pandey *et al.*, 2014 |
| Jamun | Goma Priyank, Thar Kranti, Konkan Bahadoli, Jamwant, Paras, Rajamun, Rajendra Jamun-1, Jamwant | Singh and Singh 2012a, Singh *et al.*, 2010a, 2011, 2016a, 2018b, Mishra *et al.*, 2014, |
| Custard apple | Washington PI 98797, Washington PI 107005,British Guinea, Barbados seedling, Island Gem, Bullocks Heart, Pink Mammoth, Balanagar, Mammoth, Red Sitaphal, Yellow Sitaphal, Phule Janki and Sindhan | Hiwale 2015, Vikas 2018, Singh *et al.*, 2019f |
| Mulberry | Thar Lohit, Thar Harit, Victoria-1, China White, Saharanpur Local-1, Saharanpur Local-2, S-13, S-34, S-146, S-7999, S-1635, Chak Majra | Saroj *et al.*, 2018, Singh *et al.*, 2019f |
| Karonda | Pant Manohar, Pant Sudarshn, Pant Suverna, Konkan Bold, Thar Kamal | Saroj *et al.*, 2018, Singh *et al.*, 2014 and 2019f |
| Tamarind | Goma Prateek, Prathisthan, PKM-1, T 263, Urigam, Ajanta, Yogeshwari, DTS 1 and DTS 2, Anant Rudhira | Saroj *et al.*, 2018 |
| Lasoda | Thar Gold, Paras Gonda, Puskar Local, Maru Samridhi | Saroj *et al.*, 2018, Singh *et al.*, 2019f |
| Khirni | Thar Rituraj | Saroj *et al.*, 2018, Singh *et al.*,2015a, 2019c and Singh *et al.*, 2017 |
| Phalsa | Thar Pragati | Saroj *et al.*, 2018, Singh *et al.*, 2018a, |
| Chironj | Thar Priya | Saroj *et al.*, 2018, Singh *et al.*, 2010b, |
| Mahua | Thar Madhu, NM-2, NM- 4, NM-7, NM- 9 | Saroj *et al.*, 2018, Singh *et al.* 2016c, |
| Manila tamarind | PKM (MT) 1 | Hiwale 2015, Singh *et al.*, 2019f |
| Fig | Poona Fig, Dianna, Dinkar, Conadria, Excel, Chalisgaon | Hiwale 2015, Singh *et al.*, 2019f |
| Wood apple | Thar Gaurav | Yadav *et al.*, 2018, Singh *et al.*, 2019f |

semi-arid fruits, in-situ budding and grafting has been found better with vigorous growth of grafted plants under arid and semi-arid conditions (Singh *et al*., 2014e). No work on the standardization of rootstocks has been done on such crops till now, which needs attention to assess vegetative compatibility and vigour, fruiting, fruit quality and usefulness to wastelands. Generally, seeds of deshi seedling plants are used as rootstocks for multiplication.

## Agro-techniques

Investments are needed in institutional and human capacities to plan and manage water for rainfed horticulture at the catchment scale, where local run off water resources can be diverted, stored, and managed. Under dryland conditions, tapping the potential lies in the availability of an adequate but erratic water resource provided by the rain. The major water-related challenges for rainfed horticulture in semi-arid regions are less and erratic rainfall, characterized by few rainfall events, high-intensity storms, and high frequency of dry spells and droughts. It is therefore, critical to understand how hydro climatic conditions and water management affecting yields in rainfed horticulture. However, construction of earthen and concrete check dam according to catchment area, development of micro catchment module, full moon and half moon terracing and also with the help of horti-silvi-pastoral system, water loss could be minimized under dryland conditions (Singh *et al*., 2016d).

Under arid and semi-arid conditions, intercropping during initial years of orchard of bael, chironji, wood apple and jamun had no adverse effects on plant growth up to seven years. However, intercropping in the orchard spaced at 10m × 10m can be done up to 10 years. Intercropping of guar, cucurbits, okra and

**Table 5. Commercial methods of propagation of hot semi-arid underutilized fruits**

| Fruit crops | Time period | Commercial propagation methods | References |
|---|---|---|---|
| Bael | May-June | Soft wood grafting and patch budding | Singh *et al.*, 2011b,2014b, 2014e, 2018a, 2019a, 2019c, Singh, 2018, |
| Chironji | July-August | Soft wood grafting | Singh, 2018, Singh and Singh, 2014a, 2014d, Singh *et al.*, 2007b, 2010b |
| Jamun | April -May | Soft wood grafting, patch budding | Singh 2018, Singh and Singh, 2006, 2014b, Singh *et al.*, 2007c, 2017a,2011, 2018b, |
| Lasora | April-May | Patch budding, cleft grafting | Singh, 2018, Singh *et al.*, 2003 and 2019f |
| Tamarind | July-August | Soft wood grafting and patch budding | Awasthi *et al.*, 2005, Singh and Singh, 2007 |
| Mahua | March-April | Soft wood grafting | Singh 2018, Singh and Singh, 2014c, 2015f |
| Custard apple | April- May | Soft wood grafting | Singh, 2018, Singh and Singh, 2014 |
| Wood apple | April- June | Soft wood grafting and patch budding | Singh, 2018, Singh *et al.*, 2019f |
| Karonda | June -July | Seeds and cutting | Singh, 2018, Singh *et al.*, 2018c |
| Khirni | April -May | Softwood grafting | Singh, 2018, Singh *et al.*, 2019c |
| Phalsa | December-January | Seed and hard wood cutting | Singh, 2018, Singh *et al.*, 2019f |
| Manila tamarind | May-June | Patch budding | Singh, 2018, Awasthi and Saroj, 2006 |
| Palmyra Palm | July -August | Seeds and Sucker | Singh, 2018, Singh *et al.*, 2019f |
| Mulberry | February-March | Cuttings | Singh, 2018, Singh *et al.*, 2019f |
| Wild noni | July- August | Layering | Singh and Singh, 2018, Singh *et al.*, 2014 |
| Fig | July- February | Cutting, patch budding | Singh, 2018, Hiwale 2015, Singh *et al.*, 2019f |
| Palmyra palm | July-September | Seeds | Hiwale, 2015, Singh *et al.*, 2019f |

leguminous vegetable crop increased the income 2-3 times. Cultivation of guar in orchards gave additional advantage of 800 kg seed yield than cowpea. Cover cropping with lobia, moth bean was found to increase water holding capacity of light soils as a result of increased organic carbon content in these regions. Intercropping is economically viable for increasing productivity per unit area and also minimized the risk of crop failure during drought years (Singh *et al.*, 2011a 2011b, 2019a).

Under dryland conditions, various fruit crop models can be adopted to minimize the risk and enhance the productivity. Bael, aonla and jamun based cropping model are found to be beneficial in term of enhanced yield and income. Bael + aonla + karonda + drumstick, bael+ chironji+ fig+ custad apple, bael+khirni+phalsa +wood apple cropping models are useful to enhance the productivity of dryland tracts of the country (Singh *et al.*, 2019a).Layout and plantation of these crops should be done at closer spacing with proper management of canopy so that productivity and income can be doubled and farmer can generate income throughout the year for better livelihood.

Continuous use of organic mulches are found helpful in improving the soil physico-chemical properties, microbial flora, earthworm population and soil aeration and moisture-holding capacity which ultimately resulted into better growth and yield of plant. Under semi-arid conditions, application of organic mulch (paddy straw, grasses, maize straw *etc.*) in tree basin is beneficial for successful cultivation of fruit crops like bael, jamun, custard apple, wood apple, mahua and chironji. It reduces the loss of moisture from the soil, enhances the rate of rainwater absorption in the soil, and controls the growth of weed.

Mulching can be done with any locally available organic material. Organic mulches reduce the weed population and conserve the moisture in the soil. Mulches should be applied in the tree basin (20 cm thick) after rainy season, and non decomposed organic mulches should be incorporated and mixed with soil of tree basin in the forthcoming monsoon (Singh *et al.*, 2011b). Organic mulches not only improve the soil properties and its moisture holding capacity, also reduce soil temperature (2-8°C) during summer, and increase the yield up to 20-25 per cent under dryland conditions of semi-arid ecosystem (Singh *et al.*, 2019a).

India is the homeland of many arid and semi-arid drought hardy species of fruit crops like bael, aonla, acid lime, charoli, mahua, *etc*. However, the productivity of all these fruits in India is very low (4-5 t/ha) compared with other major fruit crops grown in India. Many reasons may be attributed to the low productivity, and, to solve this problem, there is a need to develop high-yielding varieties/hybrids that are resistant to biotic and abiotic stresses having dwarf stature and responds to the pruning. By adopting the scientific practices of canopy architecture management and high density planting, yield can be doubled in lesser time and from lesser area.

High-density orcharding results in early bearing, helping to minimize weed problems. High-density planting at a spacing of 5m × 5m in bael, jamun, chironji and mahua has been found useful to double the yield and reduced the problem of harvesting over traditional planting system (Singh *et al.*, 2018d; Singh *et al*., 2019a). However, crops like phalsa, and karonda can be accommodated at lesser spacing with help of proper training and pruning. By adopting double hedgerow system of planting, the productivity and income per unit area can be enhanced to 2-2.5 times over conventional square system of planting under the rainfed condition. Bael, jamun, chironji and khirni are recommended for planting at 5m × 5m distance under semi-arid conditions to double the productivity (Singh *et al*., 2019a). Proper canopy architecture of jamun and bael has been standardized (Singh *et al.*, 2017b and Singh *et al.*, 2019a). Singh and Singh (2003) reported that time and level of pruning and application of urea were found helpful in improving the growth, yield and quality of phalsa.

The soils of semi-arid regions in India are poor in organic carbon, nutrients and water holding capacity. Soil depths in these regions are less and nutrient management becomes difficult due the presence of calcium carbonate layer at lower depth. Improved fertilizer management is required to grow crops successfully on such soils. To avoid ammonia volatilization, fertilizers containing ammonium-N or urea should be moved into the root zone with rainfall or irrigation, or be incorporated into the soil. Band placement of P minimizes soil contact thus reducing or delaying the formation of insoluble Ca and Mg phosphates. Crops planted on calcareous soils may require above normal levels of K and Mg fertilizer for satisfactory nutrition. Using tolerant rootstocks and varieties reduces the severity of nutrient related disorders. Deficiency of micronutrients can be corrected through foliar application of chelates. Adequate K supply and organic matter application in the form of cakes, FYM and organic wastes can improve the availability of microelements. Enriching soil with organic matter is found beneficial for sustainable production of fruits in fragile agro-climatic conditions (Ram and Kumar, 2019)

Most of the minor horticultural crops of semi-arid regions of India are often available only in the local markets and are practically unknown in other parts of the world. Today, consumers are becoming increasingly conscious of the health and nutritional benefits of their food basket. The minor horticultural crops are rich in mineral, vitamins and therapeutic values, and they can serve the purpose as they are growing naturally, therefore, they are free from the toxic chemicals. To achieve this, these fruits need to be popularized in national and international markets. Practically to larger extent, it can be achieved through developing suitable processing and marketing strategies for minor horticultural fruit crops (Meel *et al.*, 2018). In this regard attempts have been made as karonda, bael and aonla based organic products are becoming more popular in the domestic markets. Growing of crops through organics not only hikes the price of produce but also improve soil health.

**Post-harvest management**

Grading and packaging are the important practices to fetch better price in the market. The packages protect the produce from damage loss as it maintains quality and retains freshness. Corrugated fibre board box (CFB), wood box with suitable cushioning materials are most suitable and economically-viable packing container for transportation of semi-arid horticultural produce. Cushioning material should be physiologically inactive. Moulded pulp tray, honeycomb, cell pack are better than the traditional material like straw and grasses. A large quantity of fruits and vegetables produce goes waste due to unavailability of adequate storage facility in semi-arid dryland areas. Proper storage facility like cool storage, CA and ZECC storage can reduce the post harvest loss to greater extent and can improve the farm income (Singh *et al*., 2007c 2010a, 2018a, 2019a Singh and Singh, 2012).

The fruits grown in semi-arid regions have been prepared into various processed products by the people utilizing their acquired traditional knowledge like sun drying, pickling *etc*. However, with the application of modern techniques, the quality of products could be improved considerably. The pre-treatment of many fruits with hormone and harmless chemicals results in better quality end products (Meghwal, 2016). Solar drying and electric tray dehydration of fruits and vegetable help to reduce dust load on the product and retain natural colour. Techniques for preparation of different products from underutilized fruits have been standardized (Mishra, 2018).

Mal nutrition in resource poor areas of semi-arid region is a major problem particularly in women and children. Fruits like tamarind, custard apple, bael, khirni, karonda, phalsa, mulberry, wild noni, wood apple *etc.* are a rich source of vitamins, minerals and dietary fibres. Bael fruits contain higher in riboflavin than many fruits. Fruits like wood apple and custard apple are rich in carbohydrates and minerals which are vital for the maintenance of body and physiological function. These fruits are highly perishable in nature, the marketing of which is a major problem, *e.g.* custard apple gets spoiled within 2-3 days of harvesting, if not consumed (Singh *et al.*, 2007c 2018a, 2019a). Also with the glut in the market, the prices of these fruits drop down drastically making it uneconomical for the farmers to sustain production; the result is that the farmers uproot the trees owing to low price in the market. To avoid the situation, there is a need to extend shelf-life of these fruits and to develop post-harvest value addition technologies which are simple and adaptable at the farm level.

This will not only result in developing small-scale industry but it will also provide employment to the rural masses throughout the year resulting in increased income of both farmers and workers. Efforts made at the CIAH Bikaner and region research Centre CHES, Godhra were successful and many products, *viz.* dried and dehydrated fruits, RTS, squash, fruit bars, candies, fruit concentrates, powders, wines, and condensed fruit juices through solar drying, were prepared and demonstrated to stakeholders for further commercialization. The tamarind pulp is pressed and preserved in large masses and in dry conditions the pulp remains good for about 1 year. There is tremendous scope for preparing beverages from ripened fruit of chironji. Kernels are being used for the preparation of different kinds of sweets. The products like squash, RTS, and nectar may be prepared from the pulp of the fruits. Value added products of different hot semi-arid fruits are given in Table 6.

**Table 6. Semi-arid fruits and their value-added products**

| Crop | Value-added products |
|---|---|
| Bael | Preserve, RTS, nectar, ice cream, slab, squash, cider, canned bael slices, pickles and powder |
| Chironji | Dried kernels, fruit bar |
| Karonda | Pickle, candy, jelly, jam, preserve, wine, Chutney |
| Wood apple | Squash, powder, pickle, chutney, jelly, fruit bar |
| Khirni | Dehydrated fruits, fruit bar, RTS, jam |
| Jamun | Juice, RTS, squash, syrup, carbonated drink and wine |
| Phalsa | Juice, squash, syrup |
| Lasoda | Pickle, culinary |
| Custard apple | Jam, beverages, ice cream |
| Tamarind | Tokku (chutney), panipuri masala, juice concentrate, pulp powder, jam, syrup, candy toffee, tamarind karnel powder |
| Timru | Bidi, dried fruit |
| Pilu | Squash, dried peelu, wines |
| Kair | Pickle, dried fruits |
| Mulberry | Juice, squash and syrup |
| Mahua | Biscuits, cakes dried powder, seed oil and wine |
| Manila tamarind | Biscuits, squash and syrup |
| Aloe | Candy, jelly, pickle, cold cream, crack cream, moisturizer, gel |
| Fig | Fig paste, concentrate, powder, nuggets, jam |

*Source:* Singh *et al.*, 2016a, 2018a, 2019a, 2019f and Mishra, 2018

## CONCLUSION

Keeping in view the agroclimatic conditions of semi-arid region, it is need of hour to create awareness among farmers regarding the various technologies like high-yielding varieties, water harvesting practices, use of organics, IPM, IDM, bio-pesticides, biofertilizers, preparation of value-added products and their marketing can enhance the farm income under prevailing conditions of semi-arid region. Unproductive land can be made productive by selecting the crops having ability to grow under aberrant agroclimatic conditions by proper planning and amalgamation of suitable technologies holistically. As most of the semi-arid fruits cannot be directly used for the table purpose, and thus fetches low prices in the market. Therefore, through processing and value-addition and their efficient marketing, farmer's economic status can be effectively improved with better health and nutritional security. Therefore, focusing attention on such fruit crops is an effective way to help a diverse and healthy diet and to combat malnutrition, so called 'hidden hunger' and other dietary deficiency among the poor rural people and more vulnerable social groups specially tribes of country.

### Researchable issues

- Hot semi-arid underutilized fruits are remained neglected. Genetic resources of these crops are still available on farmers' field or in forests which needs to be conserved.
- Research work on underutilized fruit crops should be expanded in order to maximize production and overcome disease and pest problems.

- The germplasm of these crops need to be collected, documented and conserved in field gene banks.
- Ethnobotanical and nutritional value also needs to be assessed with scientific validation.
- Genetic improvement and development of new varieties for specific traits.
- Standardization of propagation techniques and timely supply of quality planting materials and development of location specific agro-techniques to exploit these crops commercially.
- Commercialization of processing, packaging and value addition in natural growing areas.

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# Effect of plant age and stress on flowering in litchi *(Litchi chinensis)*

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**ABSTRACT**

The experiment was conducted on eight year-old litchi (*Litchi chinensis* Sonn.) cv. Shahi at ICAR-NRC on Litchi, Muzaffrapur, Bihar during 2017-18. The results showed that trees started opening of flowers (male, hermaphrodite functionally female and hermaphrodite functionally male) on 4, 11 and 16 March 2017, and 11, 17 and 24 March 2018 respectively, whereas, in 15 year-old trees, anthesis of male, hermaphrodite functionally female and hermaphrodite functionally male was earlier on 1, 7 and 13 March 2017, and 7, 14 and 20 March 2018, respectively. Similarly, eight-year-old plant of Longia started opening of flowers (male, hermaphrodite functionally female and hermaphrodite functionally male) on 19, 27 and 30 March 2017, and 22, 30 March 2018 and 1 April 2018, respectively and 15 year-old trees started opening of flowers on 14, 21 and 25 March 2017 and 18, 25 and 29 March 2018, respectively. The eight year old Kasba plants located near road side were recorded with anthesis of flowers (male, female and hermaphrodite male flowers) on 12, 17 and 23 March 2017, and 16, 20 and 24 March 2018, respectively, whereas, 15-year old Kasba plant located at the centre of the field started opening of flowers on 15, 19 and 22 March 2017 and 20, 24 and 27 March 2018, respectively.

**Key Words**: Anthesis, Cultivars, Female flowers, Hermaphrodite flowers, Male flowers

Litchi (*Litchi chinensis* Sonn.), a popular member of family Sapindaceae, is an evergreen subtropical fruit tree. Mycorrhizal association is very strong in litchi and its inoculation in citrus increased the content of P and Zn (Ortas, 2017). The age of plants have great role in fruit production. Litchi produces three types of flowers [male (M1), hermaphrodite functionally female (F) and hermaphrodite functionally male (M2)] which open in succession. The pollen grain of M2 flowers are more viable and source of pollen grains significantly affect fruit set and success of hybrid fruits (Lal *et al.*, 2019a and b). The development and opening of flowers depend on age of plants. The old plants of the same cultivars commence early development and opening of flowers, while young ones produce late flowers and fruiting. Many types of stresses are known to induce flowering in litchi. These include high or low light intensity, UV light, high or low temperature, poor nutrition, nitrogen deficiency, drought, root pruning, growth retardant (Pandey *et al.*, 2017) and mechanical stimulation. Stress induces carbohydrate accumulation (Holland *et al.*, 2016; Shahryar and Maali-Amiri, 2016). Carbohydrates are important nutrients and energy sources in plant tissues. As a developmental stage, flowering can be regarded as the transition from the vegetative to the reproductive phase. An increase in carbohydrate levels in apical bud is associated with floral transition in plants (Bernier *et al.*, 1993). In litchi fruit tree, the importance of carbohydrates in flowering has been emphasized (Kumar *et al.*, 2017) by the fact that female flowers and regularity of flowering is improved by girdling. The plants located in stressed area where frequent movement of automobiles and human talk encounter near plants or facing stress by other means also induce early flowering in litchi. Keeping in view, an experiment was conducted to find out the effect of age of plant and stress on flowering in litchi.

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## MATERIALS AND METHODS

Three cultivars of litchi (Shahi, Longia and Kasba) were selected for observation. The two different age group of plants, viz. 8-year and 15-year-were selected. Different ages (8 and 15 year-old) of Longia and Shahi cultivars were selected at the centre of the field. Eight-year-old plants of Kasba located at the corner of the field were selected which stressed by human being, vehicles movement and others, and 15-year old tree of Kasba located at the centre of the field were selected which free from such stress. The observations on opening of flowers were recorded in all three cultivars during 2017 and 2018.

## RESULTS AND DISCUSSION

The result revealed that-eight-year-old plants of Shahi started opening of flowers (male, hermaphrodite functionally female and hermaphrodite functionally male) on 4, 11 and 16 March 2017 respectively, whereas in fifteen-year-old trees, anthesis of male, hermaphrodite functionally female and hermaphrodite functionally male was earlier on 1, 7 and 13 March 2017, respectively. Similarly, eight-year-old plants of Longia started opening of male, hermaphrodite functionally female and hermaphrodite functionally male flowers on 19, 27 and 30 March 2017, respectively and fifteen-year-old plants started opening of flowers on 14, 21 and 25 March 2017, respectively. During second year, eight-year-old plants of Shahi started opening of flowers (male, hermaphrodite functionally female and hermaphrodite functionally male) on 11, 17 and 24 March 2018 respectively, whereas in fifteen-year-old trees, anthesis of male, hermaphrodite functionally female and hermaphrodite functionally male flower was earlier on 7, 14 and 20 March 2018, respectively. Similarly, eight-year-old plants of Longia started opening of male, hermaphrodite functionally female and hermaphrodite functionally male flowers on 22, 30 March 2018 and 1 April 2018, respectively and fifteen-year-old trees started opening of flowers on 18, 25 and 29 March 2018, respectively. The eight-year-old plants of Kasba located near road side were recorded with anthesis of flower (male, hermaphrodite functionally female and hermaphrodite functionally male flowers) on 12, 17 and 23 March 2017, whereas fifteen-year-old trees of Kasba located at the centre of the field started opening of flowers on 15, 19 and 22 March 2017, respectively. In the second year eight-year-old Kasba showed precocity in flowering where opening of flowers started on 16, 20 and 24 March 2018 while fifteen-year-old tree located at centre of the field showed late opening of flower on 20, 24 and 27 March 2018, respectively.

A fifteen-year-old plants of Shahi commenced anthesis (M1 flowers) on 1 March 2017 and eight-year-old plant started anthesis three days later on 4 March 2017. Similarly, M2 flower was opened on 13 March 2017 in fifteen-year-old plants whereas it was opened three days later on 16 March 2017 in eight-year-old plants. The similar case was also observed in the second year where fifteen-year-old plant of Shahi started anthesis on 7 March 2018 and eight-year-old plants commenced anthesis four days later on 11 March 2018. The fifteen-year-old trees of Shahi commenced anthesis 3-4 days earlier as compare to eight-year-old plant of Shahi. The same trends of anthesis was also observed in Longia litchi where fifteen-year-old plants started anthesis on 14 March 2017 and eight-year-old plants started anthesis five days later on 19 March 2017.

Similarly in second year, fifteen-year-old plants started anthesis on 18 March 2018 and eight-year-old plants started four days later on 22 March 2018. The fifteen-year-old plant of Longia commenced anthesis 4-5 days earlier as compare to eight-year-old plant of Longia and both the cultivars were located in the centre of field. The female flowers opened and M2 flowers (Hermaphrodite male flowers) were unopened in eight-year-old plants of Longia and in fifteen-year-old trees

**Table 1. Effect of age of plants on anthesis in litchi cvs. Shahi and Longia**

| Anthesis of flowers | Age of Shahi | | | | Age of Longia | | | |
|---|---|---|---|---|---|---|---|---|
| | 2017 | | 2018 | | 2017 | | 2018 | |
| | 15 Years | 8 Years | 15 Years | 8 Years | 15 Years | 8 Years | 15 Years | 8 Years |
| Male (M1) | 01.03.17 | 04.03.17 | 07.03.18 | 11.03.18 | 14.03.17 | 19.03.17 | 18.03.18 | 22.03.18 |
| Female (F) | 07.03.17 | 11.03.17 | 14.03.18 | 17.03.18 | 21.03.17 | 27.03.17 | 25.03.18 | 30.03.18 |
| Male (M2) | 13.03.17 | 16.03.17 | 20.03.18 | 24.03.18 | 25.03.17 | 30.03.17 | 29.03.18 | 01.04.18 |

**Table 2. Effect of stress caused by location of the plant on anthesis in litchi cv. Kasba**

| Anthesis of flowers | Plant located in centre of field (15 Years) | | Plant located at road side (8 Years) | |
|---|---|---|---|---|
| | 2017 | 2018 | 2017 | 2018 |
| Male (M1) | 15.03.17 | 20.03.18 | 12.03.17 | 16.03.18 |
| Female (F) | 19.03.17 | 24.03.18 | 17.03.17 | 20.03.18 |
| Male (M2) | 22.03.17 | 27.03.18 | 23.03.17 | 24.03.18 |

of Longia, female flowers were opened 4-5 days earlier where stigma became brown and M2 flowers were also opened.

The fifteen-year-old trees of Kasba located at centre of the field started anthesis on 15 March 2017 and eight-year-old plants located at roadside commenced anthesis three days earlier on 12 March 2017. Similarly in the second year, fifteen-year-old plants started anthesis on 20 March 2018 and eight-year-old plants four days earlier on 16 March 2018. The fifteen-year-old trees of Kasba commenced anthesis 3-4 days later as compare to eight-year-old plants. The results indicated that older plants start reproductive cycle earlier as compare to young ones. The older plants of Shahi and Longia started anthesis 3-4 and 4-5 days earlier, respectively as compare the younger ones when plants were located at the centre in the field. But fifteen-year-old trees of Kasba started anthesis 3-4 days later as compare to eight-year-old plants when the locations of the plants were different. The eight-year-old plants of Kasba started anthesis 3-4 days earlier when located the roadside / near road and this is clear from Fig 2 that M2 flowers are still opening in fifteen-year-old trees of Kasba and in eight-year-old plant of Kasba, M2 flowers were completely dropped off and bified ovary started to grow.

This result indicated that young plants can enter into reproductive cycle when plants were stressed. The stresses may be due to water scarcity, human intervention (Human talks, noise, vehicle movement etc.) and other things which passes near to the plants. It is clear from the observations that older plants always may not enter into reproductive cycle earlier as compare to younger ones, the other factors are also responsible for such behaviour of the plants. However, these types of behavior are easily seen in annual / seasonal plants like mustard. Mustard plants which are located near the road / bunds enter into reproductive cycle earlier as compare to the plants located at the centre in the same field because of stress received by plants. The stress induces carbohydrate accumulation (Holland *et al.*, 2016; Shahryar and Maali-Amiri, 2016).

Many woody plants need stressful conditions to initiate or promote flowering (Zhou *et al.*, 2014; Shen *et al.*, 2016) and hormonal level of roots determines tolerance in trifoliate orange seedlings (Gao *et al.*, 2018). Flowering is positively correlated with carbohydrate level in the leaf, phloem, and xylem of litchi and Avvorhoa carambola (Wu *et al.*, 2013; Yang *et al.*, 2014). Soluble sugar and starch are carbohydrates that have conventionally been viewed as resources for respiration and metabolic intermediates as well as


Fig. 1: A: Eight-year-old plants of Longia where female flowers are opened and M2 flowers are unopened, B: Fifteen-year-old trees where female flowers are 4-5 days old to open indicating browning of stigma and M2 flowers are opened


Fig. 2: A: Fifteen-year-old trees of Kasba where M2 flowers are still opening, B: Eight-year-old plant where M2 flowers are dropped off and bified ovary started to grow up

structural components (Sheen *et al.*, 1999). Sugars are signaling molecules that control gene expression and developmental processes in plants (Jang and Sheen, 1997; Wang *et al.*, 2008). Carbohydrates play an important role in the flowering of litchi (Litchi chinensis Sonn.) (Menzel *et al.*, 1995; Chen *et al.*, 2004; Yang *et al.*, 2014), Zantedeschia (Kozlowska *et al.*, 2007), strawberry (Fragaria × ananassa Duch.) (Eshghi *et al.*, 2007), and Oncidium orchid (Wang *et al.*, 2008).

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# Standardization of propagation method in avocado *(Persea americana)*

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### ABSTRACT

The experiment was conducted to standardize the method and time of propagation of avocado (*Persea americana* Mill) through vegetative means at CHES, ICAR-IIHR, Chettalli, during 2012-13. There were four methods of multiplication *i.e.* veneer grafting, cleft grafting, T-budding and patch budding, performed throughout the year. After 90 days of grafting, mean success was highest in cleft grafting (32.5%), followed by veneer grafting (8.3%), T-budding (7.5%) and patching budding (5.8%). There was highest mean success during September (32.5%), followed by 22.5 per cent during March and August 2012. Among different combinations of months and propagation methods, highest success (70%) was recorded in cleft grafting performed during September 2012. This was closely followed by same method done during March 2012 (60%). The success in cleft grafting was higher than other three methods throughout 2012-13. The growth of the scion was higher in grafting methods than budding methods. The transplantable seedlings after one year were highest (60%) in cleft grafting done September 2012. Thus, cleft grafting during September and March was found most suitable for vegetative propagation of avocado under humid tropical conditions.


**Key Words**: Avocado, Budding, Grafting, Vegetative Propagation

Avocado (*Persea americana* Mill) is a native of tropical America especifically from Mexico and Central America. It is one of the most nutritive fruits and contains higher protein (up to 4%), fat (up to 30%) and low sugars (< 1.0 %). Avocado is mainly used as fresh or in sandwich filling or in salads. It can also be used in ice creams and milk shakes and the pulp may be preserved by freezing. Avocado can be grown on a wide range of climatic and soil conditions but it is sensitive to poor drainage and cannot withstand water logging. In India, avocado was introduced from Sri Lanka in the early part of the twentieth century (Ghosh, 2000). It is grown at a limited scale in some parts of Tamil Nadu, Kerala, Karnataka and North - Eastern Himalayan states. However, plants are found growing in the home gardens of several states of the country. In Kodagu (Karnataka) and the Nilgiri regions (Tamil Nadu), avocado is grown as one of the mixed crops in coffee-based cropping system. Almost each house is maintaining few plants of avocado (Chithiraichelvan *et al.*, 2002; Tripathi *et al.*, 2014, Tripathi *et al.*, 2016).

In India, avocado is usually multiplied by seedlings originated from zygotic embryo mono-embryonic seed (Chithiraichelvan *et al.*, 2006). Due to cross-pollination, there is great variability in seedlings produced from seeds, it is impossible to obtain genetically uniform plant as required for plantation of commercial orchards. These seedling plants take long time to start bearing and fruit quality is unreliable (Whiley *et al.*, 2002). Vegetative propagation of superior clones of avocado by budding or grafting is essential to avoid these problem. Grafting/budding is also beneficial in utilization of rootstocks with *Phytophthora* and salinity tolerance for elite line and varieties (Castro *et al.*, 2009). Thus,an experiment was conducted to standardize the time and method of propagation in avocado under tropical humid conditions of India so that vegetatively propagated plants may be provided to growers to get better yield and quality.

## MATERIALS AND METHODS

The experiment was conducted at Central

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Horticultural Experiment Station, Chettalli, Kodagu, Karnataka, during 2012-2013. The climate of Coorg is humid tropical with moderate temperature. The weather condition of Chettalli in 2012 is given in Fig. 1. Four method of propagation namely cleft grafting, veneer grafting, patch budding and T-budding were tried throughout the year (January-December) with three replications and 10 plants were maintained in each replication. For raising rootstocks, large-sized fruits from vigourous trees were collected and the seedlings were raised in potting medium of 1:1:1 (soil: sand: farmyard manure) for rootstock purpose. Four to six months old vigourous seedlings were used for grafting / budding. The shoots of current season's growth of 3-4 months age from elite trees were used as scion material. The leaves from the scion shoots were removed 3 days prior to grafting. The grafting / budding was done on 15th of every month. The survival and growth of scion was recorded after 3 months of budding / grafting. The number of transplantable grafts / budlings was recorded after one year of budding / grafting. The data were analyzed using standard statistical procedures as described by Panse and Sukhatme (1995).

## RESULTS AND DISCUSSION

The data revealed that highest mean success of grafting was recorded in cleft grafting (32.5%), followed by veneer grafting (8.3%), patch budding (7.5%) and T-budding (5.8%). Among different months of grafting, highest mean success (32.5%) was recorded during September, closely followed by cleft grafting (22.5%) during March. Among various combinations of methods and time of propagation, highest success (70%) was recorded in cleft grafting performed during September, closely followed by cleft grafting during March (60%). The success was lower (10%) in winter months in cleft grafting. Moderate success (up to 40%) was recorded in cleft grafting done during June, July and August. In veneer grafting, highest success was only 20 per cent in July, August and September. T-budding and patch budding gave 20% success during August and September but no success was recorded in these methods in most of the months (Table 1 & Fig. 2).

The higher success in cleft grafting may be due to higher alignment of parenchymatous tissues of scion and rootstock. The higher length of diagonal cut surface promotes proper alignment of vascular bundles of both graft partners to ensure fast union of grafts. Further higher success rate in cleft grafting may be due to growth of cambium both side of graft because of equal diameter of scion and rootstock. (Ayala-Arreola *et al.* 2010; Simon and Elsa, 2013).

The lower success in veneer grafting, T-budding and patch budding may be due to lesser contact of growing cells. The lower success in budding was due to lesser joining area for Cambium (Whitsell *et al.*, 1989). Higher success in cleft grafting up to 46 per cent was reported by Chithiraichelvan *et al.* (2006). The higher success in all the methods of propagation during rainy months may be attributed to the prevalence of higher relative humidity and moderate temperature during rainy season which may have provided better environmental conditions for graft union. The lower success during December, January and February may be due to lower relative humidity and higher variation in day and night temperatures (Fig 1).

The growth of scion was highest in cleft grafting (7.97 cm), followed by veneer grafting (5.01 cm). Less growth was recorded in patch budding (3.23 cm) and

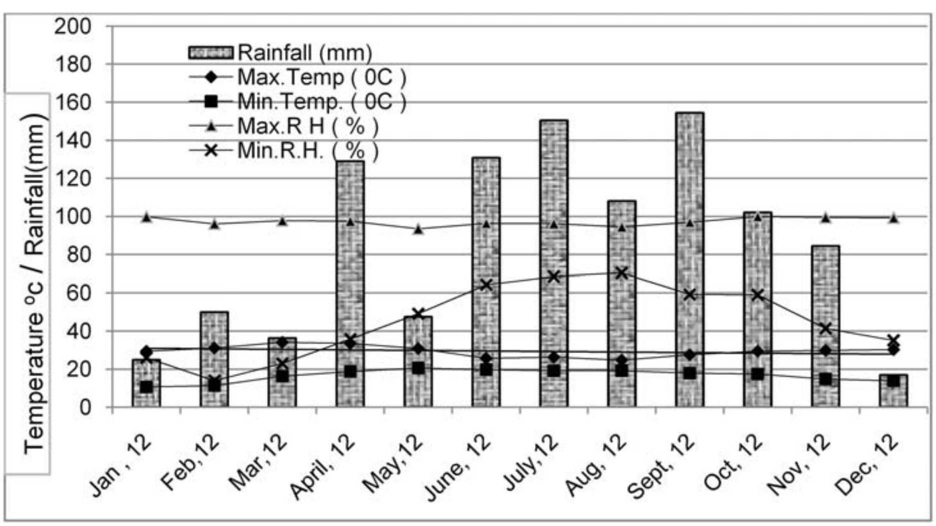


Fig. 1: Weather conditions at CHES, Chettalli

**Table 1. Grafting success (%) in different methods of propagation after 3 months**

| Months/ method | Cleft grafting | Veneer grafting | Patch budding | T-budding | Average |
|---|---|---|---|---|---|
| January | 10 | 0 | 0 | 0 | 2.5 |
| February | 10 | 0 | 0 | 0 | 2.5 |
| March | 60 | 10 | 10 | 10 | 22.5 |
| April | 30 | 10 | 0 | 0 | 10.0 |
| May | 30 | 0 | 10 | 0 | 10.0 |
| June | 40 | 10 | 10 | 10 | 17.5 |
| July | 40 | 20 | 10 | 10 | 20.0 |
| August | 40 | 20 | 20 | 10 | 22.5 |
| September | 70 | 20 | 20 | 20 | 32.5 |
| October | 30 | 10 | 10 | 10 | 15.0 |
| November | 20 | 0 | 0 | 0 | 5.0 |
| December | 10 | 0 | 0 | 0 | 2.5 |
| Average | 32.5 | 8.3 | 7.5 | 5.8 | 13.5 |
| CD (0.05) | Method | 5.32 | Month | 5.68 | |
| | (Method × month) Interaction | 8.25 | | | |

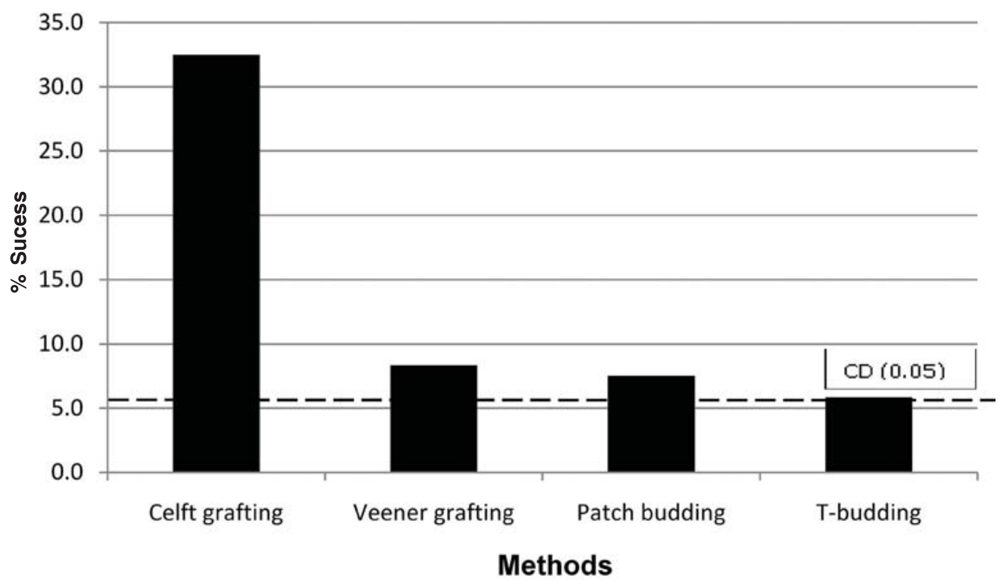


Fig. 2: Comparison of method of propagation in avocado

T-budding (2.75 cm) after three months of grafting/ budding. The mean scion growth in different months ranged from 4.45 cm to 9.10 cm but there was no significant difference among the scion length in different months. Among various combinations of propagation methods and months of propagation, highest scion growth (10.3 cm) was observed in cleft grafting performed during September, followed by cleft grafting during October with 9.4 cm scion growth (Table 2). Higher scion growth in grafting methods may be directly related with the length of scion used for multiplication. The higher length of scion in grafting resulted in faster growth while the single bud of budding methods taken more time to grow. Higher scion growth in rainy months may probably be due to active growth period of the plants (Whitsell *et al.*, 1989).

The highest transplantable grafts after one year were recorded in cleft grafting (30.8%) which was higher than veneer grafting (3.3%), patch budding (0%) and T-budding (0.83%). Among different months of grafting/budding, highest transplantable grafts were recorded during September (20.0%), closely followed by March (15.0%). Among various combinations of method and time of propagation, highest success (60%) was recorded in cleft grafting performed during September. This was closely followed by cleft grafting

**Table 2. Length of scion (cm) in different methods of propagation after 3 months**

| Months/ method | Cleft grafting | Veneer grafting | Patch budding | T-budding | Average |
|---|---|---|---|---|---|
| January | 5.9 | - | - | - | 5.90 |
| February | 6 | - | - | - | 6.00 |
| March | 7.5 | 5.2 | 2.5 | 2.6 | 4.45 |
| April | 7.3 | 5.1 | - | - | 6.20 |
| May | 8.5 | - | 3.2 | - | 5.85 |
| June | 8.5 | 5.1 | 3.1 | 2.9 | 4.90 |
| July | 8.1 | 5.3 | 3.2 | 2.8 | 4.85 |
| August | 8.8 | 5.4 | 3.5 | 2.6 | 5.08 |
| September | 10.3 | 5.6 | 3.2 | 2.9 | 5.50 |
| October | 9.4 | 3.4 | 3.9 | 2.7 | 4.85 |
| November | 8.1 | - | - | - | 8.10 |
| December | 7.2 | - | - | - | 7.20 |
| Av. | 7.97 | 5.01 | 3.23 | 2.75 | 5.74 |
| CD (0.05) | Method | 0.89 | Month | NS | |
| | (Method x month) Interaction | 8.25 | | | |

**Table 3. Per cent transplantable grafts after one year**

| Months/ method | Cleft grafting | Veneer grafting | Patch budding | T-budding | Average |
|---|---|---|---|---|---|
| January | 10 | 0 | 0 | 0 | 2.5 |
| February | 10 | 0 | 0 | 0 | 2.5 |
| March | 50 | 0 | 10 | 0 | 15.0 |
| April | 30 | 0 | 0 | 0 | 7.3 |
| May | 30 | 0 | 0 | 0 | 7.3 |
| June | 40 | 0 | 0 | 0 | 10.0 |
| July | 40 | 10 | 0 | 0 | 12.5 |
| August | 40 | 10 | 0 | 0 | 12.5 |
| September | 60 | 10 | 0 | 10 | 20.0 |
| October | 30 | 10 | 0 | 0 | 10.0 |
| November | 20 | 0 | 0 | 0 | 5.0 |
| December | 10 | 0 | 0 | 0 | 2.5 |
| Av | 30.8 | 3.3 | 0 | 0.83 | 8.7 |
| CD (0.05) | Method | 5.02 | Month | 5.31 | |
| | (Method x month) Interaction | 8.25 | | | |

during March (50%). The numbers of transplantable grafts were very low or nil in veneer grafting, T-budding and patch budding done during most of the months (Table 3). The results revealed that the mortality of grafts after 3 months was very low as most of the grafts once the reunion took place. This may be correlated with the faster growth of avocado seedlings and the climatic conditions.

Thus, it was concluded that cleft graftingdone during Septemberor-March is most appropriate for multiplication of avocado under humid tropical conditions of Western Ghats.

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# Analysis of attitude of fruit growers towards guava *(Psidium guajava)* cultivation in Sawai Madhopur district of Rajasthan, India

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## ABSTRACT

The study was undertaken to know the attitude of farmers towards guava (*Psidium guajava* L.) cultivation in Sawai Madhopur district of Rajasthan (India) during 2013. Data were solicited from randomly selected 180 guava growers in Sawai Madhopur district. A five-point Likert rating scale was applied. The results showed that most of the farmers had positive attitude towards guava growing due to more income. They perceived that cultivation of guava can boost their economy (92.22%) because of its cultivation is easier to unskilled farmers (54.44%). Farmers perceives that cultivation of guava is labour intensive enterprise (84.45%)and they had positive attitude for that lack of supportive Government policy is a big hindrance in guava plants cultivation (58.88%) and subsidy is better option for government to promote guava cultivation (91.66%). Since majority of guava cultivators in SawaiMadhopur belongs to tribal community, therefore assistance from government side is better option for economic empowerment of farmers as well as high yield of guava. Farmers were also in agreement with that motivation agencies in the area play a vital role in the promotion of guava crops (57.22%).The farmers, if provided adequate credit facility, can be attracted towards cultivation of guava (87.78%).

**Key Words**: Awareness, Guava, Knowledge level, Marketing channels, Sawai madhopur

Guava (*Psidium guajava* L.) is most important fruit crop in India. It is quite hardy and prolific bear. It is easy to grown with good economic returns as farmers point of view (Meena *et al.*, 2018). In India, It occupies an area of 2.62 lakh ha with annual production of 36.48 lakh tonnes during 2016-17 (Anonymous, 2017). It is a rich source of vitamin C and fair source of calcium, phosphorous and roughage hence; it is ideal fruit for nutritional security. It is also good source of pectin and therefore, it is useful for preparation of jam, jelly and nectar. Sawai Madhopur district is one such area where guava has become very popular in short span of time. It was started at modest 1.25 ha of land in Karmoda village by Mohammed Yakub Ali dates back to 1985. Now guava has occupied over 5000 ha area in Sawai Madhopur district. Traditionally, district has popularity of Lucknow-49 and Allahabad Safeda varieties of guava. However, sometimes back a private nursery man introduced a variety known as Gola (Barfkhan) in the district. Gola is better over Lucknow-49 and Allahabad Safeda in respect of fruit weight, size, thickness of flesh, weight of pure flesh excluding seed cavity, soft textureof seeds, ascorbic acid and TSS contents (Singh, *et al.*, 2016). Due to its taste and market price it attracts farmers as well as to consumers, respectively. Keeping in view, study was designed to find out the knowledge and attitude of guava growers towards its cultivation.

## MATERIALS AND METHODS

Local variety 'Gola' of guava (*Psidium guajava* L.) is popular for its taste and size in Sawai Madhopur district. It is very ruminative than other field crops, increasing area under guava cultivation in the district. Therefore, present study was carried out in Sawai

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Mdhopur district of Rajasthan during 2013. The selected district consists of 5 blocks, *i.e.* Sawai Madhopur, Khandar, Bonli, Gangapur and Bamanwas. The specific taste and size of Gola variety is attributed to Sawai Madhopur block, so far area is increasing. Farmers were selected on the basis of proportionate area under guava cultivation in each block. Maximum farmer number (140) from Sawai Madhopur block and 40 farmers (10 in each block) from Khandar, Bonli, Gangapur and Bamanwas were selected with the help of random sampling technique. Thus, total sample consist of 180 guava growers. The data were collected by personal interview with the help of standardized scale. To determine farmers' attitudes towards guava cultivation, a five-point Likert rating scale was applied, i.e. strongly agree, agree, undecided, disagree and strongly disagree, and score were assigned 5,4,3,2 and 1, respectively (Vyas *et al.,* 2009 and 10).

## RESULTS AND DISCUSSION

The respondents were grouped under three categories namely, low, medium and high on the basis of their mean and standard deviation of scores obtained by respondents (Table 1).

The data indicate that majority of guava growers (53.33%) had medium level of knowledge about guava production technology, whereas, 36.67 per cent respondents were observed in low knowledge level group Table 1. It was distressing to note that only 10.00 per cent of the total respondents had high level of knowledge on guava production technology. The results are in accordance with the findings of Dhayal *et al.* (2009), Sharma and Nitharwal (2011), Meena (2012) and Meena *et al.* (2013). On the basis of data, it was inferred that existing knowledge of farmers about guava production technology needs more emphasis for quality fruit production.

In general the result was under high frequency. In the five-point continuum of scale, most of the farmers were in positive side. They perceived that cultivation of guava can boost the economy of farmers (92.22%).

**Table 1. Distribution of respondents on the basis of their existing knowledge about guava production technology**

N = 180

| Knowledge level | *f* | % |
|---|---|---|
| Low (< 24.06) | 66 | 36.67 |
| Medium (24.06-48.15) | 96 | 53.33 |
| High (> 48.15) | 18 | 10.00 |
| Total | 180 | 100.00 |

*f* = Frequency

The technical skills are not needed; hence cultivation of guava is easier for unskilled farmers (54.44%). They adopted proper spacing in guava orchards (90%). Farmers were aware about micronutrients spray on guava (73.89%), training and pruning practices in guava plants (55.11%). The drip irrigation practices may also promote guava cultivation (62.78%), management of major insects and diseases in guava orchards (56.11%) (Table 2).

Farmers perceived that cultivation of guava plants is labour intensive (84.45%), hence they had positive attitude with the statement that lack of supportive government policy is a big hindrance in guava cultivation (58.88%) and subsidy is better option for the government to promote cultivation (91.66%). Majority of guava growers in district Sawai Madhopur belongs to the tribal community;therefore assistance from government side should be better option for economic empowerment of farmers as well as more yield of guava. Farmers were also in agreement that motivation agencies in the area play a vital role in promotion of guava cultivation (57.22%). If farmers, provided adequate credit facility, thus can be attracted towards cultivation of guava (87.78%). Further, farmers were disagree with the statement that only big and resource rich farmers can venture for its cultivation (57.22%). They had positive attitude about towards cultivation of guava even by resource poor farmers (50.55%). It means guava cultivation is also fruitful for small and marginal farmers. Resource sharing by poor farmers was increased, resulting in decreased social disparity.

Guava cultivation in the region was highly economic for farmers since they agreed with the statement that guava cultivation develops entrepreneurship among farmers (68.33%), while Value addition industry in the area can promote its cultivation (67.78%) and strengthening linkages between farmers and PHT industries can promote the cultivation of guava (51.67%). The extension functionaries have competence to educate us about scientific cultivation of guava (80%). Farmers were disagree with negative statement that cultivation of guava is neither feasible nor economical (43.89%). Its cultivation is not a remunerative enterprise (71.67%) and its planting is mere waste of time and energy (61.11%).

Majority of respondents were not aware about mandies at city or town level (89.44%), local market (87.78%), cooperative societies (82.22%) and whole seller (74.44%) (Table 3). It depicts that guava growers were not aware about marketing channels. Government mandi system was not supportive for guava marketing. Further, more than 50% of respondents were aware about village merchants, village traders, commission

**Table 2. Attitude of respondents about production technology of guava.**

| Statement | SA (5) | | A (4) | | UD (3) | | D (2) | | SD (1) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | f | % | f | % | f | % | f | % | f | % |
| Cultivation of guava can boost the economy of farmers | 90 | 50.00 | 76 | 42.22 | 8 | 4.44 | 2 | 1.11 | 4 | 2.22 |
| Cultivation of guava is labour intensive enterprise | 37 | 20.56 | 115 | 63.89 | 20 | 11.11 | 5 | 2.78 | 3 | 1.67 |
| Technical skills are not needed, hence cultivation of guava plants is easier for unskilled farmers | 13 | 7.22 | 85 | 47.22 | 28 | 15.56 | 48 | 26.67 | 6 | 3.33 |
| Farmers adopted proper spacing in guava orchards | 72 | 40.00 | 90 | 50.00 | 10 | 5.56 | 5 | 2.78 | 3 | 1.67 |
| Only big and resource rich farmers can venture for cultivation of guava | 4 | 2.22 | 56 | 31.11 | 17 | 9.44 | 99 | 55.00 | 4 | 2.22 |
| Cultivation of guava by resource poor farmers reduces social disparity | 4 | 2.22 | 87 | 48.33 | 26 | 14.44 | 39 | 21.67 | 24 | 13.33 |
| Subsidy is better option for government to promote guava cultivation | 116 | 64.44 | 49 | 27.22 | 7 | 3.89 | 2 | 1.11 | 6 | 3.33 |
| Value- addition industry in area can promote guava cultivation | 76 | 42.22 | 46 | 25.56 | 38 | 21.11 | 12 | 6.67 | 8 | 4.44 |
| The extension functionaries have competence to educate us about scientific cultivation of guava | 52 | 28.89 | 92 | 51.11 | 20 | 11.11 | 4 | 2.22 | 12 | 6.67 |
| Lack of supportive Govt. policy is a big hindrance in guava cultivation | 71 | 39.44 | 35 | 19.44 | 28 | 15.56 | 44 | 24.44 | 2 | 1.11 |
| Motivation agencies in the area play a vital role in the promotion of guava crops | 60 | 33.33 | 43 | 23.89 | 26 | 14.44 | 43 | 23.89 | 8 | 4.44 |
| Farmers are aware about micronutrients spray on guava plants | 76 | 42.22 | 57 | 31.67 | 21 | 11.67 | 22 | 12.22 | 4 | 2.22 |
| Farmers are aware about training and pruning practices in guava plants | 38 | 21.11 | 63 | 35.00 | 39 | 21.67 | 13 | 7.22 | 27 | 15.00 |
| Awareness about drip irrigation practices may also promote guava cultivation | 59 | 32.78 | 54 | 30.00 | 25 | 13.89 | 38 | 21.11 | 4 | 2.22 |
| Farmers are aware about management of major insects and diseases in guava orchards | 39 | 21.67 | 62 | 34.44 | 24 | 13.33 | 51 | 28.33 | 4 | 2.22 |
| Guava cultivation develop entrepreneurship among farmers | 40 | 22.22 | 83 | 46.11 | 25 | 13.89 | 24 | 13.33 | 8 | 4.44 |
| Farmers, if provided adequate credit facility, can be attracted towards cultivation of guava | 83 | 46.11 | 75 | 41.67 | 8 | 4.44 | 2 | 1.11 | 12 | 6.67 |
| Guava cultivation is mere waste of time and energy | 8 | 4.44 | 31 | 17.22 | 31 | 17.22 | 57 | 31.67 | 53 | 29.44 |
| Cultivation of guava crops is neither feasible nor economical | 3 | 1.67 | 43 | 23.89 | 55 | 30.56 | 64 | 35.56 | 15 | 8.33 |
| Strengthening linkages between farmers and PHT industries can promote the cultivation of guava | 64 | 35.56 | 29 | 16.11 | 18 | 10.00 | 60 | 33.33 | 9 | 5.00 |
| Guava cultivation is not a remunerative enterprise | 3 | 1.67 | 31 | 17.22 | 17 | 9.44 | 106 | 58.89 | 23 | 12.78 |

SA, strongly agree; A, agree; UD, undecided; D, disagree; SD, strongly disagree

**Table 3. Awareness about marketing channels available for guava growers**

**N = 180**

| Marketing channel | Awareness | | | |
|---|---|---|---|---|
| | Yes | | No | |
| | f | % | F | % |
| Whole seller | 46 | 25.56 | 134 | 74.44 |
| Local market | 22 | 12.22 | 158 | 87.78 |
| Cooperative societies | 32 | 17.78 | 148 | 82.22 |
| Mandies at city/town | 19 | 10.56 | 161 | 89.44 |
| Village merchants | 108 | 60.00 | 72 | 40.00 |
| Retailer | 104 | 57.78 | 76 | 42.22 |
| Direct consumer | 84 | 46.67 | 96 | 53.33 |
| Village traders | 122 | 67.78 | 58 | 32.22 |
| Regulated markets | 95 | 52.78 | 85 | 47.22 |
| Commission agents | 128 | 71.11 | 52 | 28.89 |
| Farmers' level | 62 | 34.44 | 118 | 65.56 |

agents and retailing of guava marketing channels (Table 3).

Thus, it can be concluded that 53.33 per cent of guava growers had medium level of knowledge whereas, farmer's attitudes towards its technology can boost economics of maximum (92.22%) farmers. Cultivation of guava is easier for unskilled growers, although it requires financial assistance from government as well as private sector.

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# Effect of biofertilizers on floral attributes and corm yield of gladiolus *(Gladiolus grandiflorus)* under hilly condition of Uttarakhand, India

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**ABSTRACT**

An experiment was conducted to study the effect of biofertilizers on floral attributes and corm yield of gladiolus (*Gladiolus grandiflora* L.) var. Arka Amar at Floriculture and Landscaping Block, College of Horticulture, VCSG, Uttarakhand University of Horticulture and Forestry, during 2016. The experiment consists of eight treatments, *viz*. control, PSB @ 2ml/l, *Azotobacter* @ 25g/l, VAM @ 20g/l and their combinations. Recommended doses of fertilizer were applied as a common basal dose in all treatments. The experiment was laid out in randomized complete block design and replicated thrice. The results revealed that minimum number of days were taken to first floret opening (111.76) and maximum number of spike per plant and per plot (2.00 and 32.00, respectively), floret diameter (12.46 cm) and number of corms per plot (31.00) were recorded from the corms inoculated with PSB @ 2ml/l + *Azotobacter* @ 25 g/l + VAM @ 20 g/l. There was maximum corm weight (60.60 g), corm diameter (6.20 cm), numbers of cormels per plant and per plot (37.33 and 600.76, respectively) from the corms inoculated with *Azotobacter* @25 g/l +VAM @20 g/l, followed by PSB @ 2ml/l + *Azotobacter* @ 25 g/l + VAM @ 20 g/l. Thus, it can be concluded that application of PSB @ 2ml/l + *Azotobacter* @ 25 g/l + VAM @ 20 g/l can be used for getting superior quality and yield in gladiolus var. Arka Amar.

**Key Words**: *Azotobacter,* Corms, Cormels, VAM, PSB, Recommended doses of fertilizers

Gladiolus (*Gladiolus grandiflorus* L.) ranks among the top ten cut flowers in international market as well as domestic market. It belongs to the family Iridaceae with chromosome number n =15. It is a nutrient responsive. The excessive use of chemicals has caused serious damage to soil rendering them, often times, saline and less suitable for cultivation (Dalvi *et al.*, 2009). Besides affecting soil health, these chemical fertilizers have adverse effect on flora and fauna. Kashyap *et al.* (2014) reported that biofertilizers have emerged as a supplement to mineral fertilizers and hold a promise to improve quality as well as quantity of flower crops. The commonly used biofertilizers are Vesicular Arbuscular Mycorrhiza, *Azotobacter* and Phosphate Solubilizing Bacteria *etc.* Hazarika *et al.* (2015) reported that inoculation of N fixing microorganisms in soil not only increases the yield but also save 20-40% nitrogen. The use of PSB as inoculants simultaneously increases phosphorus uptake by plants and finally improve crop yield. The VAM acts as accessories to root hairs in the process of nutrient absorption and mobilization. These days biofertilizers have emerged as an important component to improve an overall crop performance, yield, nutrient supply, reducing the quantity of chemical fertilizers used in agricultural production (Yadav and Kavita, 2016). Keeping these points in view, an experiment was conducted to find out the effect of biofertilizers on floral attributes and corm gladiolus var. Arka Amar under hilly condition of Uttarakhand.

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## MATERIALS AND METHODS

The experiment was conducted at Floriculture and Landscaping Block, College of Horticulture, VCSG Uttarakhand University of Horticulture and Forestry, Bharsar, Pauri, Gharwal, during in 2016. The experiment was laid out in a randomized complete block design and which were replicated thrice. The treatments consists of control, PSB @ 2ml/l, *Azotobacter* @ 25g/l, VAM @ 20g/l, PSB @ 2ml/l + *Azotobacter* @ 25g/l, PSB @ 2ml/l + VAM @ 20g/l, *Azotobacter* @ 25g/l + VAM @ 20g/land PSB @ 2 ml/l + *Azotobacter* @ 25g/l + VAM @ 20g/l. In all the treatments, RDF (120:150:150 kg/ha) was applied as a common basal dose.

Slurry was prepared by mixing biofertilizers quantity as per the treatment basis in one litre water and a small quantity of jaggery was added so that inoculants could stick to the corms properly. The corms were immersed in the suspension for 30 minutes and then drying in shade was done before planting the corms. Corms were planted at a spacing of 30 cm × 30 cm, accommodating 16 plants per plot. The observations on number of days taken to first floret opening, number of spike per plant and per plot, diameter of floret and number of corms per plot, corm weight and diameter, number of cormels per plant and per plot were recorded. The data were analyzed by statistical methods by Gomez and Gomez (1984). The critical difference was calculated at 5% level.

## RESULTS AND DISCUSSION

The data showed that minimum days taken to first floret opening (111.76 ± 0.26 days) were recorded in treatment $T_8$ (PSB @ 2 ml/l + *Azotobacter* @ 25 g/l + VAM @ 20 g/l), whereas maximum days taken to first floret opening (121.33 ± 0.33) were recorded in the control. All the treatments significantly improved the number of days taken to first floret opening as compared to the control except $T_3$ (Table 1). Earliness in first floret opening might be due to easy availability and uptake of nutrients by the use of inoculated corms and simultaneous transport of growth promoting substances to axillary buds resulting in breakage of apical dominance. Ultimately, they resulted in better sink for faster mobilization of photosynthates and early transformation of plant parts from vegetative to reproductive phase. A similar trend was also observed by Kumar *et al.* (2011), Singh *et al.* (2013) and Srivatsava and Govil (2007) in gladiolus.

Among treatments, $T_8$ (PSB @ 2 ml/l + *Azotobacter* @ 25 g/l + VAM @ 20 g/l) produced maximum number of spikes per plant and per plot (2.00 ± 0.11 and 32.00 ± 2.13, respectively), followed by $T_4$ (1.60 ± 0.11 and 25.60 ± 4.26, respectively). The minimum number of spike per plant and per plot (1.13 ± 0.06 and 18.13 ± 1.06, respectively) were recorded from the plants grown in the control plots. The increase in number of spike per plant in $T_8$ might be due to the influence of combination of biofertilizers and RDF which increased the availability of nitrogen and phosphorus as well as micronutrient like Zn. The Zn is precursor of auxin, which improves vegetative growth, dry matter accumulation and their partitioning towards the development of spikes in gladiolus. Gupta (2006) reported that Phosphate Solubilizing Bacteria (PSB) species like *Pseudomonas striata* and *Bacillus polymyxa* are beneficial in increasing the phosphorus availability in soil and thereby increases the yield. The results were in accordance with the reports of Chauhan and Kumar (2007) in marigold and Kumari *et al.* (2014) in gladiolus.

The highest floret diameter (12.46 ± 0.11 cm) was observed in treatment $T_8$ (PSB @ 2 ml/l + *Azotobacter* @ 25 g/l + VAM @ 20 g/l) which was found statistically at par with $T_5$ (12.38 ± 0.09 cm). Minimum floret diameter (8.71 ± 0.11 cm) was recorded in the control. The increment in floret diameter might be due to availability of nutrition and elevated levels of macronutrients which have positive effect on floral characteristics. The findings are in line with those reported by Kawarkhe *et al.* (2002), Kulkde *et al.* (2006) and Chaudhary (2007) in tuberose and Ahmed *et al.* (2014) in gladiolus, Kumari *et al.* (2014) in gladiolus and Chauhan and Kumar (2007) in pot marigold.

Maximum number of corms per plot (31.00 ± 1.15) was found in $T_8$, which was found statistically at par with $T_6$ (29.00 ± 0.57). Number of corms per plot was found minimum (20.66 ± 0.08) in the control ($T_1$). All the treatments and their combinations were significantly superior over the control ($T_1$). This might be due to better nitrogen fixation by *Azotobacter*, absorption of phosphorus by VAM and greater solubilization of insoluble phosphates by PSB and growth promoting substances, control of pathogens and proliferation of beneficial organisms in rhizosphere layed a significant role (Barea and Brown, 1974) in increasing number of corms in $T_8$ treatment. The present findings are in confirmation with those of Dubey and Misra (2005) and Kumar *et al.* (2011a) in gladiolus.

The treatment $T_7$ (*Azotobacter* @ 25g/l + VAM @ 20g/l) was found to be significantly superior in recording highest corm weight and diameter (60.60 ± 1.11 g and 6.20 + 0.10 cm, respectively), followed by $T_8$ (57.50 ± 0.62 g and 6.15 ± 0.69 cm, respectively) (Table 1). Corm weight and diameter were found lowest in $T_1$ (45.00 ± 0.93g and 5.23 ± 0.02cm). The increase in corm weight may be attributed to cell enlargement caused

**Table 1. Effect of biofertilizers on quality and yield attributes of gladiolus var. Arka Amar.**

| Treatment | Number of days taken first floret open (days) ± S.E(m) | Diameter of floret (cm) ± SE(m) | Number of spikes per plant ± SE(m) | Number of spikes per plot ± SE(m) | Number of corms per plot ± SE (m) | Weight of corms (g) ± SE (m) | Diameter of corms (cm) ± SE (m) | Number of cormels per plant ± S.E(m) | Number of cormels per plot ± S.E (m) |
|---|---|---|---|---|---|---|---|---|---|
| $T_1$ | 121.33±0.33 | 8.71 ±0.11 | 1.13± 0.06 | 18.13±1.06 | 20.66 ±0.08 | 45.00± 0.93 | 5.23±0.02 | 26.33±0.33 | 425.09±2.22 |
| $T_2$ | 118.50±0.28 | 11.63±0.08 | 1.20 ±0.11 | 19.20±1.84 | 24.33±1.20 | 50.38±0.18 | 5.36±0.06 | 29.00±1.52 | 468.00±2.30 |
| $T_3$ | 120.66±0.33 | 9.33±0.06 | 1.46 ±0.26 | 23.46±4.26 | 25.00±0.57 | 51.70±0.47 | 5.54±0.05 | 30.00±0.57 | 484.66±2.60 |
| $T_4$ | 116.66±0.33 | 9.73±0.17 | 1.60±0.11 | 25.60±4.26 | 23.00±0.57 | 55.33 ±0.33 | 5.86±0.04 | 31.00±0.57 | 495.33±2.33 |
| $T_5$ | 116.00±0.57 | 12.38±0.09 | 1.53±0.06 | 24.53±1.84 | 28.00±1.15 | 52.10±0.34 | 5.65±0.18 | 33.00±1.15 | 532.66±2.40 |
| $T_6$ | 114.16±0.23 | 11.43±0.27 | 1.26±0.06 | 20.26±1.06 | 29.00±0.57 | 54.70±0.70 | 5.78±0.32 | 35.33±2.60 | 568.42±1.67 |
| $T_7$ | 117.06±0.44 | 10.14±0.05 | 1.33± 0.13 | 21.33±1.06 | 27.66±0.88 | 60.60±1.11 | 6.20±.10 | 37.33±1.20 | 600.76±1.94 |
| $T_8$ | 111.76±0.26 | 12.46±0.11 | 2.00±0.11 | 32.00±2.13 | 31.00±1.15 | 57.50±0.62 | 6.15±0.07 | 36.33±0.88 | 585.42±2.24 |
| SE(d) | 0.50 | 0.20 | 0.18 | 2.90 | 1.28 | 0.98± | 0.16 | 1.76 | 2.01 |
| CD (0.05) | 1.10 | 0.43 | 0.39 | 6.28 | 2.78 | 2.13 | 0.36 | 3.82 | 4.36 |

by *Azotobacter* and VAM and it was also possibly due to increased production of carbohydrate which was transferred to corm for storage. Better vegetative growth resulted in more assimilation of food material and its diversion towards corm production and more corm weight as well as corm diameter. The present findings are in close agreement with the findings of Ahmed *et al.* (2014) in gladiolus and Kumar *et al.* (2013) in tulip.

All treatments showed significant increase in number of cormels per plant and per plot as compared to the control ($T_1$). The highest number of cormels per plant and per plot (37.33 ± 1.20 and 600.76 ± 1.94, respectively) were harvested from the plants grown in plots applied with treatment $T_7$, followed by $T_8$ (36.33 ± 0.88 and 585.42 ±2.24, respectively). Whereas, minimum cormels per plant and per plot (26.33 ± 0.33 and 425.09 ± 2.22, respectively) were observed in the control ($T_1$). The increase in cormels per pant and per plot may be attributed to cell enlargement caused by *Azotobacter* and VAM and it was also possibly due to increased production of carbohydrate which was transferred to corm for storage. It can be due to enhanced N and other nutrients availability to the plants which might results in increase in reserve carbohydrate material which causes increase number of cormels per plant and per plot Kumari *et al.* (2014) and Kumar *et al.* (2010) in gladiolus.

## CONCLUSION

Thus, application of biofertilizers along with recommended doses of fertilizers showed significantly improvement in floral attributes and corm yield of gladiolus var. Arka Amar as compared to the control. Among different treatments, maximum flowering attributes and corm yield were found from the plants grown in plots applied with PSB + *Azotobacter* + VAM + RDF due to optimum availability of nutrients under this treatment that are essential for growth and development of plants. Thus, application of PSB @ 2ml/l + *Azotobacter* @ 25 g/l + VAM @ 20 g/l can be used for getting superior quality and yield in gladiolus var. Arka Amar.

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# Response of fertilizer application on yield and economics of papaya (*Carica papaya*)

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**ABSTRACT**

The experiment was conducted to find out the response of fertilizer application on yield and yield attributes of papaya (*Carica papaya* L.) var. Red Lady" during 2016-17 at Regional Horticultural Research Station, ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari (Gujarat). The experiment was laid out with nine treatments in a randomized block Design (RBD) and replicated thrice. The treatments included 100% RDF (200:200:250 g NPK/plant) as the control in four equal splits (2, 4, 6 and 8 MAP), 100 and 80% recommended dose of nitrogen and potash in 8 equal splits starting from 2nd month after planting at 30 days interval with or without foliar application of 1% Grade-IV micronutrient and novel organic liquid fertilizer at 2, 4, 6 and 8 month after planting. Results revealed that papaya var. Red Lady plants fed with 80% RDNK (160:200 g/plant) and applied in 8 equal splits starting from 2 month after planting at 30 days interval with foliar application of novel organic liquid fertilizer at 2, 4, 6 and 8 month after planting gave maximum number of fruits per plant, average fruit weight (kg), diameter of fruit (cm), length of fruit (cm), yield (kg/plant and t/ha), maximum net realization and benefit : cost ratio.

**Key Words**: Foliar application, Grade-IV micronutrient, Novel organic liquid fertilizer, Red Lady, Split application

Papaya (*Carica papaya* L.) is an important fruit of tropical and subtropical regions of the world. Papaya is a heavy feeder and needs heavy doses of manures and fertilizers. Apart from the basal dose of manures applied in pits, 200g each of N and $P_2O_5$ and 250g $K_2O$ are recommended for getting high yield. Application of 200g N is optimum for fruit yield but papain yield increases with increase in N up to 300g. Micronutrients can tremendously boost crop yield and improve quality and post-harvest life of produce. The replacing micronutrients that have been removed or increasing organic matter to make native nutrients available, has not received sufficient attention. Papaya requires 989mg B, 300mg Cu, 3364mg Fe, 1847mg Mn, 8mg Mo and 1385mg Zn per tonne of fruit. While, separating fibers from the banana pseudo stem, the liquid available is known as banana pseudostem sap which contains amount of essential macro and micro plant nutrients. Hence, there is a vast scope to utilize banana pseudostem sap as a liquid fertilizer. Apart from direct use of sap as liquid fertilizer, an enrichment process was developed (patented) for preparing Novel Organic Liquid Fertilizer (NOLF) suitable for foliar and soil application. The OLF has been prepared using only organic inputs and hence suitable for use in organic farming system as liquid formulation. Organic liquid fertilizer is good source of plant nutrient along with growth promoting substances like cytokinin GA, *etc.* (NAU, 2014). Hence, an experiment was conducted.

## MATERIALS AND METHODS

The experiment was conducted at Regional Horticultural Research Station, ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari (Gujarat) during 2016-17. The experiment was laid out with nine treatments in a Randomized Block Design (RBD) and replicated thrice. The treatments included 100% RDF (200:200:250 g NPK/plant) as control in four equal splits (2, 4, 6, and 8 MAP), 100 and 80% recommended dose of nitrogen

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and potash in 8 equal splits starting from 2 month after planting in 30 days interval with or without foliar application of 1% Grade-IV micronutrient and novel organic liquid fertilizer at 2, 4, 6 and 8 month after planting. Yield and yield parameters were recorded and analyzed statistically.

## RESULTS AND DISCUSSION

The data clearly revealed that the yield and yield attributes, *viz.* number of fruits per plant, average fruit weight (kg), diameter of fruit (cm), length of fruit (cm), yield (kg/plant) and yield (t/ha) were significantly differ due to application of nutrients (Table 1).

Number of fruits per plant, average fruit weight (kg), diameter of fruit (cm), length of fruit (cm), fruit yield per plant (kg) and per hectare (t) were maximum when plant received 80% RDNK through 8 equal split application + foliar application of 1% novel organic liquid fertilizer. Fruit yield increased with split application of N and K in combination with 1% novel organic liquid fertilizer. Increased in fruit attributes could be due to increase in morpho-logical traits such as plant height, girth, number of leaves, leaf area, faster rate of leaf production and also higher nutrient uptake by the plant.

Higher fruit yield (t/ha) in papaya was realized due to increase in fruit number and fruit weight per plant. The higher fruit yield/plant might be due to increased fruit length, breadth and circumference, fruit number and fruit weight with split application of N and K in 8 equal splits. Steady and continuous availability of essential plant nutrients by the addition of N and K , enhances the availability of more amount of primary nutrients and growth promoting substances from the beginning of the initial vegetative stage up to completion of cropping period (Yadav *et al.*, 2010). These results are in conformity with the findings of Purohit (1977), Ghanta *et al.* (1995), Bisht *et al.* (2010) in papaya.

The split application of N and K treatment significantly increased fruit diameter (cm) and fruit length (cm).Maximum value of fruit diameter (cm) and fruit length were obtained from papaya when plant treated with 80% RDNK through 8 equal split applications. The mobility of photosynthates from source to sink, *i.e.* higher translocation was possible perhaps due to better sink capacity as indicated by higher number of fruits per plant and weight of fruit. Similarly, improvement in fruit number, fruit weight with split application of N and K were reported in various crops by Purohit (1977) and Ghanta *et al.* (1995).

There was significant increase in length and diameter of fruit (cm) due to 1% novel organic liquid fertilizer. It might be due to higher carbohydrate accumulation in plant at early stages of growth as a resulted better nutrient supply, which causes an increased in fruit size and there by increased the average fruit weight in terms of length and diameter of fruit. Similar results were reported by NAU (2014) in banana and Deore *et al.* (2010) in chilli.

The foliar application of 1% novel organic liquid fertilizer had maximized the number of fruits per plant, average fruit weight, and yield over other treatments. The lower yield of papaya recorded under the control treatment might be due to slow growth of plant, small leaf size, less number of per plant. Yield per plant increased with foliar application of novel organic liquid fertilizer due to macro and micronutrients which are present in novel organic liquid fertilizer. The nutrients N and K at higher rate exerted a significant positive

**Table 1. Response of fertilizer application on yield and economics of papaya var. Red Lady**

| Treat-ment | Number of fruits/ plant | Average fruit weight (kg) | Diameter of fruit (cm) | Length of fruit (cm) | Yield (kg/plant) | Yield (t/ha) | Gross realization | Net return ₹ | Benefit: cost ratio |
|---|---|---|---|---|---|---|---|---|---|
| $T_1$ | 20.16 | 1.42 | 19.85 | 19.52 | 28.63 | 71.57 | 715700 | 572167 | 3.99 |
| $T_2$ | 20.39 | 1.55 | 21.65 | 21.42 | 31.65 | 78.86 | 788600 | 634302 | 4.11 |
| $T_3$ | 21.72 | 1.61 | 20.64 | 19.72 | 35.05 | 87.62 | 876200 | 722408 | 4.70 |
| $T_4$ | 20.36 | 1.59 | 23.34 | 22.73 | 32.36 | 80.90 | 809000 | 657274 | 4.33 |
| $T_5$ | 22.77 | 1.71 | 24.52 | 21.76 | 38.93 | 97.33 | 973300 | 806269 | 4.83 |
| $T_6$ | 22.87 | 1.86 | 25.66 | 24.44 | 42.63 | 106.57 | 1065700 | 898935 | 5.39 |
| $T_7$ | 22.03 | 1.66 | 23.61 | 22.60 | 36.60 | 91.49 | 914900 | 756059 | 4.76 |
| $T_8$ | 20.27 | 1.54 | 22.73 | 21.58 | 31.18 | 77.94 | 779400 | 620214 | 3.90 |
| $T_9$ | 20.17 | 1.75 | 22.29 | 22.63 | 35.35 | 88.38 | 883800 | 724280 | 4.54 |
| SEm± | 0.71 | 0.08 | 1.00 | 0.89 | 2.00 | 5.03 | --- | --- | --- |
| CD (5%) | 2.12 | 0.24 | 3.00 | 2.68 | 5.99 | 15.07 | --- | --- | --- |
| CV (%) | 5.77 | 8.58 | 7.63 | 7.09 | 9.97 | 10.04 | --- | --- | --- |

influence on fruit weight. The highest fruit weight was recorded in plants treated with 1% novel organic liquid fertilizer, which might be due to higher uptake of N and K by plants. Usefulness of nutrients to determine the influence on yield attributing characters of papaya is adequately stressed and the present study also corroborated with the findings of NAU (2014) in banana; NAU (2012) in mango; NAU (2013) in papaya and Deore *et al.* (2010) in chilli.

The foliar application of 1% Grade-IV micronutrient treatment at 2, 4, 6 and 8 months after planting recorded more number of fruits per plant as compared to the control. Foliar application of micronutrients involved directly in various physiological processes and enzymatic activity. This might have resulted into better photosynthesis, greater accumulation of starch in fruits and involvement of Zn in auxin synthesis and B in translocation of starch to fruits. The balance of auxin in plant increased the total number of fruits per plant.

Micronutrients spray at 2, 4, 6 and 8 month after planting significantly increased the length and diameter of fruit. Zn plays a vital role to promote starch formation. The possible reason for increased in length and diameter of papaya by the micronutrients, might be due to faster loading and mobilization of photo assimilates to fruits and involvement in cell division and cell expansion which ultimately reflected into more length and diameter in treated plants (Ghanta and Mitra, 1993). Similar results were also found by Yadav *et al.* (2010) in banana; Shekhar *et al.* (2010), Modi *et al.* (2012) and Bhalerao *et al.* (2014) in papaya.

The yield of papaya cv. Red Lady was significantly influenced by micronutrients. The maximum yield was obtained from plant treated with 1%, Grade-IV micronutrient at 2, 4, 6 and 8 month after planting compared to control. This might be due to iron (Fe) is highly associated with chlorophyll synthesis which later on boosted the photosynthesis. Promotion of starch formation followed by rapid transportation of carbohydrates in plants is activated by micronutrients like Zn and B which are well established. The most outstanding effect of micronutrients on yield was due to favorable effect on, higher number of fruits per plant and average fruit weight (kg).These results are in confirmation with those of Yadav *et al.* (2010) in banana; Shekhar *et al.* (2010), Modi *et al.* (2012) and Bhalerao *et al.* (2014) in papaya.

Among the different treatments, maximum net return and higher benefit : cost ratio were obtained in papaya var. Red Lady plants when they were fed with 80% RDNK through 8 equal split application + foliar application of 1% novel organic liquid fertilizer treatment. In our investigation, same treatment gave maximum fruit retention, yield and yield attributing characters which leads to higher net returns and benefit : cost ratio.

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# Interactive effect of organic manures and fertility levels on growth, fruit yield and B:C ratio of ber (*Zizyphus mauritiana*) under semi-arid conditions

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**ABSTRACT**

The experiment was conducted to find out the interactive effect of organic manures and fertility levels on three-year-old ber (*Zizyphus mauritiana* Lamk.) plants of cv. Gola at SKN College of Agriculture, Jobner, Rajasthan (India), during 2015-2016. The experiment consisted of 20 treatment combinations with four levels of organic manures ($M_0$, control, $M_1$, FYM @ 20 kg/plant, $M_2$, vermicompost @ 6 kg/plant and $M_3$, poultry manure @ 8 kg/plant) and five levels of RDF ($F_0$, control, $F_1$, 50% RDF, $F_2$, 75% RDF, $F_3$, 100% RDF and $F_4$, 125% RDF) in a randomized block design with three replications. The results revealed that integration of organic manures and inorganic fertilizers was more effective in increasing growth and yield of ber plants than inorganic fertilizers alone. Among various combinations, application of vermicompost @ 6 kg/plant with 125% RDF ($M_2F_4$) proved the best treatment combination in terms of number of secondary branches per primary branch (10.39), fruit yield (18.54 kg/plant and 51.54 q/ha) and net returns (₹1,53,869/ha), whereas vermicompost @ 6 kg/plant with 100% RDF ($M_2F_3$) proved best in respect to B:C ratio (2.96) as compared to other treatment combinations.

**Key Words**: B:C ratio, Yield, Net returns, Nutrients, Organic mannures, Vermicompost, Growth

Indian jujube or ber (*Zizyphus mauritiana* Lamk.) belongs to family Rhamnaceae which has about 50 genera and more than 600 species (Pareek, 1983). In India, ber is being cultivated on an area of about 4,845 ha with a total production of 66,296 tonnes (NHB, 2014). Madhya Pradesh, Bihar, Punjab, Haryana, Gujarat and Rajasthan are the major ber growing states. The nutrients removed by ber is far an excess nutrients added through fertilizers, resulting in a negative balance of 5.5 million tonnes of NPK (Sarkar, 2000). An approach involving chemical fertilizers and organic manures to bridge this gap between nutrient demand and supply for giving a boost to crop production is only the solution. The situation further aggravates for light soil of Rajasthan, where nutrient use remains much lesser than the removal (Gupta, 2001). It is well documented that growth and yield of trees are greatly influenced by a wide range of nutrients. Integration of organic manures and chemical fertilizers is a system approach in nutrient management, especially in semi-arid regions. The conclusions from long-term experiment also support that a suitable combination of organic and inorganic sources will not only sustains soil fertility and crop productivity but also maintain higher levels of quality of produce (Pillai *et al.*, 1985 and Nambair, 1994), Keeping in view, an experiment was conducted to find out an interactive effect of organic manures and fertility levels on ber.

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## MATERIALS AND METHODS

A field experiment was conducted at Horticulture Farm, SKN College of Agriculture, Jobner, Rajasthan, India, during July 2015 - February 2016. Three-year-old ber plants having uniform-sized and vigour spaced at 6m × 6m were selected. The experiment comprised four levels of organic manures ($M_0$, control, $M_1$, FYM @ 20 kg/plant, $M_2$, vermicompost @ 6 kg/plant and $M_3$, poultry manure @ 8 kg/plant) and five levels of RDF ($F_0$, control, $F_1$, 50% RDF, $F_2$, 75% RDF, $F_3$, 100% RDF and $F_4$, 125% RDF), thereby making 20 treatment combinations in randomized block design with three replications.

The full dose of organic manures was applied as soil application in July 2015. The recommended doses of fertilizers 1100 g urea, 1400 g SSP and 200 g MoP per tree were applied. Full dose of SSP, MoP and half dose of urea in various treatments were applied as basal dose in July 2015. Remaining half dose of urea was applied before flowering. The fertilizers were applied to top soil around the plant. The fertilizers uniformly mixed into the soil and then levelled. Irrigation was applied immediately after application of manures and fertilizers. The role of nutrient elements either alone or in combination with other sources (organic manures / fertilizers) has been well established in many fruit crops; while such studies are very meagrely available in ber (Katiyar *et al.*, 2012).

The observation were recorded on number of secondary branches / primary branch, fruit yield (kg / plant and q / ha), net returns (₹ / ha) and benefit : cost ratio. Number of secondary branches / primary branch of experimental plants was recorded twice in a year, before application of treatments in July 2015 and at full bloom stage in October 2015 and gain was calculated. Ripe fruits were harvested and weight was recorded by summing up the total of fruits at different pickings obtained during 8 January 2016 - 25 February 2016 from each experimental plant. Economics of different treatments was worked out in terms of net return per hectare. Treatment wise benefit : cost (B:C) ratio was also calculated to ascertain economic viability of treatment.

To test the significance of variation of data obtained from various growth, yield and quality characters, the technique of statistical analysis of variance was suggested by Fisher (1950) for randomized block design. Significance of difference in treatment effect was tested through 'F' tests at 5 per cent level of significance and CD (critical difference) was calculated, wherever results were significant.

## RESULTS AND DISCUSSION

The interactive effect of different organic manures and fertility levels (NPK) was significant for number of secondary branches, fruit yield, net returns and B:C ratio (Table 1). The maximum number of secondary branches (10.39), fruit yield / plant (18.54 kg) and per hectare (51.54 q) were observed in treatment $M_2F_4$, *i.e.*

**Table 1. Interactive effect of organic manures and fertility levels on growth, fruit yield and B:C ratio of ber cv. Gola**

| Treatment | Number of secondary branches / primary branch | Fruit yield (kg / plant) | Fruit yield (q / ha) | Net returns (₹ / ha) | B:C ratio |
|---|---|---|---|---|---|
| $M_0F_0$ (control) | 2.86 | 4.90 | 13.61 | 16193 | 0.42 |
| $M_0F_1$ (50% RDF) | 4.09 | 7.08 | 19.69 | 38215 | 0.94 |
| $M_0F_2$ (75% RDF) | 5.01 | 8.89 | 24.71 | 57166 | 1.37 |
| $M_0F_3$ (100% RDF) | 5.62 | 9.56 | 26.57 | 63493 | 1.48 |
| $M_0F_4$ (125% RDF) | 5.68 | 9.72 | 27.03 | 64184 | 1.46 |
| $M_1F_0$ (FYM @ 20 kg / plant) | 4.12 | 7.32 | 20.35 | 41449 | 1.04 |
| $M_1F_1$ (FYM @ 20 kg / plant + 50% RDF) | 5.90 | 10.58 | 29.42 | 75481 | 1.79 |
| $M_1F_2$ (FYM @ 20 kg / plant + 75% RDF) | 7.23 | 13.28 | 36.92 | 104362 | 2.41 |
| $M_1F_3$ (FYM @ 20 kg / plant + 100% RDF) | 8.11 | 14.29 | 39.71 | 114378 | 2.57 |
| $M_1F_4$ (FYM @ 20 kg / plant + 125% RDF) | 8.20 | 14.53 | 40.40 | 115972 | 2.54 |
| $M_2F_0$ (vermicompost @ 6 kg / plant) | 5.23 | 9.34 | 25.96 | 57225 | 1.23 |
| $M_2F_1$ (vermicompost @ 6 kg / plant + 50% RDF) | 7.48 | 13.50 | 37.54 | 101271 | 2.07 |
| $M_2F_2$ (vermicompost @ 6 kg / plant + 75% RDF) | 9.16 | 16.95 | 47.11 | 138430 | 2.77 |
| $M_2F_3$ (vermicompost @ 6 kg / plant + 100% RDF) | 10.28 | 18.23 | 50.67 | 151523 | 2.96 |
| $M_2F_4$ (vermicompost @ 6 kg / plant + 125% RDF) | 10.39 | 18.54 | 51.54 | 153869 | 2.94 |
| $M_3F_0$ (poultry manure @ 8 kg / plant) | 5.13 | 8.90 | 24.74 | 54010 | 1.20 |
| $M_3F_1$ (poultry manure @ 8 kg / plant + 50% RDF) | 7.34 | 12.87 | 35.77 | 95878 | 2.03 |
| $M_3F_2$ (poultry manure @ 8 kg / plant + 75% RDF) | 8.99 | 16.15 | 44.89 | 131236 | 2.71 |
| $M_3F_3$ (poultry manure @ 8 kg / plant + 100% RDF) | 10.09 | 17.37 | 48.28 | 143660 | 2.90 |
| $M_3F_4$ (poultry manure @ 8 kg / plant + 125% RDF) | 10.20 | 17.67 | 49.11 | 145842 | 2.88 |
| SEm$\pm$ | 0.31 | 0.57 | 1.57 | 5398 | 0.07 |
| CD (P=0.05) | 0.89 | 1.66 | 4.53 | 15590 | 0.20 |

vermicompost @ 6 kg / plant + 125% RDF closely followed by $M_2F_3$ (vermicompost @ 6 kg / plant + 100% RDF), $M_3F_4$ (poultry manure @ 8 kg / plant + 125% RDF), $M_3F_3$ (poultry manure @ 8 kg / plant + 100% RDF)and $M_2F_2$ (vermicompost @ 6 kg / plant + 75% RDF) treatment combinations. Such type of increased in yield have been reported to be associated with the release of macro and micro flora nutrients during the course of microbial decomposition. Organic manures also functions as source of energy for soil micro flora which bring about the transformation of inorganic nutrients held in soil or applied through inorganic fertilizers in a form that is readily utilized by the plants.

The balance response of organic manures and inorganic fertilizers to fruit yield might also be attributed to the availability of sufficient amount of nutrients in balanced form to the plants. The combined effect of inorganic fertilizers and organic manures (vermicompost, poultry manure and FYM) might have supplied adequate amount of nutrients and favoured the metabolic and auxin activity in plants which resulted better values for yield attributing traits and fruit yield of ber (Ahlawat *et al.*, 2000). The results are also close conformity with the findings of Shivaputra *et al.* (2004), Mishra *et al.* (2011), Yadav *et al.* (2011), Bohane and Tiwari (2014) and Shukla *et al.* (2014).

Net returns and benefit : cost ratio of different treatment combinations clearly revealed that application of treatment $M_2F_4$ (vermicompost @ 6 kg / plant + 125% RDF) gave maximum net returns (₹1,53,869 / ha) which was significantly superior over rest of the treatment except $M_2F_3$ (vermicompost @ 6 kg / plant + 100% RDF), $M_3F_4$ (poultry manure @ 8 kg / plant + 125% RDF), $M_3F_3$ (poultry manure @ 8 kg / plant + 100% RDF)and $M_2F_2$ (vermicompost @ 6 kg / plant + 75% RDF) treatment combinations (Table 1). However, maximum B:C ratio (2.96) was recorded under treatment $M_2F_3$ (vermicompost @ 6 kg / plant + 100% RDF) which was significantly superior over rest of treatments except $M_2F_4$, $M_3F_3$, $M_3F_4$ and $M_2F_2$ treatment combinations.

The increase in net returns of crop under combined application of vermicompost with inorganic fertilizers might be due to better root proliferation under favourable soil environment, which in turn resulted in higher uptake and efficient utilization of added nutrients throughout the growth period, which might have resulted in higher production. The higher net returns under these treatments could be ascribed to higher fruit yield of ber obtained under $M_2F_4$ treatment.

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# Assessment of cowpea *(Vigna unguiculata)* varieties under semi-arid conditions of central Gujarat

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**ABSTRACT**

The experiment was conducted to assess cowpea [*Vigna unguiculata* (L.) Walp] varieties at five farmers' fields of the Panchmahal district in Gujarat during 2014-15 and 2016-17. The five varieties were taken to see their performance. There was a significant difference among varieties in growth, flowering, fruiting, yield and economics. There was the maximum germination (85.44%), number of leaves at first harvesting (36.24), root length (24.88 cm), root weight 60 days after sowing (26.73g), pod weight (9.23g), pod length (31.56) and pod diameter (2.56 cm) after 60 days of sowing in Kashi Kanchan, whereasminimum days of flowering (41.44 days) and fruit harvesting (51.78 days) were recorded in Kashi Unnati. The maximum number of cluster / plant (9.97), number of pods / plant (30.61), gross return (?1,28,856), net return (?94,781), and cost benefit : ratio (3.78) were also recorded in Kashi Unnati.

**KEY WORDS**: Fruit characters, Germination, Gross return, Qualitative characters, Semi-arid, Vegetative characters, Variety

Cowpea {*Vigna unguiculata* (L.) Walp} is an important vegetable crop of India, particularly for resource poor farmers. It is commercially grown throughout the India for its pods as a vegetable, seeds as pulse and foliage as fodder. It is prime component of farming system under arid and humid tropics. It is mainly grown for immature green pods.In India, total area, production and productivity of cowpea is 407.93 lakh ha, 7925.25 lakh tones and 19.47 tones / ha, respectively. In Gujarat, area, production and productivity of cowpea is 24.89 lakh ha, 540.95 tonnes and 21.73 tones / ha, respectively (NHB, 2015). In Panchmahal district cowpea is most important vegetable crop during summer. The area, production and productivity of cowpeain Panchmahal district are 500 ha, 4905 tonnes and 9.51 tones / ha respectively (GSGR, 2017). The productivity of cowpea in Panchmchal district is low comparedto National and state level. The major factors responsible for low productivity are non-adoption of improved variety, quality irrigation water, proper seed rate, planting distance, nutrient management, insect pest management practices etc. Different cultivars respond differently in varied agro-climatic conditions (Chakraborty, 1997). The on farm trial plays an important role in adoption of technologies by recognizing economic benefits. Keeping in view on farm trials (OFTs) were undertaken to find out the suitable variety of cowpea forPanchmahal district of central Gujarat.

## MATERIALS AND METHODS

The present experiment was conducted at five farmer's fields in various villages, *viz*. Aeral, Nesda, Bukhi and Richiya Watain Panchmahal district under on farm testing during 2014-15 and 2016-17. The trial was laid out with five varieties, Pusa Komal, Kashi Kanchan, Kashi Unnati, Rashili and Gujrat Anand Cowpea-1 as treatments. The seed of these varieties were collected from reliable sources and distributed to the selected farmers. The framers were imparted technical know- how on cowpea cultivation. The crop was sown during first week of February. All five varieties were sown at all farmers' fields. The data on

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growth, flowering, fruiting, qualitative characteristics and economics were recorded at different intervals. The standard methods as suggested by Gomez and Gomez (1984)were used for analysis of various quantitative and qualitative parameters. The experiment was set up with fivevarieties as treatments and five replications in randomized block design and analyzed the pooled data of two years by using standard method as suggested by Snedecer and Cochran(1989).

The climatic yield potential and yield goals were fixed at 70-80 per cent of climatic yield potential because beyond that level, internal nutrient efficiencies in plant decline. Moreover, about 80 per cent of the climatic yield potential seems to be maximum possible yield that can be obtained by most farmers under field conditions.

## RESULTS AND DISCUSSION

All cowpea varieties had significant difference in germination per cent, plant stature, plant height, number of leaves at first harvesting, root length and root weight. The range of germination per cent in various varieties was recorded between 81.30and 85.40, maximum being in Kashi Kanchan, followed by Kashi Unnati (84.50 %), Pusa Komal (83.10 %), Rashili (82.20) and Gujarat Anand Cawpea-1 (81.30 %) (Table 1). The plant growth stature was observed bushy type in Pusa Komal and Rashili, dwarf and bushy in Kashi Kanchan, Kashi Unnati and Gujarat Anand Cawpea-1.

The maximum plant height (42.21 cm) was recorded in Pusa Komal, followed by Kashi Kanchan (37.29 cm), Kashi Unnati (36.37 cm), Gujarat Anand Cawpea-1 (33.46 cm) and Rashili (32.67 cm). The range of number of leaves at first harvesting varied 29.84 to 36.24, maximum in Kashi Kanchan, followed by Kashi Unnati (35.34), Pusa Komal (33.13), Gujarat An and Cawpea-1 (32.70),while minimum was observed in Rashili (29.84). The highest root length 60 days after sowing was recorded in Gujarat Anand Cawpea-1 (26.49 cm), followed by Rashili (25.56 cm), Kashi Kanchan (24.88 cm), Kashi Unnati (23.45cm) and lowest in Pusa Komal (23.42 cm).

The root weight 60 days after sowing was varied from 25.41 to 26.77g, maximum being in Kashi Kanchan, followed by Kashi Unnati (26.58g), Gujarat Anand Cawpea-1 (25.66 g), Rashili (25.50g) and Pusa Komal (25.41 g). This may be due to variability in the varieties. The similar findings are also reported in various cowpea varieties by Amanullah *et al.* (2000) with respect to plant height, days to flowering and days to harvesting; Vavilapalli *et al.* (2013) in plant height ; Ichi *et al.* (2013) in plant height. Pandey *et al.* (2006) reported significant difference in cowpea varieties in flowering and days to first harvesting.

**Table 1. Growth attributes of different cowpea varieties**

| Treatment | Germination (%) | | | Plant stature | Plant height (cm) | | | No. of leaves at first harvesting | | | Root length at 60 days (cm) | | | Root weight (g) at 60 days | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2015 | 2017 | Mean | | 2015 | 2017 | Mean | 2015 | 2017 | Mean | 2015 | 2017 | Mean | 2015 | 2017 | Mean |
| Pusa Komal | 82.80 | 83.30 | 83.10 | Bushy | 42.25 | 42.16 | 42.21 | 33.21 | 33.05 | 33.13 | 23.48 | 23.36 | 23.42 | 25.44 | 25.38 | 25.41 |
| Kashi Kanchan | 85.10 | 85.70 | 85.40 | dwarf & bushy | 37.42 | 37.15 | 37.29 | 36.34 | 36.14 | 36.24 | 25.02 | 24.73 | 24.88 | 26.77 | 26.76 | 26.77 |
| Kashi Unnati | 84.30 | 84.70 | 84.50 | dwarf & bushy | 36.55 | 36.18 | 36.37 | 35.55 | 35.12 | 35.34 | 23.58 | 23.32 | 23.45 | 26.62 | 26.53 | 26.58 |
| Rashili | 82.10 | 82.30 | 82.20 | Bushy | 32.76 | 32.58 | 32.67 | 29.9 | 29.78 | 29.84 | 24.64 | 25.47 | 25.56 | 25.52 | 25.48 | 25.50 |
| GAC-1 | 81.25 | 81.35 | 81.30 | dwarf & bushy | 33.57 | 33.34 | 33.46 | 32.86 | 32.54 | 32.70 | 26.66 | 26.31 | 26.49 | 25.67 | 25.64 | 25.66 |
| SEm± | - | - | 0.053 | - | - | - | 0.537 | - | - | 0.031 | - | - | 0.017 | - | - | 0.007 |
| CV | - | - | 0.178 | - | - | - | 3.278 | - | - | 0.208 | - | - | 0.157 | - | - | 1.050 |
| CD (5%) | - | - | 0.160 | - | - | - | 1.610 | - | - | 0.093 | - | - | 0.052 | - | - | 0.021 |

All varieties showed significant difference in flowering and fruiting attributes. The commencement of flowering ranged from 41.44 to 54.08 days after sowing and it was highest in Rashili, followed by Gujarat Anand Cowpea-1 (45.62 days), Pusa Komal (44.62 days), Kashi Kanchan (42.15 days) whereas, lowestin Kashi Unnati (41.44 days). The days to first harvesting from sowing were minimum (51.78 days) in Kashi Unnati, followed by Kashi Kanchan (52.53 days), Pusa Komal (55.80 days), Gujarat Anand Cowpea-1 (54.38 days) and Rashili (61.85 days). The maximum number of clusters/plant (9.97) were recorded in Kashi Unnati, followed by Pusa Komal (9.90), Kashi Kanchan (9.77), Gujarat Anand Cowpea-1 (9.48) and Rashili (8.92) (Table 2).

The range of number of pods/cluster were recorded2.85 -3.09 among all varieties. Rashili gave highest number of pods/cluster (3.09), followed by Kashi Unnati (3.07), Kashi Kanchan (2.98), Gujarat Anand Cowpea-1 (2.95) and Pusa Komal (2.85). The maximum number of pods/ plant (30.61) was noted in Kashi Unnati, followed by Kashi Kanchan (29.16), Pusa Komal (28.26), Gujarat Anand Cowpea-1 (27.97) and Rashili (27.56). Nwofia (2004) reported significant differences in cowpea varieties due to genetic make-up of variety. Pandey and Singh (2011) reported significant differences in cowpea varieties for days to flowering, days to maturity, days from flowering to physiological maturity (pod filling duration), due to genetic variability. The similar findings are also reported by Peksen (2004) in cowpea.

The pod weight ranged between 7.53 and 9.23g, maximum being in Kashi Kanchan (9.23g), followed by Kashi Unnati (9.12g), Gujarat Anand Cowpea-1 (7.97g), Pusa Komal (7.77) and Rashili (7.53) (Table-3). The pod length ranged from 13.76 to 31.56 cm, whereas it was maximum in Kashi Kanchan (31.56 cm), followed by Kashi Unnati(31.39 cm), Pusa Komal (28.55 cm), Gujarat Anand Cowpea-1 (14.58 cm) and Rashili (13.76 cm). The fruit diameter varied from2.18 to 2.56 cm. The highest diameter was recorded in Kashi Kanchan (2.56 cm), followed by Kashi Unnati (2.53 cm), Pusa Komal (2.28 cm), Gujarat Anand Cowpea-1 (2.18 cm) and Rashili (2.04 cm).

The pod yield was maximum in Kashi Unnati (125.62 q), followed by Kashi Kanchan (121.18 q), Gujarat Anand Cowpea-1 (100.31q), Pusa Komal (98.81 q), and Rashili (93.39 q). The fruit color of varieties was dark green of Pusa Konmal, Rashili and Gujarat Anand Cowpea-1 and light green of Kashi Kanchan and Kashi Unnati. These results are in agreement with the findings as reported by Vavilapalli *et al.* (2013) in cowpea varieties for pod weight; Peksen (2004) for yield; Pandey *et al.* (2006) for pod diameter and pod length; Khan *et*

**Table 2. Flowering and fruiting attributes of different cowpea varieties**

| Treatment | Days to flowering from sowing | | | Days to first harvesting from sowing | | | Number of cluster/plant | | | Number of pods/cluster | | | No. of pods/plant | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2015 | 2017 | 2015 | 2017 | 2015 | 2017 | 2015 | 2017 | Mean | 2015 | 2017 | Mean | 2015 | 2017 | Mean |
| Pusa Komal | 44.62 | 44.62 | 44.62 | 56.65 | 54.95 | 55.80 | 9.9 | 9.91 | 9.9 | 2.85 | 2.86 | 2.855 | 28.22 | 28.34 | 28.26 |
| Kashi Kanchan | 42.15 | 42.52 | 42.15 | 52.4 | 52.65 | 52.53 | 9.77 | 9.78 | 9.77 | 2.98 | 2.99 | 2.985 | 29.11 | 29.24 | 29.16 |
| Kashi Unnati | 41.44 | 41.68 | 41.44 | 51.25 | 52.30 | 51.78 | 9.97 | 9.98 | 9.97 | 3.05 | 3.09 | 3.07 | 30.41 | 30.84 | 30.61 |
| Rashili | 54.08 | 54.42 | 54.08 | 62.1 | 61.60 | 61.85 | 8.92 | 8.91 | 8.92 | 3.08 | 3.1 | 3.09 | 27.47 | 27.62 | 27.56 |
| GAC-1 | 45.62 | 45.62 | 45.62 | 54.55 | 54.20 | 54.38 | 9.48 | 9.47 | 9.48 | 2.94 | 2.96 | 2.95 | 27.87 | 28.03 | 27.97 |
| SEm± | - | - | 0.040 | - | - | 0.061 | - | - | 1.084 | - | - | 0.009 | - | - | 0.548 |
| CV | - | - | 0.197 | - | - | 0.231 | - | - | 28.160 | - | - | 0.631 | - | - | 4.148 |
| CD (5%) | - | - | 0.120 | - | - | 0.184 | - | - | 3.252 | - | - | 0.028 | - | - | 1.643 |

**Table 3. Fruit yield and qualitative attributes of different cowpea varieties**

| Treatment | Pod weight (g.) | | | Pod length (cm) | | | Pod diameter (cm) | | | Fresh pod yield, Q/ha | | | Fruit color |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2015 | 2017 | Mean | 2015 | 2017 | Mean | 2015 | 2017 | Mean | 2015 | 2017 | Mean | |
| Pusa Komal | 7.76 | 7.78 | 7.77 | 28.66 | 28.44 | 28.55 | 2.38 | 2.18 | 2.28 | 98.54 | 99.22 | 98.81 | dark green |
| Kashi Kanchan | 9.22 | 9.25 | 9.23 | 31.64 | 31.48 | 31.56 | 2.64 | 2.47 | 2.56 | 120.78 | 121.71 | 121.18 | light green |
| Kashi Unnati | 9.10 | 9.14 | 9.12 | 31.51 | 31.26 | 31.39 | 2.58 | 2.47 | 2.53 | 124.53 | 126.84 | 125.62 | light green |
| Rashili | 7.51 | 7.55 | 7.53 | 13.88 | 13.64 | 13.76 | 2.12 | 1.96 | 2.04 | 92.83 | 93.84 | 93.39 | dark green |
| GAC-1 | 7.96 | 7.98 | 7.97 | 14.68 | 14.48 | 14.58 | 2.22 | 2.13 | 2.18 | 99.83 | 100.66 | 100.31 | dark green |
| SEm± | - | - | 0.533 | - | - | 0.536 | - | - | 0.524 | - | - | 0.019 | - |
| CV | - | - | 12.61 | - | - | 1.609 | - | - | 47.623 | - | - | 0.039 | - |
| CD(5%) | - | - | 1.398 | - | - | 4.952 | - | - | 1.571 | - | - | 0.057 | - |

**Table 4. Economics of different cowpea varieties**

| Treatment | Cost of cultivation (Rs) | | | Gross return (Rs) | | | Net return (Rs) | | | B:C Ratio | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2015 | 2017 | Mean | 2015 | 2017 | Mean | 2015 | 2017 | Mean | 2015 | 2017 | Mean |
| Pusa Komal | 31700 | 32450 | 32075 | 98540 | 104181 | 101360.50 | 66840 | 71731.00 | 69285.50 | 3.11 | 3.21 | 3.16 |
| Kashi Kanchan | 33500 | 34800 | 34150 | 120780 | 127795.5 | 124287.75 | 87280 | 92995.50 | 90137.75 | 3.61 | 3.67 | 3.64 |
| Kashi Unnati | 33500 | 34650 | 34075 | 124530 | 133182 | 128856.00 | 91030 | 98532.00 | 94781.00 | 3.72 | 3.84 | 3.78 |
| Rashili | 34800 | 35250 | 35025 | 92830 | 98532 | 95681.00 | 58030 | 63282.00 | 60656.00 | 2.67 | 2.80 | 2.73 |
| GAC-1 | 32500 | 33850 | 33175 | 99830 | 105693 | 102761.50 | 67330 | 71843.00 | 69586.50 | 3.07 | 3.12 | 3.10 |

*al.* (2010) for pod length; Pandey and Singh (2011) for pods/plant, pod length and yield have reported variation in quality attributes of cowpea varieties which may be due to genotypic dissimilarity.

The cost of cultivation varied from Rs. 32,075 to Rs. 35,025/ha, maximum cost being in Rashili (Rs. 35,025), followed by Kashi Kanchan (Rs. 34,150), Kashi Unnati (Rs. 34,075), Gujarat Anand Cowpea-1 (Rs. 33,175) and Pusa Komal (Rs. 32,075). The higher cost of cultivation in Rashili is due to more cost of seed. The maximum gross returns (Rs. 1,28,856.00/ha), net returns (Rs. 94,781.00/ha) and highest B:C ratio (3.78) was recorded in Kashi Unnati, followed by Kashi Kanchan (1,24,287.75, 90,137.75 and 3.64), Pusa Komal (1,01,360.50, 69,285.50 and 3.16), Gujarat Anand Cowpea-1 (1,02,761.50, 69,586.50 and 3.10) and the same was minimum in Rashili (95,681.00, 60,656.00 and 2.73) respectively (Table-4). The maximum gross return, net returns and B:C ratio was recorded in Kashi Unnati due to higher yield and quality of fruits. The similar findings are also reported by Lal *et al.* (2016) in cowpea and Kumar *et al.* (2017) in tomato, Choudhary *et. al.* (2017) in pea.

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# Effect of trunk cross sectional area on growth, yield and quality of almond *(Prunus dulcis)*

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**ABSTRACT**

The experiment was conducted on 10-year-old almond (*Prunus dulcis.* Mill) cultivar Pranyaj planted at 4m × 4m spacing at ICAR-Central Institute of Temperate Horticulture, Srinagar, Jammu and Kashmir, during 2013-14. The plants were received uniform cultural practices and grouped into eight categories on the basis of trunk cross sectional area (TCSA) of trees. The maximum canopy volume (30.45 $m^3$), nut number (1340), nut yield (3.95 kg/ tree and 2.46 tonnes/ha), and leaf NPK content (2.31, 0.18, 1.75%) were recorded with highest TCSA (114.96 cm2). The nut weight (3.32g) and productivity efficiency (37.57cm2) were registered with minimum TCSA (82.25cm2). The positive correlation were obtained between TCSA and canopy volume, nut number, nut yield and leaf NPK content. Similarly, there was negative correlation between TCSA and nut weight and productivity efficiency in almond cultivar Pranyaj.

**Key Words**: Almond, Growth, Leaf nutrients, Quality, Trunk cross sectional area, Yield

Almond, an important temperate nut crops of India is mainly grown in Kashmir valley. The total area under its cultivation is 12,000 ha with an annual production of 7,000 tonnes and productivity of just 0.58 tonne/ha (Kashmir 2015). Its kernels are useful for maintaining good health due to rich source of fat, protein and fibre. The area and production of almond is decreasing day by day while demand is increasing. There are several varieties available in our country, viz. Makhdoom, Waris, Shalimar, Pranyaj, Primorskij, Merced, California Paper Shell and IXL for commercial cultivation. The shelling percentage in these varieties is also high with soft shell. There are variations in growth, yield and quality if single cultivar is planted in the field due to rootstock, soil nutrient, irrigation and cultural practices.

The prominent character such as trunk cross-sectional area of trees is a useful index for estimation of fruit yield and quality in almond. The differences in tree size had shown differences in their performances in respect of canopy volume, fruit yield and quality characters. The trunk cross-sectional area of the trees is positively correlated with growth, yield and quality in Kinnow (Dalal and Brar, 2012); Kumar *et al.*, 2008 in guava and Kumar *et al.*, 2014 in apricot. These type of work will upgrade our scientific knowledge to predict the yield and quality traits of almond in relation to trunk cross sectional area. Therefore, an experiment was conducted to develop relationship between pseudostem cross-sectional area of tree with growth, yield, quality and leaf nutrient status of almond under Kashmir valley conditions.

## MATERIALS AND METHODS

The field experiment was conducted at ICAR-Central Institute of Temperate Horticulture, Srinagar, Jammu and Kashmir, India, during 2013 and 2014 on 10-year-old almond cultivar, Pranyaj, spaced at 4m x 4m. The experimental soil is classified as silty loam with 38.5% sand, 24.2% silt and 37.3% clay having medium fertility levels of nitrogen, phosphorus and potassium. Pranyaj variety is a regular bearer, blooming during third week of March and ready to harvesting after 144-148 days from full bloom stage. The tree has upright growth habit and suitable for high density planting. The nuts are medium sized, light colour, very soft shelled with plumpy kernels. Total 48 plants of uniform were selected and categorised into eight

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different group on the basis of TCSA (82.25, 87.12, 91.75, 95.45, 99.32, 105.72, 110.24, 114.96 $cm^2$) calculated 15 cm above the ground level.

Two tree in each group with almost uniform trunk cross sectional area were selected and marked with red paint for identification and recording observations on different parameters. The experiment was designed in a randomized block with three replications. The trunk cross sectional area of tree was calculated by using the formula TCSA = $Girth^2 / 4\Pi$. The observations on vegetative growth, fruit yield and quality characters were recorded as per the treatments. Plant height and spread were measured by measuring tape, and canopy volume by the formula ascribed by Castle (1983), *i.e.* tree volume = 0.5238 × canopy height (m) × canopy diameter ($m^2$). Productive Efficiency (PE) was worked out by using the formula PE ($g/cm^2$) = fruit yield (g/tree)/TCSA ($cm^2$). Fruits were harvested at maturity stage, hulled, dried and nut weight in gram and yield in kg per tree was recorded.

For analysis of leaf nitrogen, phosphorus and potassium content, fully developed 30 number of leaf samples were collected from the middle portion of bearing shoots of the almond tree as per the treatments (Singh *et al.*, 2007). The leaf samples were thoroughly washed and kept in digital hot oven at 60 °C for 48hr for drying (Bhargava and Raghupati, 1993). After drying, the leaf samples ground to pass a 0.5 mm mesh and analysed for macronutrient content. The leaf nitrogen, phosphorus and potassium content were estimated by the modified micro-Kjeldahl Vanado-molybdate (Jackson,1967) and flame photometric methods respectively. The data were statistically analysed as per the procedure of Steel and Torrie (1986).

## RESULTS AND DISCUSSION

The canopy volume of tree increases with increasing the trunk cross sectional area of tree. Maximum canopy volume (30.45 $m^3$) was registered with 114.96 $cm^2$ TCSA and it was on a par with 28.22 $m^3$ with 110.24 $cm^2$ TCSA and significantly superior to other TCSA. The nut number varied from 932 to 1340, maximum nut number (1340/tree) was recorded with highest TCSA (114.96 $cm^2$) and on a par with 1305 nuts with 110.24 $cm^2$ TCSA (Table 1). The higher TCSA of plant improved canopy volume, fruit number and yield might be due to optimum uptake of nutrient and water resources from soil to aerial parts of plants and distribution of available photosynthates for vegetative growth and fruit yield.

Similar findings were reported by Dhaliwal and Dhillon (2003) and Kumar *et al.* (2008) in guava and Dalal and Brar (2012) in Kinnow. Maximum nut weight (3.32 g) was recorded with minimum TCSA (82.25 $cm^2$) and minimum (2.95 g) was recorded with maximum TCSA (114.96 $cm^2$). An improvement in nut weight with minimum trunk cross sectional area might be due to lesser numbers of nuts/tree, which in turn more nutrients diverted for the development of limited number of nuts available on the tree. Similar findings were reported by Khan, 1998.

Maximum nut yield (3.95 kg/tree and 2.46 tonnes/ha) was recorded with highest TCSA (114.96 $cm^2$) and the differences were non-significant among the different trunk cross sectional area. The productivity efficiency varied from 34.35 to 37.57 and maximum productivity efficiency (37.57 $g/cm^2$) was recorded with minimum TCSA (82.25 $cm^2$), while minimum (34.35$g/cm^2$) was recorded with maximum TCSA (114.96 $cm^2$) in cultivar Pranyaj. The maximum fruit yield in higher TCSA might be due to more number of fruits retained on tree, thereby increased the nut yield. Similar findings were reported by Kumar *et al.* (2014) in apricot and Srivastava *et al.* (2015) in cherry.

Leaf nutrients content was influenced by trunk cross sectional area (Fig. 1). The leaf nutrient content

**Table 1. Effect of TCSA on growth and yield of almond cv. Pranyaj**

| *TCSA ($cm^2$) | Canopy volume ($m^3$) | Nut number/tree | Nut weight (g) | Nut yield (kg/tree) | Yield (tonnes/ha) | **PE ($g/cm^2$) |
|---|---|---|---|---|---|---|
| 82.25 | 12.26f | 932f | 3.32 | 3.09 | 1.93 | 37.57 |
| 87.12 | 15.37ef | 990ef | 3.25 | 3.21 | 2.01 | 37.30 |
| 91.75 | 18.24e | 1020e | 3.21 | 3.27 | 2.04 | 35.64 |
| 95.45 | 20.75d | 1102d | 3.15 | 3.47 | 2.17 | 36.35 |
| 99.32 | 22.39cd | 1180c | 3.12 | 3.68 | 2.30 | 37.05 |
| 105.72 | 25.24bc | 1240bc | 3.08 | 3.82 | 2.38 | 36.13 |
| 110.24 | 28.22ab | 1305ab | 2.98 | 3.89 | 2.43 | 35.28 |
| 114.96 | 30.45a | 1340a | 2.95 | 3.95 | 2.46 | 34.35 |
| SEm± | 1.25 | 25.33 | 0.24 | 0.45 | 0.26 | 1.95 |
| CD at 5% | 3.32 | 65.86 | NS | NS | NS | NS |

*TCSA, Trunk cross sectional area; **PE-productivity efficiency.

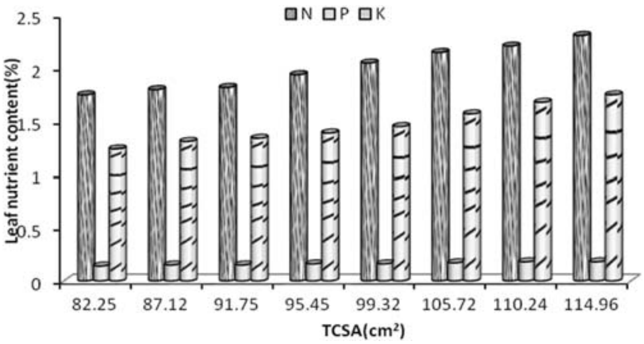


Fig. 1: Leaf N, P and K content as influenced by TCSA in almond

increased with increase in trunk cross sectional area of tree. The maximum leaf NPK contents (2.31, 0.18, 1.75%) were analysed with 114.96 $cm^2$ TCSA, closely followed by 110.24 $cm^2$ TCSA (2.21, 0.18, 1.68%) and 105.72 $cm^2$ TCSA (2.15, 0.17, 1.57), respectively. Minimum leaf NPK content (1.75, 014, 1.24%) were recorded with lowest TCSA 82.25 $cm^2$ in Pranyaj. Higher leaf nitrogen, phosphorus and potassium contents were recorded with highest TCSA. It might be due to more transportation of available nutrients from soil to aerial part of plants. These findings are in accordance with the report of Dalal and Brar, (2012) in kinnow.

Correlation coefficient were studied among different traits in almond for all possible combinations such as growth, yield and leaf nutrient parameters (Table 2). The significant and positive correlation was observed between trunk cross sectional area and canopy volume (0.987), fruit number (0.992), fruit yield (0.981), yield (0.980), leaf nitrogen (0.988), leaf phosphorus (0.983), leaf potassium (0.989). Similarly, positive correlation between canopy volume and nut number (0.989), nut yield (0.987), yield (0.986), leaf nitrogen (0.980), leaf phosphorus (0.967), leaf potassium (0.958). The nut number is positively correlated with nut yield (0.995), yield (0.995), leaf nitrogen (0.994), leaf phosphorus (0.982), leaf potassium (0.980). Nut yield is positively correlated with yield (0.999), leaf nitrogen (0.989), leaf phosphorus (0.968), leaf potassium (0.961). Leaf nitrogen is positively correlated with leaf phosphorus (0.977) and leaf potassium (0.984). Leaf phosphorus is positively correlated with leaf potassium (0.981). Similarly, Salvador *et al.* (2006) reported that fruit size and quality correlated with crop load in apple and relationship between tree size and yield in mango as reported by Oppenheimer (1960).

There was negative correlation between TCSA and nut weight (-0.992) with productivity efficiency (-0.828). Similarly, negative correlation between canopy volume and nut weight (-0.992) and productivity efficiency (-0.772). Nut weight is negatively correlated with yield (-0.970), leaf nitrogen (-0.977), leaf phosphorus (-0.989), leaf potassium (0.984). Productivity efficiency is negatively correlated with leaf nitrogen (-0.754), leaf phosphorus (-0.795) and leaf potassium (-0.829) in Pranyaj. Thus, it was concluded that trunk cross sectional area of tree increases canopy volume, nut yield and leaf nutrient status of almond. There was positive correlation obtained between trunk cross sectional area and canopy volume, nut yield and leaf nutrient status in almond under Kashmir valley conditions.

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**Table 2. Correlation coefficient for different characters in almond cv. Pranyaj**

| Character | TCSA | CV | Nut | Nut wt (g) | Yield (kg/tree) | Yield (tonnes/ha) | PE | N | P | K |
|---|---|---|---|---|---|---|---|---|---|---|
| TCSA | 1.00 | 0.987 | 0.992 | -0.992 | 0.981 | 0.980 | -0.828 | 0.988 | 0.983 | 0.989 |
| CV | | 1.00 | 0.989 | -0.992 | 0.987 | 0.986 | -0.775 | 0.980 | 0.967 | 0.958 |
| Nut | | | 1.00 | -0.987 | 0.995 | 0.995 | -0.759 | 0.994 | 0.982 | 0.980 |
| Nut wt | | | | 1.00 | -0.970 | -0.970 | 0.830 | -0.977 | 0.989 | -0.984 |
| Yield kg/tree | | | | | 1.00 | 0.999 | -0.711 | 0.989 | 0.968 | 0.961 |
| Yield (tonnes/ha) | | | | | | 1.00 | -0.705 | 0.988 | 0968 | 0.960 |
| PE | | | | | | | 1.00 | -0.754 | -0.795 | -0.829 |
| N | | | | | | | | 1.00 | 0.972 | 0.984 |
| P | | | | | | | | | 1.00 | 0.981 |
| K | | | | | | | | | | 1.00 |

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# Evaluation of fertilizer best management practices by SSNM and customized fertilizers for cassava *(Manihot esculenta)* cultivation in India

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**ABSTRACT**

The field experiments were conducted to develop fertilizer best management practice (FBMP) by site specific nutrient management (SSNM) and SSNM zonation maps and customised fertilizer ratios at ICAR-CTCRI, Thiruvananthapuram, Kerala, India, during 2012-2015. The SSNM plot resulted in an average actual tuberous root yield of 36.80, 37.40 and 38.70 t/ha during 2012, 2013 and 2014 respectively against a yield target of 40 t/ha. The average yield difference between SSNM and PR for the three crops grown was 5.50 t/ha (17%, P=0.001) and was similar during all the three years. On an average, plant N accumulation increased by 48 kg/ha (25%, P=0.003), P accumulation by 9 kg/ha (50%, P=0.003), and K accumulation by 39 kg/ha (20%, P=0.005). Among the three crops grown, the AEN increased by 34 kg/kg (72%, P=0.002), REN by 0.04 kg/kg (8%, P=0.003) and PEN by 55 kg/kg (58%, P=0.005). The guidelines in estimating the fertilizer N, $P_2O_5$ and $K_2O$ required by cassava based on tuberous root yield response to fertilizer N, P and K and efficiency of fertilizer N, P and K use also were developed. Soil fertility maps and agro-ecological units, SSNM zonation maps and customised fertilizer ratios were also developed for all the major cassava-growing regions in India.

**Key Words**: Cassava, Customised fertilizers, FBMP, Nutrient-use efficiency, SSNM

Tamil Nadu, Kerala and Andhra Pradesh of southern India account for 92% of national cassava (*Manihot esculenta* Crantz.) production. About 0.23 million ha of arable land is used for cassava production, of which 0.17 million ha is rainfed, while the remaining is irrigated. In Kerala, adjustment of blanket recommendation is based on soil test data (Aiyer and Nair, 1985). In order to overcome the limitations of soil test based, blanket fertilizer recommendation, the concept of site specific nutrient management (SSNM) was developed which is specific to soils and crops, yield oriented and also takes into account nutrient interactions with the aid of models such as Quantitative Evaluation of Fertility of Tropical Soils (QUEFTS) (Witt *et al.,* 1999). Results of on-station and on-farm research demonstrated large and potentially manageable variability in soil nutrient status and that soil and plant based, yield targeted and knowledge intensive approaches using the Quantitative Evaluation of Fertility of Tropical Soils (QUEFTS) model could significantly increase the yield of cassava (Byju *et al.*, 2012; Suchitra and Byju, 2015; Sabitha and Byju, 2014, 2017).

Field validation of the developed methodology was also done by conducting 59 on-farm experiments in three major cassava-growing regions in India. Fertilizer best management practice (FBMP) is aimed at managing the flow of nutrients in the course of producing affordable and healthy food in a sustainable manner that protect the environment and conserve natural resources, at the same time profitable to producers (IFA., 2007). The basic principle behind fertilizer best management practices is simple, that is the 4R using the right fertilizer product(s) at the right rate, right time and right place which conveys how fertilizer applications can be managed to achieve economic, social and environmental goals. Having developed the SSNM technology for cassava in India

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using the QUEFTS model, it was felt important to develop FBMP also by incorporating secondary and micronutrients and develop customised fertilizers for major cassava-growing regions in India. With this concept the experiments were conducted to find out the effect of FBMP by SSNM on cassava yield, nutrient uptake and nutrient-use efficiency, to develop SSNM recommendations and to develop SSNM zonation maps and customised fertilizer ratios for major cassava-growing regions in India.

## MATERIALS AND METHODS

### QUEFTS model validation

The theoretical framework of QUEFTS model for making fertilizer recommendations has already been explained in detail (Witt *et al.*, 1999; Liu *et al.*, 2006; Byju *et al.*, 2012). The maximum yield of cassava obtained under experimental condition (80 t/ha) was fixed as the climatic yield potential and yield goals were fixed at 70-80 per cent of climatic yield potential because beyond that level, internal nutrient efficiencies in plant decline. Moreover, about 80 per cent of the climatic yield potential seems to be maximum possible yield that can be obtained by most farmers under field conditions (Cassman and Harwood, 1995).

### Field experiments

Field experiments were conducted at the farm of ICAR-CTCRI, Thiruvananthapuram, Kerala, during 2012 - 2015. The experiment was laid out in a randomized complete block design (RCBD) with five treatments and four replications per treatment. The treatment details are given below.

***0N-nitrogen omission plot :*** Only P and K at 150 per cent recommended NPK rate were applied to ensure that macronutrients other than N did not limit plant N uptake from indigenous sources (Nair *et al.*, 2004). This treatment was sampled at harvesting for each of the three years to estimate indigenous N supply (INS), defined as total plant N accumulation at maturity in a 0-N plot. These measurements were used to estimate : (a) N-use efficiencies using the difference method and (b) INS used as an input parameter for SSNM.

***0P-phosphorous omission plot :*** Only N and K at 150 per cent of the recommended NPK rate were applied to ensure that macronutrients other than P did not limit plant P uptake from indigenous sources (Nair *et al.*, 2004). This treatment was sampled at harvesting for each of the three years to estimate indigenous P supply (IPS), defined as total plant P accumulation at maturity in a 0-P plot. These measurements were used to estimate: (a) P-use efficiencies using the difference method and (b) IPS used as an input parameter for SSNM.

*0K-potassium omission plot :* Only N and P at 150 per cent of the recommended NPK rate were applied to ensure that macronutrients other than K did not limit plant K uptake from indigenous sources (Nair *et al.*, 2004). This treatment was sampled at harvesting for each of the three years to estimate indigenous K supply (IKS) defined as total plant K accumulation at maturity in a 0-K plot. These measurements were used to estimate: (a) K-use efficiencies using the difference method and (b) IKS used as an input parameter for SSNM.

***SSNM-site-specific nutrient management plot :*** In this plot, nutrient recommendations were made following the SSNM approach using the calibrated QUEFTS model and the concept of fertilizer best management practice (FBMP). Specific optimal NPK fertilizer rates were predicted using indigenous nutrient supplies and yield in nutrient omission plots. The calibrated QUEFTS model was used to work out NPK recommendations at the beginning of each growing season (Byju *et al.*, 2012). A linear optimization procedure was used in Microsoft Excel Solver module to find the best combination of N, P and K fertilizer rates to achieve the yield goal under the constraint of optimizing the internal N, P and K efficiencies in the plant.

The model was constrained to arrive at a solution close to the situation of most balanced nutrition, that is, where the ratio between accumulation and potential supply of each macronutrient was close to 0.95 (Janssen *et al.*, 1990). . In order to meet the principles of fertilizer best management practices (FBMP) (http://www.nutrientstewardship.com/what-are-4rs), based on soil test data, modified QUEFTS model and crop need of secondary and micronutrients (Lozano *et al.*, 1981; Howeler, 1996), secondary and micronutrient fortified customised fertilizer formulation was prepared and used as SSNM treatment. The SSNM treatment was sampled at harvesting for each of the three years to estimate tuberous root and above the ground biomass yields and plant nutrient (N, P and K) accumulation. This treatment was used for comparison with the present recommendation treatment for yield, nutrient accumulation and nutrient use efficiency.

***PR-present recommendation plot :*** In this plot, nutrient recommendations were made following standard package of practices (Nair *et al.*, 2004). The PR treatment was sampled at harvesting for each of the four years to estimate the tuberous root and above the ground biomass yields and plant nutrient (N, P and K) accumulation. This treatment was used for comparison with the SSNM treatment for yield, nutrient accumulation and nutrient use efficiency.

**Field and laboratory measurements**

***Initial soil samples :*** Before the beginning of field experiments, soil samples were collected for characterisation of the soil physico-chemical parameters. The soil samples were air dried and sieved through a 2-mm sieve and analysed for pH (Byju, 2001), organic carbon (Walkley and Black, 1934), available N (Page *et al.*, 1982), available P (Bray and Kurtz, 1945) and exchangeable K (Knudsen *et al.*, 1982).

***Soil and plant samples 3 months after planting :*** From individual treatment plots, soil samples were collected at the active growth stage of elephant foot yam (3 months after planting). The soil samples were air dried and sieved through a 2-mm sieve and analysed for pH, organic carbon, available N and P and exchangeable K following the procedures referred above. Youngest fully expanded leaf (YFEL) blades without petioles were also collected at 3 months after planting to assess the crop nutritional status for different treatments based on critical nutrient concentrations.

Leaf samples were dried in a hot air oven at 65°C for 48 hr until constant weight was attained. Then the dried samples were ground in a stainless steel Wiley Mill. Plant N, P and K contents were estimated using dried and ground samples of the leaves. The total N content was determined by digesting the samples in sulfuric acid ($H_2SO_4$) followed by analysis of total N by Kjeldahl method (Bremner and Mulvaney, 1982). Tissue P was determined after digestion with triple acid ($HNO_3$ : $HClO_4$ : $H_2SO_4$ 10:4:1) by the vanado-molybdo phosphoric yellow colour method and tissue K by using a flame photometer (Jackson, 1972).

***Soil and plant samples at harvest :*** From individual treatment plots, soil samples were collected at the time of harvesting 7 months after planting. The soil samples were air dried and sieved through a 2-mm sieve and analysed for pH, organic carbon, available N and P and exchangeable K following the procedures referred earlier. At maturity, total weights of leaf, stem and tuberous root were measured from three plants of each plot and leaf, stem and tuberous root samples (50 g each) were also collected separately. Total weights of tuberous roots were taken from all the plants in each plot excluding the border row for estimation of tuberous root yield at the time of final harvest.

Leaf, stem and tuberous root samples were dried in a hot air oven at 65°C for 48 hrs until constant weight was attained and the dry weight of the samples was recorded. Then the dried samples were ground in a stainless steel Wiley Mill. Plant N, P and K contents were estimated using dried and ground samples of leaf, stem and tuberous root following the procedures referred earlier.

**Agronomic calculations**

***NPK uptake :*** Based on dry weights of leaf, stem and tuberous root and N, P and K contents of leaf, stem and tuberous root (per cent), total N, P and K uptake at harvest was estimated in kg ha-1.

***Nutrient-use efficiency :*** Nutrient use efficiencies were estimated using the differences between N, P or K fertilized treatments and the nutrient omission plots (Cassman et al., 1996). Terms used are agronomic efficiency (AE; kg tuberous root yield increase per kg N, P or K applied), recovery efficiency (RE; kg N, P or K removed from fertilizer per kg N, P or K applied) and physiological efficiency (PE; kg tuberous root yield increase per kg N, P or K removed).

$$\text{Agronomic efficiency} = (Y - Y_0)/F$$
$$\text{Recovery efficiency} = (U - U_0)/F$$
$$\text{Physiological efficiency} = (Y - Y_0)/(U - U_0)$$

where, Y - tuberous root yield (kg/ha) in fertilized field; $Y_0$ - tuberous root yield (kg/ha) in unfertilized field; U - total plant uptake of N/P/K (kg/ha) in fertilized field; $U_0$ - total plant uptake of N/P/K (kg/ha) in unfertilized field; F - rate of application of N/P/K fertilizer (kg/ha).

**Statistical analysis**

The statistical analysis of data consisted of analysis of variance (ANOVA) for different soil and plant parameters, yield, NPK uptake, nutrient use efficiency and economic parameters using SAS statistical software (SAS Institute Inc. 2002). Least significant difference (LSD) test was used at 0.05 level of probability to test differences between treatment means.

## RESULTS AND DISCUSSION

The fertilizer best management practices by SSNM resulted in an average actual tuberous root yield of 36.80, 37.40 and 38.70 t/ha during 2012, 2013 and 2014 respectively. The model predicted a yield of 40 t/ha during all the years. There was a gradual improvement in tuberous root yield over the three years and there were good agreement between predicted and measured yields during all the years, which indicated that the calibrated model can be used to improve NPK fertilizer recommendations for cassava in India. The results of validation experiments of SSNM of cassava conducted in Tamil Nadu (Yethapur) and Andhra Pradesh (Venkataramannagudam) showed better performance of the treatment compared to present recommendation (AICRP, 2013 and 2014).

The average yield difference between SSNM and PR for the three crops grown was 5.50 t/ha (17%, P=0.001) and was similar in all the three years (Table 2). Seasonal differences in the performance were not statistically significant (crop year, P = 0.167). There

**Table 1. Predicted yield of cassava by the QUEFTS model during 2012, 2013 and 2014**

| Nutrient | Indigenous supply (kg/ha) | NPK fertilizer requirement (kg/ha) | Predicted nutrient uptake (kg/ha) | Predicted yield (t/ha) | Measured yield (t/ha) |
|---|---|---|---|---|---|
| | | **2012** | | | |
| N | 110.5 | 80 | 250 | 40.00 | 36.80 |
| P | 16.0 | 20 | 29 | | |
| K | 106.4 | 120 | 232 | | |
| | | **2013** | | | |
| N | 105.6 | 90 | 250 | 40.00 | 37.40 |
| P | 14.5 | 20 | 29 | | |
| K | 98.5 | 120 | 232 | | |
| | | **2014** | | | |
| N | 103.5 | 100 | 250 | 40.00 | 38.70 |
| P | 13.5 | 20 | 29 | | |
| K | 92.5 | 100 | 232 | | |

**Note:** The yield potential was set to 80.0 t/ha.

**Table 2. Effect of fertilizer best management practices by SSNM on tuberous root yield and plant nutrient accumulation in cassava during 2012, 2013 and 2014**

| | Levels † | Treatment ± | | Δ § | P>\|T\| ¶ |
|---|---|---|---|---|---|
| | | SSNM | PR | | |
| Tuberous root yield, t/ha | All | 37.6 | 32.1 | 5.5 | 0.001 |
| | Year 1 | 36.8 | 32.2 | 4.6 | 0.017 |
| | Year 2 | 37.4 | 32.0 | 5.4 | 0.005 |
| | Year 3 | 38.7 | 32.2 | 6.5 | 0.008 |
| Total N uptake, kg/ha | All | 239 | 191 | 48 | 0.003 |
| | Year 1 | 235 | 187 | 48 | 0.008 |
| | Year 2 | 240 | 190 | 50 | 0.012 |
| | Year 3 | 243 | 197 | 46 | 0.018 |
| Total P uptake, kg/ha | All | 28 | 18 | 9 | 0.003 |
| | Year 1 | 26 | 15 | 11 | 0.011 |
| | Year 2 | 28 | 19 | 9 | 0.009 |
| | Year 3 | 29 | 21 | 8 | 0.005 |
| Total K uptake, kg/ha | All | 231 | 192 | 39 | 0.005 |
| | Year 1 | 235 | 189 | 46 | 0.018 |
| | Year 2 | 231 | 194 | 37 | 0.021 |
| | Year 3 | 228 | 192 | 36 | 0.016 |

† All, all three crops grown during 2012, 2013 and 2014.
± SSNM, site specific nutrient management, FFP, farmers' fertilizer practice.
§Δ, SSNM - FFP.
¶ P>|T|, probability of a significant mean difference between SSNM and FFP.

were significant increases in plant N, P and K accumulation in SSNM compared with PR treatment. On an average, plant N accumulation increased by 48 kg/ha (25%, P=0.003), P accumulation by 9 kg/ha (50%, P=0.003), and K accumulation by 39 kg/ha (20%, P=0.005). Crop-season effects were not significant, *i.e.* similar increases in nutrient uptakes were achieved during all the years.

Significant increases in N-use efficiency were achieved through the field- and season-specific N management practised in SSNM treatment (Table 3). The $AE_N$, $RE_N$ and $PE_N$ were significantly increased in

**Table 3. Effect of SSNM on NPK-use efficiency in cassava during 2012, 2013 and 2014**

| | Levels † | Treatment ± | | Δ § | P>│T│¶ |
|---|---|---|---|---|---|
| | | SSNM | PR | | |
| AEN, ±± kg tuber/kg N | All | 80 | 47 | 34 | 0.004 |
| | Year 1 | 77 | 46 | 31 | 0.003 |
| | Year 2 | 80 | 50 | 35 | 0.011 |
| | Year 3 | 82 | 46 | 36 | 0.006 |
| $RE_N$, §§ kg N/kg N | All | 0.53 | 0.49 | 0.04 | 0.003 |
| | Year 1 | 0.53 | 0.47 | 0.06 | 0.014 |
| | Year 2 | 0.53 | 0.52 | 0.01 | 0.005 |
| | Year 3 | 0.54 | 0.49 | 0.05 | 0.008 |
| $PE_N$, ¶¶ | All | 150 | 95 | 55 | 0.005 |
| | Year 1 | 148 | 97 | 51 | 0.012 |
| | Year 2 | 150 | 95 | 55 | 0.021 |
| | Year 3 | 152 | 94 | 58 | 0.008 |
| $AE_P$, ±± kg tuber/kg P | All | 86 | 69 | 17 | 0.011 |
| | Year 1 | 84 | 70 | 14 | 0.005 |
| | Year 2 | 87 | 69 | 18 | 0.007 |
| | Year 3 | 90 | 69 | 21 | 0.015 |
| $RE_P$, §§ kg N/kg P | All | 0.13 | 0.10 | 0.03 | 0.007 |
| | Year 1 | 0.31 | 0.30 | 0.01 | 0.057 |
| | Year 2 | 0.31 | 0.29 | 0.02 | 0.053 |
| | Year 3 | 0.31 | 0.28 | 0.03 | 0.006 |
| $PE_P$, ¶¶ | All | 281 | 236 | 45 | 0.019 |
| | Year 1 | 275 | 228 | 47 | 0.003 |
| | Year 2 | 281 | 234 | 47 | 0.011 |
| | Year 3 | 286 | 245 | 41 | 0.007 |
| $AE_K$, ±± kg tuber/kg K | All | 117 | 77 | 33 | 0.005 |
| | Year 1 | 111 | 78 | 33 | 0.011 |
| | Year 2 | 115 | 80 | 35 | 0.008 |
| | Year 3 | 117 | 86 | 31 | 0.014 |
| $RE_K$, §§ kg N kg $K^{-1}$ | All | 0.50 | 0.44 | 0.06 | 0.006 |
| | Year 1 | 0.49 | 0.47 | 0.02 | 0.061 |
| | Year 2 | 0.49 | 0.44 | 0.05 | 0.007 |
| | Year 3 | 0.51 | 0.42 | 0.09 | 0.013 |
| $PE_K$, ¶¶ | All | 60 | 42 | 24 | 0.017 |
| | Year 1 | 55 | 37 | 23 | 0.003 |
| | Year 2 | 57 | 35 | 26 | 0.018 |
| | Year 3 | 60 | 36 | 27 | 0.019 |

† All, all two crops grown during 2010 and 2011; Year 1, 2010 crop; Year 2, 2011 crop.

± SSNM, site specific nutrient management, FFP, farmers' fertilizer practice.

§Δ, SSNM - FFP.

¶ P>│T│, probability of a significant mean difference between SSNM and FFP.

# Source of variation of analysis of variance of the difference between SSNM and FFP by farm.

†† P>│F│, probability of a significant F value.

±± $AE_N$, $AE_P$ and $AE_K$, agronomic efficiency of N, P and K.

§§ $RE_N$, $RE_P$ and $RE_K$, recovery efficiency of N, P and K.

¶¶ $PE_N$, $PE_P$ and $PE_K$, physiological efficiency of N, P and K.

## $PFP_N$, $PFP_K$ and $PFP_K$, partial factor productivity of N, P and K.

SSNM treatment compared with PR. Among the three crops grown, the $AE_N$ increased by 34 kg/kg (72%, P=0.002), $RE_N$ by 0.04 kg/kg (8%, P=0.003) and $PE_N$ by 55 kg/kg (58%, P=0.005). The $AE_P$, $RE_P$ and $PE_P$ were significantly increased in SSNM compared with PR. Among the three crops grown, the $AE_P$ increased by 17 kg/kg (25%, P=0.011), $RE_P$ increased by 0.03 kg/kg (30%, P=0.007) and $PE_P$ increased by 45 kg /kg (19%, P=0.019). The K use efficiency parameters also significantly increased in SSNM treatment compared with PR. Among the three crops grown, the $AE_K$ increased by 33 kg/kg (43%, P=0.022), $RE_K$ increased

**Table 4. Fertilizer N rates according to the attainable yield response (yield target - yield in 0N plots) and the expected agronomic N efficiency (AEN) (kg tuberous root yield / kg N fertilizer applied)**

| Yield response to fertilizer N application (t/ha) | $AE_N$ | | | |
|---|---|---|---|---|
| | 70 | 80 | 90 | 95 |
| | N application (kg/ha) | | | |
| Below 10 | 100 | 50 | -- | -- |
| 10-20 | 200 | 100 | 50 | -- |
| 20-30 | 300 | 200 | 100 | 50 |
| 30-40 | -- | 300 | 200 | 100 |
| 40-50 | -- | -- | 300 | 200 |

-- Unrealistic yield target. Apply each 50 per cent of fertilizer N as basal and at 45-60 days after first application. For irrigated crops, 80 per cent of the N rates above.

**Table 5. Fertilizer $P_2O_5$ rates according to attainable yield response (yield target - yield in 0P plots) and the expected agronomic P efficiency (AEP) (kg tuberous root yield/kg P fertilizer applied)**

| Yield response to fertilizer P application (t $ha^{-1}$) | $AE_P$ | | |
|---|---|---|---|
| | 280 | 340 | 360 |
| | N application (kg/ha) | | |
| Below 10 | 20 | -- | -- |
| 10-20 | 30 | 20 | -- |
| 20-30 | 45 | 30 | 20 |
| 30-40 | -- | 45 | 30 |
| 40-50 | -- | -- | 45 |

-- Unrealistic yield target. Apply 100 per cent of fertilizer P as basal application. For irrigated crops, 80 per cent of the N rates above.

**Table 6. Fertilizer $K_2O$ rates according to the attainable yield response (yield target - yield in 0K plots) and the expected agronomic K efficiency ($AE_K$) (kg tuberous root yield/kg K fertilizer applied)**

| Yield response to fertilizer K application (t/ha) | $AE_K$ | | | |
|---|---|---|---|---|
| | 75 | 80 | 85 | 90 |
| | $K_2O$ application (kg/ha) | | | |
| Below 10 | 100 | 50 | -- | -- |
| 10-20 | 200 | 100 | 50 | -- |
| 20-30 | 300 | 200 | 100 | 50 |
| 30-40 | -- | 300 | 200 | 100 |
| 40-50 | -- | -- | 300 | 200 |

-- Unrealistic yield target. Apply each 50 per cent of fertilizer K as basal and at 45-60 days after first application. For irrigated crops, 80 per cent of the N rates above.

**Table 7. SSNM recommendation chart for cassava cultivation in major growing environments of India based on modified QUEFTS model**

| O.C (%) | Yield target (t/ha) | | | | | Available P (kg/ha) | Yield target (t/ha) | | | | | Exchangeable K (kg/ha) | Yield target (t/ha) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 20 | 30 | 40 | 50 | 60 | | 20 | 30 | 40 | 50 | 60 | | 20 | 30 | 40 | 50 | 60 |
| | N rate (kg/ha) | | | | | | $P_2O_5$ rate (kg/ha) | | | | | | $K_2O$ rate (kg/ha) | | | | |
| **Kerala (rainfed)** | | | | | | | | | | | | | | | | | |
| Below 0.4 | 100 | 200 | -- | -- | -- | Below 10 | 20 | 30 | -- | -- | -- | Below 100 | 100 | 200 | -- | -- | -- |
| 0.4 - 0.8 | 50 | 100 | 200 | -- | -- | 10-20 | 10 | 20 | 30 | -- | -- | 100-200 | 50 | 100 | 200 | -- | -- |
| 0.8 - 1.2 | 25 | 50 | 100 | -- | -- | Above 20 | 10 | 20 | 30 | -- | -- | 200-300 | 25 | 50 | 100 | -- | -- |
| Above 1.2 | 15 | 30 | 50 | -- | -- | | | | | | | Above 300 | 15 | 30 | 50 | -- | -- |
| **Kerala (irrigated)** | | | | | | | | | | | | | | | | | |
| Below 0.4 | 80 | 160 | 240 | -- | -- | Below 10 | 15 | 30 | 45 | -- | -- | Below 100 | 80 | 160 | 240 | -- | -- |
| 0.4 - 0.8 | 40 | 80 | 160 | 240 | -- | 10-20 | 10 | 15 | 30 | 45 | -- | 100-200 | 40 | 80 | 160 | 240 | -- |
| 0.8 - 1.2 | 20 | 40 | 80 | 160 | -- | Above 20 | 10 | 20 | 25 | 30 | | 200-300 | 20 | 40 | 80 | 160 | -- |
| Above 1.2 | 10 | 20 | 40 | 80 | -- | | | | | | | Above 300 | 10 | 20 | 40 | 80 | -- |
| **Tamil Nadu (rainfed)** | | | | | | | | | | | | | | | | | |
| Below 0.3 | 100 | 200 | 300 | -- | -- | Below 15 | 25 | 50 | 75 | -- | -- | Below 200 | 100 | 200 | 300 | -- | -- |
| 0.3 - 0.6 | 50 | 100 | 200 | 300 | -- | 15-22 | 15 | 25 | 50 | 75 | -- | 200-400 | 50 | 100 | 200 | 300 | -- |
| 0.6 - 1.0 | 25 | 50 | 100 | 200 | -- | Above 22 | 15 | 20 | 25 | 50 | -- | 400-600 | 25 | 50 | 100 | 200 | -- |
| Above 1.0 | 15 | 30 | 50 | 100 | -- | | | | | | | Above 600 | 15 | 25 | 50 | 100 | |
| **Tamil Nadu (irrigated)** | | | | | | | | | | | | | | | | | |
| Below 0.3 | -- | 160 | 240 | -- | -- | Below 15 | -- | 40 | 60 | 80 | -- | Below 200 | -- | 160 | 240 | -- | -- |
| 0.3 - 0.6 | -- | 80 | 160 | 240 | -- | 15-22 | -- | 20 | 40 | 60 | 80 | 200-400 | -- | 80 | 160 | 240 | -- |
| 0.6 - 1.0 | -- | 40 | 80 | 160 | 240 | Above 22 | -- | 15 | 20 | 40 | 60 | 400-600 | -- | 40 | 80 | 160 | 240 |
| Above 1.0 | -- | 20 | 40 | 80 | 160 | | | | | | | Above 600 | -- | 20 | 40 | 80 | 160 |
| **Andhra Pradesh (rainfed)** | | | | | | | | | | | | | | | | | |
| Below 0.2 | 100 | 200 | -- | -- | -- | Below 15 | 25 | 50 | -- | -- | -- | Below 100 | 100 | 200 | -- | -- | -- |
| 0.2 - 0.7 | 50 | 100 | 200 | -- | -- | 15-30 | 15 | 25 | 50 | -- | -- | 100-175 | 50 | 100 | 200 | -- | -- |
| 0.7 - 1.2 | 25 | 50 | 100 | 200 | -- | Above 30 | 15 | 20 | 25 | 50 | -- | 175-250 | 25 | 50 | 100 | 200 | -- |
| Above 1.2 | 15 | 25 | 50 | 100 | -- | | | | | | | Above 250 | 15 | 25 | 50 | 100 | -- |
| **Maharashtra (irrigated)** | | | | | | | | | | | | | | | | | |
| Below 0.3 | -- | 160 | 240 | -- | -- | Below 15 | -- | 40 | 60 | 80 | -- | Below 200 | -- | 160 | 240 | -- | -- |
| 0.3 - 0.6 | -- | 80 | 160 | 240 | -- | 15-22 | -- | 20 | 40 | 60 | 80 | 200-400 | -- | 80 | 160 | 240 | -- |
| 0.6 - 1.0 | -- | 40 | 80 | 160 | 240 | Above 22 | -- | 15 | 20 | 40 | 60 | 400-600 | -- | 40 | 80 | 160 | 240 |
| Above 1.0 | -- | 20 | 40 | 80 | 160 | | | | | | | Above 600 | -- | 20 | 40 | 80 | 160 |

by 0.06 kg / kg (14%, P=0.006) and $PE_K$ increased by 24 kg / kg (57%, P=0.017). The results showed that the current NPK management practices for cassava in India are inconsistent with the physiological NPK requirements of crop, leading to large amount of nutrient losses.

There was an agronomic efficiency of 95 kg tuberous root yield per kg N applied is often achievable in the cassava-growing regions in India with good crop management in high-yielding seasons, and an AEN of 80-90 kg tuberous root yield per kg N applied is achievable with good management in low yielding seasons (Table 4). An $AE_N$ of 70 kg tuberous root yield per kg N applied is a realistic target for environments where existing fertilizer N management practices are very inefficient, with $AE_N$ in farmers' fields of about 60 kg tuberous root yield per kg N applied.

The agronomic efficiency of 360 kg tuberous root yield per kg P applied is often achievable in the cassava-growing regions in India with good crop management in high-yielding seasons, and an $AE_P$ of 340 kg tuberous root yield per kg P applied is achievable with good management in low-yielding seasons (Table 5). An $AE_P$ of 280 kg tuberous root yield per kg P applied is a realistic target for environments where existing fertilizer P management practices are very inefficient, with $AE_P$ at farmers' fields of about 220 kg tuberous root yield per kg P applied.

The agronomic efficiency of 90 kg tuberous root yield per kg K applied is often achievable in cassava-growing regions in India with good crop management in high-yielding seasons, and an $AE_K$ of 80-85 kg tuberous root yield per kg K applied is achievable with good management in low-yielding seasons (Table 6). An $AE_K$ of 75 kg tuberous root yield per kg K applied is a realistic target for environments where existing fertilizer K management practices are very inefficient, with $AE_K$ in farmers' fields of about 220 kg tuberous root yield per kg K applied.

### Customised fertilizer formulation

The results obtained by running the modified QUEFTS model were used for preparation of SSNM zonation maps (Byju *et al.*, 2012) (Table 7). The soil fertility maps available at the website, http://www.iiss.nic.in/STCR.html were also used to categorise the major cassava growing environments. The results of SSNM validation experiments conducted across India by AICRP on Tuber Crops were also used for delineation of the different zones (AICRPTC, 2013, 2014). The SSNM recommendations and published information on soil nutrient status and plant requirement of secondary and micronutrients, secondary and micronutrient fortified customised fertilizer ratios were developed (Table 8). Future research is needed to validate and test the customised fertilizer ratios to fine tune the recommendations for specific regions within a district.

The results clearly showed that balanced application of plant nutrient following the principles of fertilizer best management practices by SSNM significantly increased tuberous root yield and nutrient-use efficiency of cassava. Opportunities therefore exist for further increases in yield and profit with existing varieties through integrated use of best crop management practices and balanced fertilization with SSNM principles. In SSNM, there was an unattained yield gap of 10-25% caused by climatic factors, poor weed and water management and poor quality planting materials. Future research should focus on further fine tuning of nutrient application regime and validation of the customised fertilizer ratios so that it becomes fully synchronised with the above variables.

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