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Avocado

Avocado (*Persea americana*) belongs to the family Lauraceae. Total world production is more than 4.5 million tonnes, with about 25% of the crop traded around the globe. Nearly half of the international trade is from Mexico. During the past decade, consumption of avocado has increased significantly throughout the world. Mexico is the largest producer with a total production of about 1.5 million tonnes (28% of world production). In India, avocado is not a commercial fruit crop and only some non-descript seedling population of Avocado are found growing in parts of Karnataka, Maharashtra, Tamil Nadu, Kerala and parts of Sikkim since British India. It was introduced in India from Sri Lanka in the early part of the twentieth century. The avocado plants are mainly grown in homesteads for family consumption. Farmers, only from Sikkim, are reported to be successfully growing avocados in the north-east at elevations between 800 and 1,600 m. The crop is yet to attain commercial status in the country.

Avocado is the most nutritive among fruits and is regarded as the most important contribution of the New World to human diet. The pulp is rich in proteins (up to 4%), but is low in carbohydrates. Avocado is also called as butter fruit owing to its very high (up to 30%) fat content. The avocado oil is similar to olive in composition and contains oleic acid, a mono-unsaturated fat that may help lower cholesterol. Avocados have the highest energy value (245 cal/100 g) of any fruit and has many benefits in combating malnutrition and obesity. It is a good source of potassium, a mineral that regulates blood pressure; has significant quantities of vitamin E, a high fiber content of 75% insoluble and 25% soluble fiber. The fruit is a powerhouse of heart-healthy fats and brain-boosting omega fatty acids. Fruits have the most protein concentration of any tropical fruit and contain all of the essential amino acids. It is estimated that between 500-1,000 metric tonnes of avocados are currently produced for the domestic market. Fruits have the most protein concentration of any tropical fruit, and contain all of the essential amino acids. It is estimated that between 500-100 metric tonnes of avocado are currently produced annually for the domestic market.

Climate and soil

Avocado is a sub-tropical to tropical tree, and can be grown successfully from the tropics to the subtropics at latitude of 35°. All 3 horticultural races 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. Depending on the race and varieties, avocados can thrive and perform well in climatic conditions ranging from true tropical to warmer parts of the temperate zone. In tropical and near-tropical areas, only the 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 to 1,600 m. Both the Mexican and Gautemalan races are grown successfully in Sikkim. In avocado-growing areas of Sikkim, temperatures range from 12° to 30°C with an average annual rainfall of 2,000 mm. The Mexican race is cultivated on mid-altitude hills.

It cannot tolerate the hot dry winds and frosts of northern India. Climatically, it is grown in tropical or semi-tropical areas experiencing some rainfall in summer, and in humid, subtropical summer rainfall areas. Most cultivars are sensitive to water deficits, and to excess soil water caused by poor drainage. The trees are very susceptible to root rot caused by *Phytophthora cinnamomi* in areas with poor soils or high water-tables. Avocados can be grown on wide range of soils, but they are extremely sensitive to poor drainage and cannot withstand water-logging. They are intolerant to saline conditions. Optimum range of pH is from 5 to 7.

Varieties

There are over 1,000 varieties of cultivated avocados documented. The genus *Persea* has three major species,

P. americana, *P. guatemalensis* and *P. drymifolia* which correspond to the horticultural races such as West Indian, Guatmalan and mexican. Their important characters are given here.

Guatemalan race: This race is native to the highlands of Central America. Fruits are fairly large, weighing up to 600 g and borne on long stalks. The fruits ripen in 9 to 12 months after flowering. Their pericarp is thick and brittle and often warty. Its seeds, held tightly in the hollow of the fruit, are small. The oil content ranges between 8 and 15%.

Mexican race: It is most cold hardy of the avocado races; also more resistant to heat and low humidity. Least tolerant to soil salinity. It is characterized by small fruits weighing 250 g ripening in 5 to 8 months after flowering. Fruits have thin smooth pericarp with a large-seed fitting loosely in the central cavity. Its oil content is up to 30%, the highest of all the three races

West Indian race: This group with medium-size fruit; is native to the low lands of Central India and milky to watery pulp in flavour; and lower oil content than the other two races. It is least hardy of the three races to cold and to low humidity, but most tolerant to soil salinity, as either rootstock or top. At the point of fruit attachment, the pedicels have a unique nail head configuration. The fruit pericarp is smooth but leathery and glossy. The oil content of the fruit is low, ranging between 3 and 10%.

The features of some important varieties belonging to those 3 group are discussed here.

Cultivars belonging to A group

Hass: Originated as a seedling; it is a leading variety accounting for 80% of cultivated avocados in the world. Fruits are medium-size (150-250 g), oval-shape having small to medium seeds. Skin turns from green to purplish-black when ripe. The pulp has nutty rich flavuor with high oil content (19%). It has excellent shelf-life. This variety is more suitable for sub-tropical climate.

Lula: A popular hybrid variety originated in Florida. Bears individual pear-shape fruits weighing around 400 to 700 g and having a green, thick peel and well recognized for its flavour and high (15%) oil content. This is commercially grown in the tropical climate of Florida, USA. It is also commonly used as a rootstock for nursery production.

Pinkerton: A hybrid Guatemalan type having large pear shaped fruits with small seed. It has excellent peeling characteristics and green skin darken in colour as it ripens. The thick pulp has a smooth, creamy texture, good flavour and high oil content. It shows some cold tolerance and bears consistently heavy crops.

Pollock: This has large fruits that weigh up to 1 kg or more but the oil content is less, ranging between 3 and 5%. This is also commercially grown in Florida, USA.

Cultivars belonging to B group

Bacon: A green-skinned variety of good quality. Oval-shaped fruits are medium in size having medium to large seed. Yellow green pulp with light. When ripe, the skin remains green, but darkens slightly, and fruit yields to gentle pressure. It is cold-hardy down to –5°C.

Brogden: The variety was recognized for its cold-hardiness to –5°C and became commercially propagated as nursery-stock for home growing. It is noted for its dark purple skin at maturity.

Ettinger: Mature trees tolerate 4 hour at –6°C. The fruit has a smooth, thin, green skin that does not peel easily. The flesh is very pale green.

Fuerte: This is the most popular variety of avocado. It belongs to group B and is a hybrid of the Mexican and Guatemalan races grown in California. Fruits are pyriform, weighting between 225 and 450 g with 18 to 26% oil. It is fairly resistant to cold, better suited to sub-tropical than tropical climate and is grown successfully in the mid-altitude hills of Sikkim.

Monroe: It became a major commercial cultivar due to its cold hardiness and production qualities. The fruit is large, averaging over 800 g in weight, has an elliptical shape, and glossy green glossy skin. Hardy to -3°C.

Sharwil: A medium-size fruit with rough green skin, it closely resembles the Fuerte, but is slightly more oval in shape. The fruit has greenish-yellow flesh with a rich, nutty flavour and high oil content (20 to 24%) and a small seed. The skin is green when ripe. It is a regular and moderate bearer with excellent quality fruit, but is sensitive to frost. Disease and pest resistance are superior to Fuerte. It is commercially grown in Hawaii and Australia.

Zutano: It is a Mexican variety which is hardy to low temperature (–4°C). The large pear-shape fruit has a shiny thin yellow-green skin that peels moderately easily. The pulp is pale green with fibers and has a light flavour.

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 in India from Ceylon in 1941.

The following varieties were introduced at the Fruit Research Station, Kallar Tamil Nadu: Long, Round, Fuerte, Pollock, Peradeniya Purple Hybrid, Shambaganur and Trapp. Improved commercial varieties such as Hass, Furete, Gwen, Bacon, Zutano,

Reed, Queen, Pinkerton from University of Florida and Xanh, Tim, Ba Sep da San from Vietnam.

Propagation and rootstocks

Avocado is commonly propagated through seeds. The viability of seeds of avocado is quite short (2 to 3 weeks) but this can be improved by storing the seed in dry peat or sand at 5°C. Removal of seed coat before sowing hastens germination. The seeds taken from mature fruits are sown directly in the nursery or in polyethylene bags. When they attain 6-8 months of age, the seedlings 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. The best results in avocado clonal propagation have been achieved by double grafting, a technique that is expensive and time consuming. Cleft grafting in September and March was found most suitable for the vegetative propagation of avocado under humid tropical conditions of India. Other methods of vegetative propagation of avocado include layering, inarching and chip-budding. Rootstocks play significant role in avocado production. Mexican rootstocks are the most important. The most popular rootstock is 'Dusa', followed by 'Duke 7' and 'Bounty'. West Indian stocks are preferred in warmer regions or where salinity is a problem.

Cultivation

Planting: Avocado is planted at a distance of 6 to 12 m depending on the vigour and growth habit of the variety. Wider spacing is suggested for spreading type varieties, viz. Fuerte. In Sikkim, a planting distance of 10 m × 10 m on hills slopes (on half-moon terraces) is preferred and planting is done in June-July. Pits of 90 cm × 90 cm are dug during February-March, and filled with farmyard manure and top soil (1:1 ratio) before planting. In Coorg region of Karnataka, these are also planted primarily as a mixed crops in coffee-based cropping system.

Nutrition: Avocado needs heavy manuring, and application of nitrogen has been found most essential. In general, young avocado trees should receive N, P_2O_5 and K_2O in a proportion of 1:1:1 and older trees in the proportion of 2:1:2. At a pH of above 7, iron deficiency symptoms may appear which can be corrected by applying iron chelate @ 35 g/tree. Different micronutrients (Fe, Zn and B) reportedly have profound influence on tree growth, nutrient uptake and yield of avocado. In Sikkim, the soil is deficient in nitrogen, zinc and boron. Application of urea in two split doses, in March/April and September/October (just before and after the onset of the monsoon) is recommended. Foliar application of zinc sulphate (0.5%) may be undertaken in April-May, and other fertilizers applied in soil during March-April. Samples for leaf analysis should be collected in March-April and consist of terminal spring flush leaves (5-6 months of age) from non-fruiting and non-flushing shoots.

Irrigation: Avocado is shallow rooted and roots extend up to 1.5 m. The majority of feeder roots are found in the top 60 cm of soil and root extension can continue throughout the year. During flowering, the canopy surface area available for water loss is considerably increased. In Mediterranean climate, peak rates of water use (in summer) appear to be between 3 and 5 mm per day. For mature trees, the crop coefficient (K_c) is usually within the range 0.4–0.6. The best estimate of water productivity is between 1 and 2 kg fruit/m^3. Soil flooding and the resultant reduction in oxygen level can damage roots even in the absence of root rot. Avocado is particularly sensitive to salinity, notably that caused by chloride ions. Both drip and under-tree micro-sprinklers were successfully used to irrigate avocado trees. Mulching of young trees is a recommended water conservation measure and has other benefits. Sprinkler irrigation improves the fruit size and oil percentage besides advancing harvesting time. Irrigation at intervals of 3 to 4 weeks during the dry months is beneficial to avocado. To avoid moisture stress during winter, mulching with dry grass/ leaves is desirable. Flooding is undesirable as it promotes root rot incidence.

Aftercare: Avocado branches frequently need propping to avoid breaking with the weight of the developing fruit. Some growers find it profitable to interplant bananas until the avocado trees reach bearing age. Branches exposed to sun by defoliation are extraordinarily susceptible to sunburn. Such branches should always be white washed. Pruning is rarely practiced except with upright varieties such as Pollock. In spreading varieties like Fuerte, branches are thinned and shortened. Heavy pruning promotes excessive vegetative growth, consequently reducing the yield.

Harvesting and post-harvest management

Avocado plants raised from seeds start bearing in 5-6 years after planting. Mature fruits of purple varieties change their colour from purple to maroon, whereas fruits of green varieties become greenish-yellow. Fruit size is also considered as an index of maturity. Fruits are considered mature and ready for harvest only when the colour of seed coat within the fruit changes from yellowish white to dark brown. Avocados are mature before picking, but not ready to eat. They must be softened off the tree. The softening process takes from a few days to a week, depending upon the degree of maturity, storage temperature and variety. Mature fruits ripen 6-10 days after harvesting. Oil percentage

is another maturity criteria, which depends on the race of the variety. Fruits should be harvested along with 1.2 to 1.5 cm stalk. Avocados are easily bruised or scratched. Use of proper picking equipments such as ladders, poles, clippers etc., is recommended. The yield ranges from 100 to 500 fruits/tree depending on the variety and region of cultivation. In Sikkim, 300-400 fruits are harvested from 10-15 years old trees. Fruits of purple variety are harvested during July, and of green varieties in September-October. 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. In India, fruits of 250 to 300 g in size are preferred. Most popular varieties are Hass, Fuerte and Green. Hard, mature fruits are harvested and allowed to ripen during transport and distribution. Up to 14 days transport time is considered satisfactory, though unripe avocados can be stored up to four weeks between 5.5 and 8°C.

Handling and storage: The harvested fruits should be removed from the orchard as soon as possible. It is important to pack and dispatch the fruit to the market, or to place it in cold storage, on the day it is harvested. Fruit refrigerated below ordinary temperatures may not soften properly. After the fruit has softened, it can be held in the refrigerator for a few more days. Fruits can be kept for about a month in cold storage, the optimum temperature being 7°C for Fuerte, 4.5°C for Lula and 8°C for Booth. In general, 5.5 to 6.7°C is the temperature range for cold storage of avocado fruits. Fruits stored in an atmosphere of 2% O_2 and 10% CO_2 have two-fold storage life of comparable fruits stored under ambient conditions.

Grading and packing: Each fruit stem must be cut back with a knife to a length of 6 to 12 mm. At the same time, the fruit is graded for export according to appearance. The avocados are treated with a suitable post-harvest fungicide and after waxing, are packed with cellophane into a suitable box. To delay ripening, fruit must be at low temperature, if possible. The lower the temperature, the longer the fruit will take to ripen. However, storage temperatures that are too low will cause cold damage to fruit. A temperature of 5°C is generally considered good. Early maturing avocados may be kept at a slightly higher temperature while late season fruit may be kept at slightly lower temperature.

Ripening of avocados may be hastened by exposure to 10 ppm ethylene for 25 to 49 hr after harvest in ethylene chambers.

Dipping in latex delays decay in avocados stored at room temperature. Avocados ship well and are sent to foreign markets under refrigeration. The avocados are subject to chilling damage, which results in dark-brown or grey discolouration of the mesoearp in refrigerated storage and degree of susceptibility varies with the cultivar and stage of harvesting. Most commercial cultivars can be stored safely between 4.5 and 12.8°C for at least two weeks. The best ripening temperature after removal from storage is 15.5°C. Removal of ethylene from controlled atmospheric storage of 2% O_2 and 10% CO_2 prolongs the marketable life of avocados.

Controlled atmosphere plus refrigeration remains the most commonly used method of delaying ripening in transit avocados exported to other countries. The hot water treatment (HWT), done to improve quality of Hass avocado following disinfestations for fruit files, at 41°C for 25-30 min or 42°C for 25 min improves external and internal fruit quality of avocado and reduces fruit flies infestation.

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