

Smart Fruits for 21st Century

G Karunakaran, P C Tripathi, Pritee Singh, M Arivalagan and S Sriram

Email: ganesan.karunakaran@icar.gov.in

Some parts of India are bestowed with congenial agroclimatic variations ranging from tropical to subtropical conditions that could permit sufficient scope for growing a large number of novel fruit crops, viz. avocado (*Persea americana* Mills.), dragon fruit (*Hylocereus* spp.), passion fruit (*Passiflora edulis* Sims), Rambutan (*Nephelium lappaceum* L.), mangosteen (*Garcinia mangostana* L.), durian (*Durio zebithinus* L.), longan (*Nephelium longana* L.), karonda (*Carissa carandas* L.), kokum (*Garcinia indica* Choisy.), soursop (*Annona muricata* var. *subonica* L.), jamun [*Syzygium cumini* (L.) Skeels], rose apple (*Syzygium aqueum*), malayan apple (*Syzygium malaccense*) etc., in view of their nutritive value, potential health benefits for niche markets.

Further, prevailing challenges of malnutrition, ensuring profitability to growers and the threat of weather dynamics could catapult these crops to the trajectory of 'smart fruit crops'.

Many of these fruits are also rich in antioxidants and nutraceutical properties including therapeutic values. It may also be possible to ensure sustainable fruit culture activities through crop diversification in some of the agro-ecologies through integrating them in production systems by suitably manipulating crop geometry and due cultural attention. Recently, cultivation of some of these fruits gained substantial momentum due to steady appreciation of health benefits, increasing market demands and emergence of niche markets. Commercial planting under few of these crops in recent years have increased appreciably to about less than 1,000 acres in parts of Kerala, Karnataka, Tamil Nadu and also other states, where, they are being grown commercially in small or chards, mixed fruit orchards as well as popular homestead candidates.

DRAGON FRUIT

Dragon Fruit (*Hylocereus* sp.) is a perennial, world wide known as red pitaya, have recently drawn much attention of Indian growers, not only because of their red or pink colour, bunch of functional food supplements and economic value as fruit, but also for their rich antioxidant activity, high in vitamin C, fibers and nutrition. Therefore, dragon fruit can be called as a “healthy food”. It strengthens the human immune system and is used in the treatment of diabetes. Fruits can be processed to juice, ice cream or wine. Dragon fruits are currently being grown commercially in South East Asia and the USA. In India it was introduced somewhere in late 90s. And is still the area under Dragon fruit is very limited. In India, it is cultivated in very limited scale. A very few farmers of Karnataka, Kerala, Tamil Nadu, Maharashtra, Gujarat and Andhra Pradesh have taken up dragon fruit cultivation. Total area under dragon fruit cultivation may be less than 500 acres. Majority of dragon fruits available in India, is imported from Thailand, Malaysia, Vietnam and Sri Lanka. There is good potential of dragon fruit cultivation in India for domestic and international markets. It belongs to family of Cactaceae consists of climbing or epiphytic cacti with angular stems and mostly white, fragrant, night-blooming flowers which is native to the Central and South America. One of the widely grown cultivars and most commonly available is the *H. undatus* (red colour skin with white flesh). Other one that have been commercialised are the *H. polyrhizus* (red skin with red flesh) and *H. megalanthus* (yellow colour skin with white flesh).

The ripe fruits of dragon fruit are used as fresh fruits. Fruits are rich in vitamins and minerals (Table 1). Fruit has huge demand due to taste, nutritional and medicinal properties. Dragon fruit increases the digesting power of the foods. Also it has ability to control cancer, diabetics, high cholesterol as well as blood pressure.

Climatic and Soil

It prefers a tropical climate with an average temperature of 20-30°C and with well distributed annual rainfall of 100-150 cm, but can withstand temperatures of 38-40°C, and as low as 0°C for short periods (Karunakaran, *et al.*, 2014). The plants are sensitive to extremes in temperature. The plants will be damaged at temperatures above 40°C, causing yellowing of areas of the stem. Heavy rain fall areas are not suitable. As excessive rain causes flower drop and fruit drop (Karunakaran and Arivalagan, 2019), it prefer sandy loam with high organic matter and grow well in soil having good drainage.

Table 1. Nutritional value of dragon fruit

Nutrition	Quantity/100g edible portion	Nutrition	Quantity/100g edible portion
Water	82.5- 83 g	Iron	0.55 - 0.65mg
Protein	0.159- 0.229 g	Vitamin C	8.0 - 9.0 mg
Fat	0.21- 0.61 g	Thiamin	0.28 - 0.30 mg

Nutrition	Quantity/100g edible portion	Nutrition	Quantity/100g edible portion
Fiber	0.7- 0.9 g	Riboflavin	0.043 - 0.044 mg
Carotene	0.005- 0.012 mg	Niacin	1.297 - 1.30 mg
Calcium	6.3- 8.8 mg	Ash	0.28 g
Phosphorus	30.2- 36.1mg	Other	0.54 - 0.68 g

Plants can tolerate any type of soil, however they grow well in soil having good drainage. Good drainage system is important to dragon fruit cultivation. The plants prefer light acidic soil with pH ranging from 5.5 to 6.5. Sandy loam soil with high organic matter are suitable for its cultivation. Sandy soils with organic matters also provides good condition for plant growth.

Varieties

Three species are popular. The first species has red colour fruit coat with white colour pulp, second species has red colour fruit coat with red colour pulp and third species has yellow colour fruit coat with white colour pulp. The species with red colour fruit coat with red colour pulp are most popular.

The flowers start on small spiral button type attract structures at the stem margins. These develop to flower buds in 10-15 days. The flowers are hermaphrodite nature and 25-30 cm length with white inside and greenish yellow with purple dyes on the outside. They are scented and only bloom at night and last for only night. Flower production generally takes place during May - September and harvesting 30-40 days after fruits setting. Quality of the fruit does vary between varieties, but harvesting time has a much greater effect on quality than varietal differences. There are self-compatible and self-incompatible varieties. The majority of the varieties from Asia are self-compatible. There is considerable variation in fruit size and shape between the varieties. At present, very little knowledge is available on varietal and production aspects.

Propagation

It is propagated easily through cuttings, the most common method. Cuttings may permit the production of plants with identical characteristics to the parent plant. Additionally, they reach in production stage earlier compared to seedling plants. Well-hardened cuttings of 20 cm or longer are taken by cutting in the stem or branch from elite mother plants. The cutting should be prepared one-two days prior of planting and the latex oozing out of cut is allowed to dry. The base cut of the cutting should be slated. These cuttings are planted in 12cm × 30 cm size polyethylene bags filled with 1:1:2 ratio of soil: FYM and sand. These cutting roots profusely and become ready for planting with 4-5 months (Tripathi *et al.*, 2014).

Planting

It prefers full sunlight, and open area are very suitable for planting. The shady areas are not suitable for dragon fruit planting. Generally, in single post system planting is done at 3 m × 3 m distance. Single post vertical height of pole 1.5 m -2 m at which point they are allowed to branch and hang down. Planting should be done near the poles to enable them to climb easily. Number of plants per pole may be 2-4 depending on the climatic condition.

Dragon fruit needs support to up right growth, stone or concrete poles can be used. Immature stem must be tied to that poles. But thereafter aerial roots develop and bound to poles. Lateral shoots must be limited and 2-3 main stems are allowed to grow. Because lateral shoots must be removed time to time (Karunakaran, 2019). It is important to arrange round metal/concrete frame to maintain balanced shrub.

Fertilizer Schedule

Its plants respond well to most of the fertilizers, although care must be taken not to burn the shallow root system. It is newly introduced plant for cultivation. Good yield can be obtained by applying organic fertilizers. Apply 10-15 kg of organic manures per plant before planting and increase the amount by 2kg per year up to 20kg. At initial stage more nitrogen should be applied for good vegetative growth. In later stages more amounts of phosphorus and potash are applied. Application of calcium and other micronutrient is beneficial for proper growth of fruits. The dragon fruit can be grown organically without applying chemical fertilizers and pesticides. The farmyard manure and poultry manures may be used for supplementing nutrients. There is no published information about fertilization of these plants, and a proper schedule is needed to be worked out to increase flowering and fruit production.

Water Requirement

Although its plants are cacti, they take more water than expected for a typical desert cactus. It must be remembered that they come from areas of high precipitation and humidity. Irrigation through drip system with small quantity of water (2-4 litres weekly twice) is more beneficial to these plants than a larger amount of water less often. They have a very shallow fibrous root system and it responds well when the upper portion of the soil is kept continuously moist. Excessive irrigation may cause fungal disease. Therefore proper drainage should be provided in rainy season. Frequent dry period without irrigation reduces the yield and quality of fruits. The dry period before flowering is required for production of more fruits. Drip irrigation is beneficial for better yield and growth.

Training and Pruning

Its plants are fast growing vines and produce more thick dense branches in initial stage. The lateral buds and branches should be pruned to grow towards stands. Once

vines reach up to the top of stands, the branches are allowed to grow. The removal of tip of main stem to allow growth of new shoots to grow laterally and climb at the rubber tire to form an umbrella like structure of vines where flowers emanate and develop into fruits induces lateral branching. This pruning referred as structural pruning or making a structure on the trellis. The well grown vine may produce 30-50 branches in 1 year and may be more than 100 branches in 4 year. Excessive number of growing lateral stems increase the advent of pest and diseases, hence, desirable number of lateral stems only should be maintained to ensure vigorous growth, better aeration, easy cultural operation and prevention of diseases and pests.

Many trellis designs are used in India. IIHR- Experimental Farm, hirehalli, evaluated four different trellis system of single pole with cement and ring, continuous pyramid stands and 'T' stands with two different cultivars. For our analysis, each trellis consisted of one 6 feet height by 5 or 6 inch thickness of poles erected 2 feet depth. Single pole system showed better performance in growth and yield when compared with other trellis system. Single pole with ring type of trellis that can support the weight of the plants and allow easy access to flower and fruit will work for commercial production. The wooden poles are hard but their durability is least compare to cement poles. It is not possible to change the poles in between because of the growth and entangled branches. Therefore, it is better to go with concrete poles its cost may be high for cement pole but they are durable and can be used.

In some areas rubber tires cut across are placed on the top of the poles for stringing wines. Steel or metal wire should be used for supporting the vines. As it damage the vines. Its plant may be planted near the poles to enable them to climb easily. Number of plants per pole may be 1-4 depending on the climatic conditions.

Continues type Stands are made of G.I. pipe and G.I. angles can also be used. This pyramid shape with a length of 10-15 m with grounding at each and every point. This way, more number of plants may be planted but precaution would be taken with adequate care to provide adequate aeration to avoid disease and pests. The plants may be planted at 2-3 feet distance both the sides of the structure. The distance between two structure may be 5-6 m (Karunakaran *et al.*, 2014a).

Fruit Quality

Fruit has excellent taste and its texture. On an average fruit weight in white-fleshed is higher (457.0 g) than the red- fleshed cultivar (457.0 g). Maximum fruits per pole was recorded in red fleshed (14.40) compared with white fleshed. It has 74.44 % and 70.28% pulp recovery ratio, respectively. The cultivar having deep red or purple colour pulp (11.54 °Brix) with the higher TSS compared to that having white colour pulp (9.75 OB), which is an important parameter related with fruit quality (Table 2).

Table 2. Quality parameters (average of ten poles)

Cultivars	*No. of fruits/pole	Fruit weight (g)	Fruit length (cm)	Fruit breadth (cm)	Pulp weight (g)	Skin weight (g)	Seed weight (g)	Pulp recovery ratio (%)	TSS (°Brix)
White fleshed	14.40	457.00	15.21	27.35	321.20	122.60	2.02	70.28	9.75
Redfleshed	22.40	331.40	14.56	24.31	246.70	84.00	1.88	74.44	11.54

Phytochemicals

Dragon fruit is rich in various biochemical compounds. The biochemical analysis of 100 g fresh fruits revealed that fruits have moisture content of 83-88%. The fruit is slightly acidic and titratable acidity varies from 0.20 to 0.40 mg lactic acid equivalents. The TSS varies from 8-14°Brix. It is one rich sources of vitamin-C (10-14 mg/100 g). The consumption of 100 g of dragon fruit could able to provide about 16-22% of the recommended daily allowance (RDA) of vitamin-C. The total sugar content is about 3.5-7.0 g. Fruits with pink flesh have higher phenolics and flavonoids content (40-60 mg GAE and 20-40 mg QE, respectively) compared to white pulped fruits (15-20 mg GAE and 10-20 mg QE, respectively). Similarly, antioxidant activity measured by DPPH method also revealed that antioxidant activity of the pink pulped fruits (250 to 400mM TE/100 g) are higher than the white pulped fruits (100 to 125 mM TE/100 g). (Note: GAE- Gallic acid equivalent; QE- Quercetin equivalent and TE- Trolox equivalent).

Harvesting

Flowering occurs and initiate during warmer months of May. As many as 4-8 flowering cycles may occur in tropical areas. Flowering and fruit setting are highly dependant on temperature and photoperiod. Maturity can be judged with the change of fruit colour from green to red. Proper time of harvesting is after four days of colour changing. Harvesting may be done three-four times in a month during July-September. Dragon fruit normally fruits 15-18 months after planting. Peak ripening reaches 40-45 days after flowering (Karunakaran and Arivalagan, 2019). The fruit weight ranges from 300 to 800g and initially each plant produces 10 - 15 fruits/ pole 15 months after planting. Approximately one pole normally yields range 10- 15 kg fruits from three years old plantation.

JACKFRUIT

Artocarpus is popularly known as poor man's fruit in the eastern and southern parts of India. The ripened fruit significantly contributes to the nutrition of lower income families as it is a good source of vitamins, minerals and calories. The fruit, a gigantic syncarp, is the largest of all cultivated fruits. Different shapes (obloid, spheroid, high spheroid, ellipsoid, clavate, oblong, broadly ellipsoid, etc) of fruits are found in jackfruit. The fruits can have 10-500 flakes and seeds. Jackfruit is a monoecious, evergreen, late producing tree, with male and female inflorescences appearing separately on the same

tree. Whereas male and female inflorescences are similar during early development, the female is later distinguished by a thicker peduncle and a large annular disc at the base of the spike.

Jackfruits are eaten unripe at 25-50% of full size as a vegetable or ripe as a fruit (Baliga *et al.*, 2011). When used as vegetable, it is peeled, sliced and boiled and then seasoned or mixed with other food. The ripe fruit is a rich source of beta-carotene (a precursor to vitamin A), iron, pectin and contains 1.9-2.2% protein on fresh weight basis. The seeds are very rich in carbohydrate and protein. The seeds are boiled or roasted and used in many culinary preparations (Karunakaran *et al.*, 2015). The skin of fruit and its leaves are excellent cattle feed. Its timber is valued for furniture making since it is rarely attacked by white ants. The latex from the bark contains resin. Pickles and dehydrated leather are its preserved delicacies. Canning of flakes can be done. They can be bottled and served after mixing with honey and sugar. Nectar is prepared from its pulp.

The diversity, conservation and knowledge of *Artocarpus* (Moraceae) to which the Jackfruit belongs to, is not commonly known. Jackfruit has a wide range of genetic variation, particularly in India, which could facilitate selection of superior and desirable types. For sustainable use, genetic diversity is a valuable resource for present and future. It has innumerable types, categorized according to the phenotypic and organoleptic characteristics, contributing to diverse land races at farmer fields over years. Being a highly cross-pollinated crop, method of propagation from time immemorial was of sexual route, considerable variability exists in local jack plantations. There is no distinct cultivar or recommended variety for cultivation in India. Different types of jackfruit have come into commercial cultivation in Karnataka with different local names, viz., Gumless, Rudraskhi, Chandra halasu, Mangala red, Toobugare, All season, Singapore, Hemachandra, Ramachandra. There are numerous cultivars of each type in regions where jackfruit is a significant food crop, including South India.

Different types of varieties available are in Kerala, Tamil Nadu and Karnataka. Jack fruit types like 'Varikka', 'Koozha', 'Navarikka', 'Rudraksha Chakka' or 'Thamara Chakka' and other wild forms were found from Wynad Plateau in the Western Ghats during the year 1986. Three types of jackfruit, viz., 'Rasdar', 'Khajwa' and 'Sugandh' were identified through survey in the plains of Eastern Uttar Pradesh. Jackfruit, NJT1, NJT2, NJT3 and NJT4, collections from Faizabad have large fruits with excellent quality, low fibre content and suitable for table purpose. NJC1, NJC2, NJC3 and NJC 4 have small to medium-sized fruits with thin rind, soft flesh and suitable for culinary purpose. In Sikkim, Soft Flesh, Firm Flesh, Sudrakshi and Singapore etc are cultivated. In Assam, nurserymen have given names such as 'Mammoth', 'Ever bearer', and 'Rose-scented'.

Varietal improvement in jackfruit has so far been limited to selection of high-yielding, better quality genotypes. Whatever varieties are grown commercially they are all selections made by enlightened growers or enthusiasts based on their own ideas of suitability. Major constraints faced by growers are non-availability of vegetative

propagated, true-to-type planting materials in large number, long juvenile. Further, there is no released varieties especially in orange reddish/coppery red flakes in our country which is having huge demand consumer.

Farmers Variety

ICAR-IIHR- Experimental Farm, Hirehalli, Karnataka, undertook extensive survey for identifying superior jackfruit with coloured flakes during 2014- 2018 in traditional jackfruit growing tracts of southern Karnataka. These regions were found dominated by seedling orchard and considerable amount of variability existing in tree morphology and fruit parameters. During survey, 65 plus trees were identified based on the basic horticultural traits including colour of flakes and organoleptic evaluation. Two of selection emerged from participatory breeding research having attractive coppery red flakes with enhanced nutritional benefits compared to local jackfruits. They are: Siddu and Shankara.

Vegetative Propagation

Inarching: In South India, inarching of jackfruit is successful using *A. hirsuta* or Rudrakshi as rootstocks. The young root-stock is tied onto mother plant and is grafted to selected bunch of mother plant. In this method, the success percentage is high but the method is laborious and time consuming, besides restricting the operation at mother plant place only.

Epicotyl: Involves grafting with mature, plump, terminal scion shoot on germinating jackfruit seedling of about 8-10 weeks by wedge method during April-May could be successful. Epicotyl grafts attain saleable size within a year. The grafts become ready for planting in one or two years after grafting.

Budding: Among different methods of budding, forkert budding, chip budding and patch budding may be used successfully for the propagation.

Spacing

Commonly, square system is followed for planting. Hexagonal system may be followed in less fertile soil. In fertile soil, spacing up to 12 m x 12 m, accommodating 70 plants/ha will be sufficient for this fruit crop. On average soil, its trees may be planted at 10 m apart. Higher density of planting can be practices in lighter and poorer soils; shorter spacing in fertile soil leads to top crowding of trees.

Planting

For planting jackfruit, pits of 1m x 1 m x 1 m size are dug at least 10 days before planting. About 30 kg well-rotted farmyard manure is mixed with soil and pit is refilled. Chlorpyrifos may be applied in pits to avoid insect attack. *In situ* planting of 3-4 seeds per pit leads to stronger plant. But nursing and rising of a large number of plants in this way are difficult. After planting, soil is pressed firmly to avoid water logging in pits

during rainy season. Jackfruit cannot withstand water logging. The young plants should be protected from stray goats and cattle. The best time for planting grafts or seedlings is June-August. In the case of budded/ grafted plants, care should be taken not to cover the graft union with soil. Shade should be provided for initial 2-3 weeks. Prolonged dry weather after planting may lead to the death of plants. The taproot should not be distributed while planting to avoid damage to the plants.

Training and Pruning

Jackfruit does not respond well to indiscriminate pruning and it is not commonly practiced. Young trees do not need pruning in first year. However, when older trees are not pruned a strong central leader usually develops which is desirable for its timber value. Nonetheless, where fruit production is the main purpose, pruning of the first lateral branches should be carried out in year to slowdown upward growth and enhance the spreading of the canopy. One or two pruning of shoot tips during summer causes lateral bud break and makes the tree more compact. Grafted trees have a dwarfing tendency but produce a large number of branches from the beginning. These branches should be continuously pruned to get a reasonable trunk. Thereafter, branches may be allowed to remain but removal of vigorously growing upright shoots is recommended. Inner branches of the canopy should be removed to allow more light and air penetration within the canopy. Regular pruning of weak, dead and diseased branches and removal of parasitic plants at the end of the rainy season is recommended. This prevents insect infestation and disease infection. Tree height and size may also be controlled, if desired, by pruning.

Old flowering shoots should be removed after harvesting and after after completion of harvesting, branches should be thinned out to increase light penetration to the inner canopy. The height of the tree might be maintained at 4- 5m by periodic selective pruning. Selective pruning is also effective for equipment movement and other management operations. Trees may also be mechanically topped at 4- 5m and hedged at a 5-10° angle from the vertical.

Fruit thinning is also recommended to prevent damage to branches as heavy fruit load break branches and can result in death or stunting of the tree. Limiting number of fruits per limb may also improve quality of fruits besides increasing their size.

Cropping Systems

The jackfruit requires a long time to occupy the entire spacing provided during planting for future mature trees. It is desirable that the interspaces should not be left unutilized. Root distribution studies of wild jackfruit tree revealed that most of the physiologically active roots were concentrated within the radius of 75 cm and 30 cm depth, although tap roots might reach even deeper layer of soil strata. The tree roots seldom extend beyond 2.25 m laterally from the stem, hence the effect of overlapping root zones and associated competitive effects may not be serious problem for intercropping during first few years (< 10 years after planting) of tree growth. Intercropping with

vegetables like beans, brinjal, chilli, gram and other crops can be taken if moisture is not a limiting factor. Suitable crops should be grown every year till the trees reach bearing stage. When trees come into bearing, pulses can be grown as intercrops. These crops improve the nitrogen status in soil.

Harvesting

Tender jackfruit is harvested for use as vegetable during early spring and summer until seeds harden. The fruit matures towards the end of summer in June. Period of fruit development is February to June. The optimum stage of harvesting matured jackfruit has been reported to be 90-110 days after appearance of the spike, depending on the individual tree, growing conditions and weather; therefore, time from flowering alone is not a good indicator of maturity. It takes some experience to gauge maturity. There are four primary indicators 1) skin turns from light green to yellowish or brownish green; 2) points of spines grow further apart and flatten slightly, and the skin yields slightly to pressure; 3) last leaf on the stalk turns yellow; 4) fruit produces a dull, hollow sound when tapped. Usually two or more of these indicators are used to evaluate maturity of fruit.

Seedling trees start bearing from seventh to eight year onwards, while grafted ones from third year, when a few fruits may develop. The tree attains its peak bearing stage 15-16 years of planting. At this stage normally a tree bears up to 250 fruits annually with annual fluctuation in yield. The weight of fruits also varies depending on type. On an average, 40-50 tonnes of fruits per hectare could be obtained. In order to achieve best fruit quality, the fruit must be allowed to develop to full maturity on tree, and then ripen after harvesting. Harvested even a few days too early, fruit do not ripen to their quality.

In recent decades, number of scientific and economic interests have emerged to promote and commercialize the jack fruit products. The primary reason for this is that the crop is already well suited to household and farming systems of farming communities vulnerable to food shortages and nutritional deficiencies. Hence, identification of these potential varieties besides increasing the area and production could also address the issues of sustainability as the crop is climate resilient and profitability frequently faced by growers. Further, jackfruit also contribute towards food and nutritional security as they provide good calories and a range of functional food components. There however remains challenge to produce in large numbers true-to-type vegetative propagated plants for supply to growers along with package of practices.

Thus, need and precedents for Jackfruit Research and Processing Centers are evident. Utilization of jackfruit. An naturally abundant and nutritious resource, will enormously strengthen.



India is a leading jackfruit producer, to take the lead in jackfruit research and commercialization and to usher in a bright future for jackfruit. There exists ample scope for area expansion with superior fruit types in Karnataka, Kerala, Tamil Nadu, Maharashtra Andhra Pradesh, Goa, Assam, Meghalaya, Bihar, Orissa, Maharashtra and West Bengal.

AVOCADO

Avocado is the most nutritive fruit and is regarded as the most important contribution of new World to human diet. The fruit is relished by some people, but not by others. The pulp is rich in fat (up to 30%), but low in carbohydrates. The fat is similar to olive oil in composition and is widely used in the preparation of cosmetics. Avocados have the highest energy value (245 cal/100 g) of any fruit besides being a reservoir of several vitamins and minerals. Avocado contains a significant amount mono-saturated fat, which helps reduce bad cholesterol, and vitamin E which aid in prolonging of aging of skin. It is also a great source of potassium which is known to prevent high blood pressure and fluid retention. Avocado is mainly used fresh, 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. Three antifungal compounds have been isolated from the peel extracts of immature fruits of green cultivar. In India, avocado is not a commercial fruit crop. It was introduced from Sri Lanka in the early part of the twentieth century. In a very limited scale and in a scattered way it is grown in Tamil Nadu, Kerala, Maharashtra, Karnataka in the south-central India and in eastern Himalayan state of Sikkim. It cannot tolerate the hot dry winds and frosts of northern India. Climatically, it is grown in tropical or semitropical areas experiencing some rainfall in summer, and in humid, subtropical summer rainfall areas.

The agroclimatic conditions prevailing in various parts of the country appear to be favourable for bringing more areas under avocado. Presently, plantations are not well organized and they are scattered. Also, quite a good number of improved varieties are now available with higher yield potential. Vegetative propagation techniques have also been standardized. Multiplication of a large number of high-quality nursery plants of selected varieties and their systematic planting, both in tropical southern India and humid semi-tropical areas of the northeastern region of India, could help to place avocado properly on the fruit map of India. The research support for the crop is still very poor, but the available research information from Tamil Nadu and Sikkim amply demonstrate that size, colour and quality of fruits attained in India are comparable with those of avocado fruits grown elsewhere. Avocado is grown successfully in neighbouring country Sri Lanka, where good-quality fruits are harvested during May to August and

December to January at different regions. Similar agro-climatic conditions to Sri Lanka are available in the Andamans and Nicobar Islands and in the tropical southern India. With proper varietal selection, it should be possible to exploit also the possibility of out-of-season production, thus enhancing the availability of fruits for a longer period during the year. Avocado fruits produced in the country can be marketed without much difficulty, particularly to meet the requirement of the growing tourist industry. The mainland India and the Andaman and Nicobar Islands are attracting foreign tourists in a large number of places, where avocado could find a good market access. Avocado has also a good export potential.

Varieties

All three horticultural races adapted to tropical and sub-tropical conditions, i.e. West Indian, Guatemalan and Mexican have been tried in India. The cultivars of West Indian race are grown in localized pockets in Maharashtra, Tamil Nadu and Karnataka. In tropical and near-tropical areas, only West Indian race is well-adapted but its hybrids with Guatemalan (e.g. Booth selection) perform well and are considered valuable for extending the harvest season. In less tropical regions, hybrids of Guatemalan with Mexican race predominate since they combine the cold hardiness of the latter with the superior horticultural traits of both and also bridge the two seasons of maturity. In the eastern Himalayan state of Sikkim, avocado has been introduced successfully in hill ranges with an altitude of 800- 1,600 metres. Both the Mexican and Guatemalan races are grown successfully in Sikkim.

The varieties that are cultivated in India go by several names, such as Purple, Green, Fuerte, Pollock, Peradeniya Purple Hybrid, Trapp, Round and Long. Among the several existing varieties, perhaps Fuerte is the most widely grown, but it is regarded as unsuitable for the tropics. The Purple and Green varieties were introduced into India from Ceylon in 1941. The following varieties have been introduced at the Fruit Research Station, Kallar, Tamil Nadu: Long, Round, Fuerte, Pollock, Peradeniya Purple Hybrid, Shambaganur and Trapp. In Kodagu, 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 and Karunakaran, 2013). Lots of variability of avocado is available in Coorg and adjoining areas.

Propagation

In India, avocado is commonly propagated through seeds. The viability of seeds of avocado is quite short (2-3 weeks) but this can be improved by storing the seed in dry peat or sand at 5°C. The seeds taken from mature fruits are sown directly in the nursery or in polyethylene bags. The seedlings, 6-8months old, are ready for transplanting. Such seedling trees at 10-15 years produce 300 to 400 fruits. Vegetative propagation by means of budding or grafting has resulted in establishment of selected varietal clones. West Indian stocks are preferred in warmer regions or where salinity is a problem. Need of *Phytophthora*-resistant rootstocks is recognized as the most important

factor for the success of its cultivation. At the Fruit Research Station, Kallar, in the Nilgiri Hills of Tamil Nadu, inarching gave up to 75 per cent success, while in West Bengal chip-budding is reported to be successful. In India, presently, there is many commercial nursery engaged in vegetative propagation of avocado. It was concluded that cleft grafting in the month of September and March was found most suitable for the vegetative propagation of avocado under humid tropical conditions (Tripathi and Karunkaran, 2014).

Planting

If avocado plantation is to be established in a relatively new area, the varieties to be selected for planting should belong to both A and B groups and their flowering must overlap. The proportion of A and B group varieties can be 1:1 or 2:1. Avocado is planted out to a distance of 6 metres depending on the vigour of variety and its growth habit. For varieties having a spreading type of growth, like Fuerte, a wider spacing should be given. In areas prone to excess water, they should be planted on mounds as avocados cannot withstand water logging. In Sikkim, a planting distance of 10m x 10m on hills slopes (on half-moon terraces) is preferred and planting is done in June-July. Pits of 90cm x 90cm are dug during February-March, and filled with farmyard manure and top soil (1:1 ratio) before planting. In Coorg, a region of Karnataka state, they have been planted also as one of the mixed crops in a primarily coffee-based cropping system.

The pollination in avocado is mainly performed by insects. The studies conducted revealed that insect species including 7 hymenopterans, 7 dipterans, 3 coleopterans were recorded on avocado flowers. Among all the visitor groups, hymenoptera order constituted the major pollinators (52.66%), followed by dipteran order (39.57%) and coleopteran was the least (7.62%) of the total pollinators in avocado orchard. In the group of Hymenoptera it was found that *Apis cerena* as major pollinator with 17.56% followed by *Apis florea* with 11.3%. Similarly 8.82% of *Tetragonula* sp. and ants each followed by 6.16 % of wasp were observed. *A. cerena* starts foraging from 6.00 AM and continues till 12.00 Noon. However, it was observed that the peak foraging period for *A. florea*, *Tetragonula* sp. was from 9.00-12.00hrs. Of total bee population, *A. cerena* had the maximum number of visits (7.87 visits/30 min/bunch) followed by *A. florea* (5.06 visits/30 min/bunch), and *Tetragonula* sp. and ant species (3.96 visits/30min/bunch) each (Tripathi *et al.*, 2014).

Disease and Pests Management

Among insect pests, stem borer, scales, mealy bugs and mites are the important ones, and may be controlled by suitable insecticides. Fruit spot disease caused by *Colletotrichum gleosporioides* results in shedding of young fruits. Fruits often become deformed. The infection may remain latent in some fruits. Another strain of the same fungus causes leaf spot. The Fuerte cultivar is reported to be more susceptible to anthracnose (*Glomerella cingulata* var. minor) and stem-end rot (*Dothiorella aromatica*) from fruit set till harvest. The time of infection has been found to vary with the seasons

and is related to rainfall. In addition, *Cercospora* sport (*Cercospora purpurea*) and scab (*Sphaceloma perseae*) have been found to attack both leaves and fruits also.

The most serious disease of avocado is the root rot caused by *Phytophthora cinnamoni*, leading to death of plant. The disease situation is aggravated by ill drained and waterlogged conditions.

Harvesting

Avocado plants raised from seeds start bearing four to five years after planting. Mature fruits of purple varieties change their colour from purple to maroon, whereas fruits of green varieties become greenish- yellow. Fruits are ready for harvest when the colour of seed coat within the fruit changes from yellowish white to dark brown. Mature fruits ripen six to ten days after harvesting. The fruits remain hard as long as they stay on the trees, softening only after harvest. The yield ranges from about 100 to 500 fruits per tree. In Tamil Nadu, July-August is the peak harvest time. The yield performance of avocado, both in tropical southern India and humid sub-tropical north eastern India is highly satisfactory.

Avocados do not ripen on the tree, and fruits soften only after picking. Fruits need to be picked carefully. They should be harvested at the correct stage of maturity, when they are still hard and have a minimum oil content of 12 per cent. In India, fruits of 250 to 300 grams in size are preferred. Presently, there is no organized marketing system for avocado as the production is small and production areas are scattered.

One of the important constraints appears to be due to the consumer preference. In the domestic market the avocado may not be liked by the common people due to the nature of its taste and also due to availability of many other tropical fruits throughout the year which are more palatable than avocado. Nevertheless, due to increasing health consciousness among the educated population and the high nutritive value of avocado, it is expected to find its rightful place in the Indian market in due course. The successful introduction of avocado and its wide acceptance among the tribal population of the hilly state of Sikkim indicate that for household nutrition security avocado should be a potential fruit crop in India. Presently, there is plan to strengthen research and development of avocado in India. Research centres in Karnataka and in Tamil Nadu are maintaining some germplasm of avocado in their collections. Due to the availability of a large number of fruit crops in India and consumer preference for more palatable fruits of sweet taste, avocado has not caught the imagination of the average Indians. With some governmental support, it can be popularized in the country and it can provide much needed household nutrition security to the Indian population.

REFERENCES

- Baliga M.S., Shivashankara A., Haniadka R., Dsouza J. and Bhat, H. 2011. Phytochemistry, Nutritional and pharmacological properties of *Artocarpus heterophyllus* Lam. *Food Res. Int.* **44**(7): 1800-11.
- Chithirachelvan R, Sakthivel T, Karunakaran G. and Sulladmath V.V. 2002. Genetic variability of Avocado (*Persia Americana*. Mill.) in the hilly area of Kodagu. *In: National Seminar on Emerging Trends in Horticulture*, during 14-15 February 2002, at Annamalai University, Annamalai Nagar.
- Tripathi P.C., Sankar V., Jayanthimala B.R., Sunanada S. and Karunakaran G. 2014. Studies of flowering behaviour of avocado accessions under humid tropical conditions of Coorg region. *In: National Seminar-Cum-Workshop on Physiology of Flowering in Perennial Fruit Crops*, CISH, Lucknow, 24-26 May, 2014.
- Karunakaran G. and Singh, Pritee. 2019. "Jackfruit varieties serves niche for growers" *Indian Horticulture*, pp. 18-19.
- Karunakaran G. and Arivalagan, M. 2019. Dragon Fruit - A New Introduction Crop with Promising market. *Indian Horticulture* **63**(1): 8-11.
- Karunakaran G., M. Arivalagan and Sriram. 2019. Dragon fruit country report from India, *In: Proceedings of Dragon Fruit Network: Marketing and Whole Value Chain*. Vietnam Academy of Agricultural Sciences and Southern Horticultural Research Institute, 9-10 September 2019, pp 105-12.
- Karunakaran G., Tripathi P.C., Sankar V., Sakthivel T. and Senthilkumar, R. 2014. Dragon Fruit - A new introduction crop to India: a potential market with promising future. *In: National Seminar on Strategies for Conservation, Improvement and Utilization of Underutilized Fruits*, 1-3 December 2014, pp. 138-39.
- Karunakaran G. 2019. "Dragon fruit" in Agriculture and Industry survey, pp. 23-25.
- Karunakaran G., Loganadhan N., Hegde M.R, Senthil Kumar M., Jagadish. K.N. Ramesh P.R. Prahant J.M., Hanumanthe Gowda B., Radha R. Banakar, Somashekhar, Shashidhar. K.N and Srinivas Reddy K.M. (Eds). "*Jack Fruit.... A Versatile Fruit*". Indian Institute of Horticultural Research, Bangalore, p. 97.
- Tripathi P.C. and Karunakaran G. 2013. Bharat Mai Navaneet Phal (Avocado) Ki Kheti:Varthamansthithievam Sambhavanaye (In Hindi) (Avocado cultivation in India: Present status and possibilities) Bhumi Nirman (Bhopal), 16 Jan -15 Feb : **11**.
- Tripathi P.C. and Karunakaran G. 2019. Standardization of time and method of propagation in avocado. *Journal of Applied Horticulture* **21**(1): 67-69.
- Tripathi P.C., G. Karunakaran, V. Sankar and Senthilkumar, R. 2014. Dragon fruit: Nutritive and Ruminative Fruit, *Technical Bulletin No. 11/2014*, Indian Institute of Horticultural Research, Bengaluru, India, pp. 1-9.

