CHARACTERIZATION OF AVOCADO
(*Persea americana* Mill.)

by
ANU ANN AUGUSTINE
(2017-12-003)

DEPARTMENT OF FRUIT SCIENCE
COLLEGE OF HORTICULTURE
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KERALA, INDIA

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THESIS

Submitted in partial fulfilment of the requirement for

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DEPARTMENT OF FRUIT SCIENCE
COLLEGE OF HORTICULTURE
KERALA AGRICULTURAL UNIVERSITY
VELLANIKKARA, THRISSUR- 680656
KERALA, INDIA

2020

DECLARATION

I, hereby declare that this thesis entitled **"Characterization of avocado (*Persea americana* Mill.)"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, associate ship, diploma, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

Certified that this thesis entitled **"Characterization of avocado (*Persea americana* Mill.)"** is a record of research work done independently by **Ms. Anu Ann Augustine (2017- 12-003)** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associate ship to her.

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We, the under signed members of advisory committee of **Ms. Anu Ann Augustine (2017-12-003),** a candidate for the degree of **Master of Science in Horticulture** with major in **Fruit Science**, agree that the thesis entitled **"Characterization of avocado (*Persea americana* Mill.)"** may be submitted by **Ms. Anu Ann Augustine (2017-12-003),** in partial fulfilment of the requirement for the degree.

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Dedicated to my teachers, family and Horticoz

Introduction

1. INTRODUCTION

Avocado (*Persea americana* Mill.) commonly known as butter fruit, is a subtropical fruit tree belonging to family Lauracaeae. It has its orgin in the tropical American regions and was unknown to the outside world until Spanish invasion. However after 1900s, avocado orchards became widely established and got distributed to different parts of the world (Popenoe, 1935).

Avocado also known as the fruit of the 20th century, is well known for its nutritional and therapeutic properties. It is one of the choicest salad fruit in the world owing to its high nutritional quality and buttery flavour. The pulp of avocado is a rich source of fat (up to 30%) and proteins (up to 4%) but low in carbohydrates. It has high energy value of 245 cal per 100g and also a reservoir of vitamins and minerals. Dietary studies shows that on an average half an avocado is a complex source of dietary fibre (4.6 g), total sugar (0.2 g), potassium (345 mg), sodium (5.5 mg), magnesium (19.5 mg), vitamin A (5.0 µg RAE), vitamin C (6.0 mg), vitamin E (1.3 mg), vitamin K1 (14 µg), folate (60 mg), vitamin B-6 (0.2 mg), niacin (1.3mg), pantothenic acid (1.0 mg), riboflavin (0.1mg), choline (10 mg), lutein/zeaxanthin (185 µg), cryptoxanthin (18.5 µg), phytosterols (57 mg), and high-monounsaturated fatty acids (6.7 g) which may support a wide range of potential health effects (USDA, 2011; ADA, 2009).

Avocado can be regarded as one of the potential future crop of Kerala and it can be considered as an ideal fruit for nutritional security. With increasing health consciousness and blend of international flavours in local cuisines, avocado is gaining importance day by day. It is also one of the ideal fruit for weight loss as it is a source of healthy fats of plant origin, making its demand even higher. Being very low in sugar content it can be used by diabetic patients too. Avocado fruits are much sought after in the world market and hence has high export potential.

Avocado oil which is extracted from the fruit pulp and not from the seeds is high in quality considered next to olive oil and is used as both cooking and salad oil and also in the manufacture of skin care products.

Avocado is known to exhibit a unique flowering behavior known as protogynous diurnally synchronous dichogamy. Based on this, there are two flowering types, referred to as A and B types. Type A varieties open as female in the morning of the first day and closes in late morning or early afternoon of the same day. The second day the flower will open as male in the afternoon. Type B varieties open as female on the afternoon of the first day, close in late afternoon and re-open as male during the following morning.

The world avocado production was 5.61 million tonnes in 2016 which was boosted to 5.92 million tonnes in 2017. As per FAOSTAT data, Mexico is the leading producer of avocado in the world with a production of 2.01 million tonnes accounting for 34 per cent of the total production, followed by Dominican Republic and Peru. In India, avocado is cultivated in very few pockets of states Karnataka, Kerala, Tamil Nadu and Sikkim and was introduced from Sri Lanka (Ghosh, 2000).

Being a region of humid tropics, Kerala is ideal for the cultivation of avocado. Avocado have found a place in many homestead gardens across Kerala especially in the high ranges of Idukki and Wayanad where it is now being grown on a commercial scale by many farmers. In the recent years, Wayanad has emerged as a niche market for avocado and its cultivation has gained importance in this region on a commercial scale. However, still there are no varieties identified or local selections of avocado suited to the agro-climatic regions of Kerala.

The present study is a pioneer work taken up in KAU on avocado to study in detail the different characteristics of avocado accessions prevailing in the high ranges of Kerala and thereby providing a platform for carrying out further investigations for popularizing the cultivation of avocado throughout the state.

The objective of the study was to study the morphology, flowering pattern and fruit set in avocado (*Persea americana* Mill.) grown in high ranges of Kerala.

Review of Literature

2. REVIEW OF LITERATURE

2.1 Orgin and Distribution

Avocado, (*Persea americana* Mill.), belongs to family Lauraceae consisting of 50 genera and 3000 species (Rohwer, 1993). Avocado is regarded as a crop of the new world and is cultivated widely in Mexico, South America, Australia and South Africa, from where it was distributed to various parts of the world including India (Morton, 1987 and Knight, 2002). They are believed to be originated along the Eastern and Central Mexican highlands extending from Guatemala to Central America (Storey *et al.*, 1986; Bergh, 1992). The present name has been a modification of Spanish name, aguacate or ahuacate. There are atleast eight botanical varieties or subspecies of *P.americana*, out of which three are referred to as horticultural races: West Indian (*Persea americana var. americana),* Mexican (*P. americana var. drymifolia)* and Guatemalan (*P. americana var. guatemalensis)* (Scora *et al.*, 2002).

2.2 Variability Studies

Mhameed *et al.* (1997) studied the genetic relationships within the avocado cultivars and other Persea genus by analyzing 24 *Persea americana* cultivars using minisatellite DNA markers and observed high degree of variation among the avocado cultivars and Persea species.

The different avocado varieties maintained at Venezuelan orchards were classified based on the oil content and parameters *viz.* moisture, oil content of pulp, weight (whole fruit, pulp, peel), shape, length and width of fruit, peel roughness, peel colour and ease of peeling (Gómez-López, 1998; Gómez-López, 2000; Gómez-López, 2002).

RAPD analysis was used to evaluate the genetic diversity in 42 accessions maintained at Chiayi Agricultural Experimental Station (Chiayi, Taiwan) and results revealed that an average of five scorable bands per primer were obtained by polymerase chain reaction amplification of the detected 107 polymorphic bands octamer primers (Chang *et al*., 2003).

Taah *et al.* (2003) attempted to characterize the avocado germplasms existing in Ghana using molecular approaches of AFLP techniques inorder to understand the variability present within the germplasm in terms of fruit shape, size, flesh quality and peel characteristics.

An experiment was conducted by Ramírez *et al.* (2005) to study the diversity prevailing in avocado varieties cultivated in Cuba based on 22 morphological and agrological traits and DNA (microsatellite and AFLP) markers. It was observed that the phenotypic traits such as leaf dimension, length of peduncle, duration from flowering to fruit maturity and time of harvest could be used in addition to the classical fruit traits for race classification. Results also indicated that there is high correlation between phenotypic and DNA marker system data.

Nkansah *et al.* (2013) characterized the local and introduced germplasm collections in Ghana for morphological traits like tree shape and trunk surface, leaf colour, leaf shape and leaf margin, fruit shape, fruit clustering habit, fruit apex shape, ridges on fruit, pedicel position on fruit, gloss of skin, fruit weight and number of fruits. As a result, 46 independent accessions and 20 clusters constituting a total of 66 groups were identified proving the existence of wide genetic variability in the avocado germplasm.

A morpho-anatomic leaf analysis performed on selected 76 accessions at Venezuela resulted in the identification of new morphoanatomical characters and

discriminating attributes among cultivars especially the Mexican type and also observed that the Guatemalan and West Indian cultivars had a close relationship (Pereira *et al.*, 2017).

Abraham *et al.* (2018) studied the morphological characteristics of avocado in Ashanti and Central regions of Ghana and results showed that though wide variability existed in morphology, the characters were similar to those of West-Indian accessions.

2.3 Tree characteristics

Avocado is an evergreen tree with tree height up to 9 m or sometimes 18 m and trunk diameter ranging from 30 – 60 cm. However, to facilitate easy orchard management and harvesting operations, it is desirable to maintain trees at relatively lower heights as 8 m (Gaillard and Godefroy, 1995).

Based on a study on morphological characters of avocado in eight districts of Ghana, Abraham *et al.* (2018) reported that tree height ranged from 5 to 16m and tree canopy spread ranged in between 6 and 12m in 92 per cent trees with mean trunk circumference was 113.4 cm and branching pattern predominantly irregular (54.72 %) followed by ascendant (28.30 %) and then verticillate, axial and horizontal in equal proportions (5.66 %).

Shoot growth in avocado follows a monopodial pattern and within the same year, several cycles or flushes of shoot growth occurs. Axillary branches follows proleptic or sylleptic pattern and is not cultivar dependent. (Thorp and Sedgley, 1993; Thorp *et al*., 1994). Gregoriou and Kumar (1982) identified five distinct type of shoot based on its location, growth pattern and average length. Long shoots had an average length of 50 – 80 cm, intermediate shoots of length 23 to 34 cm and short shoots with length less than 20 cm.

Leaves are arranged alternately, dark green in colour and leaf blade shape was lanceolate, broadly elliptic, oval, sub-obovate or obovate. Leaf blade is glossy on adaxial surface and whitish on abaxial side with six to nine pairs of secondary veins diverging at 40^0 -60^0. Leaf apices are acute to acuminate and bases obtuse to rounded (Morton, 1987; Lavah and Lavi, 2002; Whiley *et al.*, 2002; Scora *et al.*, 2002).

Nkansah *et al.* (2013) observed wide variability in leaf shape, colour, leaf margins and leaf base shape. Among 124 accessions studied, five leaf shape was observed out of which, 82 % had roundish, 28 % had lanceolate and 5 % accessions with obovate, 8% with oval and 82 % with oblong-lanceolate leaves. Leaf colour was green (48 %), dark green (48 %) and light green (10 %). Two leaf margins were either entire (53 %) or undulate (47 %) and leaf base shape was observed to be either acute (72%) or obtuse (28%) in the accessions.

According to Abraham *et al.* (2018), leaves were oblong- lanceolate (35.85 %), oval (32.08 %), rounded (11.32 %), narrowly obovate (9.43 %), lanceolate (5.66 %), ovate (3.77 %) and obovate (1.89 %) in shape and leaf apex was predominantly acute (49.10 %) in shape.

2.4 Inflorescence and flowering behaviour

According to Schroeder (1944), the flowering shoots of avocado are of two types, determinate and indeterminate types. Indeterminate type is the most predominantly found type in which floral lateral branches ended in a vegetative bud at the tip of shoot axis and the fruits spotted inside the peripheral foliage of tree. In case of determinate type, the shoot tip ended as a flower having no leafy bud at the tip of panicle.

Inflorescence of avocado is a compound panicle. The flower is a perfect flower with pale greenish-yellow sepals and petals each three in number, 5 mm long and arranged alternately. One staminode and one stamen is aligned along with each petal. Each sepal has two stamen aligned with it. A pair of nectaries is present at the base of the interior stamen. Thus, a total of nine stamens with four pollen sacs each are present within a flower (Schroeder, 1944; Bergh, 1976). The number of pollen grains varied from 500 to 700 depending upon the cultivar and environmental condition (Schroeder, 1955). The pistil located at the centre, consists of a slender style and small stigmatic surface. The stigma and style are asymmetrical and has a distinct groove extending upto 3.5 mm length of style (Sedgley and Buttrose, 1978).

Though the flowers of avocado bears both male and female functional parts, they exhibit a unique mechanism for alteration of sex with time thus facilitating outcrossing. Nirody (1922) first observed the dichogamous behaviour of flowers wherein they first have a female phase when the stigma is receptive and then followed by a male phase where stigma becomes unreceptive and the anthers begin to dehisce and expose pollen. Each flower in the inflorescence open twice; first as functional female (stage I) and next time as functional male (stage II). In stage I, the mature stigma is receptive but the pollen sacs remain closed whereas in stage II, pollen is shred following anther dehiscence but upper part of the style remains shrivelled and brown. The two openings take place in morning or afternoon hours, prolonging upto half a day and are separated by an overnight period. This mechanism is called as protogynous diurnally synchronous dichogamy (Stout, 1923; Bergh, 1974; Bergh 1975).

Stout (1923) classified avocado cultivars based on the flowering behaviour into two types; namely type A and type B. In type A, the cultivars first open in the morning hours as functional female, closes by midday and then reopens next day

as functional male in the afternoon (Stout, 1927; Galang and Morada, 1935; Traub *et al*., 1941; Davenport, 1986). In case of type B, the first opening as functional female takes place in the afternoon and second opening as functional male takes place in the morning hours of the following day (Stout, 1927; Galang and Morada, 1935; Traub *et al*., 1941; Davenport, 1986). Adequate proportion of both A and B cultivars with theirs blooms overlapping is necessary to obtain good fruit set (Samson,1980). However, there is no influence of different flowering pattern on flowering characters like number of panicles/shoot, length of panicles, number of flowers/panicle and fruiting characters like initial and final fruitset, fruit yield and fruit weight (Tripathi *et al.,* 2016).

Davenport (1982) gave an insight on the ten different stages in morphological development of avocado inflorescence. Temperature plays a key role in the development of panicle but the duration and rate of development varies with cultivar.

All flowers of avocado in a tree opens in unison when the inflorescence becomes mature (Davenport, 1986). Flowering continues for several weeks on a daily basis with the proximal flowers opening first and later the distal ones.

Based on the type of flowers, Ito and Fujiyama (1980) classified 47 Hawaiian avocado cultivars into two groups and 17 cultivars belonged to class A and rest 30 belonged to class B. It was observed that in type A, pistillate flowers opened between 7:15 AM to 10:30 AM, closed between 11:30 AM to 3:00 PM and reopened as staminate the next day. In the case of cultivar Fuerte belonging to type B, pistillate flowers opened at 2:45 PM and next day remained as staminate flowers between 6:45 AM to 2:45 PM.

A study was conducted by Tripathi *et al.* (2016) in 35 accessions of avocado maintained at Chethali to investigate the flowering and fruiting

behaviour. Flowering shoots were observed to be predominantly determinate type and panicles developed on the terminal buds. The panicle length was maximum in PA-XVII-2 (16.10 cm) and minimum in PA-XII-1 (4.10 cm). Number of panicles per shoot varied from 2.6 (PA-I-4) to 13.8 (PA-VII-2) and number of flowers per shoot varied from 16.71 to 218.96. Duration of flowering was between 26 to 53 days and was noticed from third week of September to second week of November. Out of the 35 accessions, 19 accessions belonged to type A and 16 of them belonged to type B. Double opening was noticed in all accessions and flowers opened between 8.00 AM to 10.00 AM in morning hours or 2.00 PM to 5.00 PM during evening hours. The average initial fruit set was 3.62 % and average final fruit set was 0.32 %. There was incidence of up to 100 per cent fruit drop in selected panicles of 24 accessions.

2.5 Fruitset

In Southern Spain, the developmental phases in adult trees of *Persea americana* variety *Hass* grafted on Topa- Topa rootstocks were observed by Alcaraz *et al*. (2013) and they identified *s*even principal growth stages from vegetative bud development (stage 0) to fruit development till harvest maturity (stage 719). Vegetative flushing was noticed in spring and autumn season. Flowering occurred in March to April and fruits were ready for harvest within 31 to 37 weeks after flowering.

Fruit development in avocado follows single sigmoid curve (Valmayer, 1964; Robertson, 1971; Alcaraz *et al.*, 2013). The increasing trend in fruit dimensions with progressive developmental stages can be attributed to the cell division activity (Schroeder, 1958).

2.6 Fruit characteristics

The fruit is a one seeded berry which is oval, round or pyriform in shape and has a short neck. Pericarp consists of exocarp (skin), mesocarp (flesh) and a thin layer around seed coat,the endocarp (Cumming and Schroeder, 1942). Mesocarp (pulp) is the edible fruit portion and is primarily constituted by specialised parenchyma cells called idioblasts containing oil (Platt-Aloia and Thomson, 1981; Priego *et al*., 1996; Scora and Bergh, 1992).

The fruit size ranged between 50 g to 2 kg. Fruit length varied from 7.7 to 33 cm and maximum fruit size was 15 cm. The fruit skin colour was yellowish green, dark green or reddish purple to dark purple, whereas the flesh colour was pale to bright yellow. The fruit flavour was nut- like or buttery flavour (Whiley *et al.*, 2002).

A study on the low- oil content varieties of avocado was conducted by Gomez- Lopez (1998) and reported that fruit length varied from 4.13 cm to 10.52 cm, fruit width varied from 6.40 cm to 9.44 cm and fruit weight was minimum in Princesa (213.13g) and maximum in Booth 7 (501.64 g). In case of medium oil containing varieties, the variety Puebla was the smallest (7.90 x 4.62 cm) and the lightest (107 g) (Gomez- Lopez, 2000). Characterization of 13 high oil containing varieties revealed that the fruit weight ranged from 108.84 g in Duke to 463.00 g in Ortega. Fruit length ranged from 8.48 cm to 17.22 cm and fruit width ranged from 5.86 to 7.96 cm (Gomez- Lopez, 2002).

Abraham *et al.* (2018) observed wide variability in fruit skin characteristics *viz.* peel colour (red, green, purple, light green, dark green and yellow), peel (smooth, rough and intermediate), glossiness (strong, medium or weak). Pedicel position of fruits was either central (50.90 %) or asymmetrical (49.10%). Ideal peduncle length was between 2 to 6 cm and pedicel length 1.5 cm.

External characterisation of 12 varieties in Venezuela showed that fruit peel was either rough or smooth and the peel colour was either purple or green (Gomez- Lopez, 1998).

Pradeepkumar *et al*. (2001) evaluated the performance of four varieties namely Pollock, Round, Fuerte and Purple Hybrid in Wayanad and identified Fuerte giving the highest yield of 94.50 kg per tree.

2.6.1 Seed characters

Avocado seed is a rich source of crude protein (6.34 %), crude fibre (3.97%), carbohydrate (67.68 %) and energy (4.49 Kcal/100 g). Quantitative analysis proved that the seeds also contained high amount of minerals like calcium 12.30±0.08 mg; iron 0.307±0.13mg; magnesium 12±3.86 mg; phosphorus 46.00±1.72 mg; potassium 103.8±0.22 mg; sodium 0.302± 0.02 mg; and zinc 0.087±0.01 mg per 100g dry weight. Various anti nutritional components present included oxalate, phytate, saponins, tannins, flavonoids and cyanogenic glycoside at concentrations of 27.25±4.10, 5.44±0.03, 33.23±1.73, 56.11±0.21, 1.90 ± 0.08 and 24.01± 0.25 mg/100g dry weight, respectively making it potentially toxic (Nwaogu *et al*., 2008). Talabi *et al*. (2016) reported that the amount of anti-nutritional factors could be reduced significantly by boiling and soaking of avocado seeds.

Abraham *et al.* (2018) observed wide variability in seed morphological characters such as seed shape, length of seed, free space of seed cavity and attachment of seeds to cotyledons.

2.7 Maturity index and harvesting

In seedling plants, avocados comes to bearing in five to six years and in three to four years in grafted plants Avocados are climacteric fruits which when harvested immature do not ripen properly (Lee *et al.,* 1983; Lewis, 1978). Unless left behind for a very long time, the mature fruits do not begin to ripe on tree. Low ACC synthase (1-aminoacyclopropane 1-carboxylate synthase) activity and trace levels of ethylene and ACC in attached fruits inhibits on-tree ripening (Sitrit and Blumenfield, 1986). Removal of fruit from tree triggers the climacteric rise in respiration caused by ethylene production, thereby inducing ripening (Chen *et al.*, 1993; Rice *et al.,* 1993; Samson, 1980).

Studies by Hodkin (1939) and Stahl (1933) proved that there is no correlation between fat content and consumer perception of good quality. Two varieties of high demand in terms of palatability *viz.* Pollock and Trapp had low fat content whereas varieties Collinson and Linda with same esteem in terms of palatability had double the fat content.

Harding (1954) studied 200 different lots representing Florida avocados and concluded that the date of picking and minimum fruit weight could be fairly correlated with harvesting maturity. At 75 ^{O}F, post- harvest studies of lots were conducted and recorded physiological loss in weight as five percent and average total decay as one per cent. The rate of softening was observed to be quite uniform at this temperature and took average of 5 days to reach fully ripening.

The optimum time for harvest of Bacon, Fuerte and Zutano avocado cultivars grown in Turkey was found to be during last week of November to mid December so as to get fruits at optimum commercial maturity with sufficient storage time (Özdemir *et al.,* 2009). The peak ripening was occurred between 4 to

12 days in avocado fruits of Venezuealan orchards (Gómez-López, 1998, 2000 and 2002).

In India, the peak harvesting season of avocado is during July to October in Sikkim region, June to October in Coorg area and in July- August in Tamil Nadu with an average yield of 100 to 500 fruits per tree (Ghosh, 2000).

2.8 Quality Attributes

Total soluble solids of avocado cultivars grown under Adana conditions in Turkey were ranged from 6.0 to 8.1 ^{0}B (Kaplankıran and Tuzcu, 1994). Toplu *et al*. (1998) reported that the highest TSS content in cultivar Fuerte (7.36%) followed by Bacon (7.05%), Zutano (6.91%) and cultivar Hass (6.40%) grown under Iskenderun conditions. Hass avocados of American origin have a TSS of 5.1 ^{0}B and titrable acidity 0.04±0.01% (Arias *et al*., 2012). Özdemir (2009) determined the TSS content of Bacon, Fuerte and Zutano cultivars at harvest maturity time and observed that it ranged from 7.33 ^{0}B in Fuerte to 8.10 ^{0}B in Zutano. Vinha *et al*. (2013) determined Algarvian Hass avocados had TSS of 6.68 ^{0}B and titrable acidity of 1.07±0.02 %.

Takenaga *et al.* (2008) reported that the total lipid (TL) content of mesocarp was highest in cultivar Bacon (21.8 $\pm$ 0.62%) followed by cultivar Fuerte (18.7 $\pm$ 0.61%) and Hass cultivar (18.2 $\pm$ 0.53%). The neutral lipid (NL) fraction contributed to 95% of the TL content and triacylglycerol accounts for 90 % of NL. Monoenic acid accounted for 65 % of total fatty acid and oleic acid constituted for almost 50 % of the monounsaturated fatty acid.

The amount of total phenolic content is higher in the seed (88.2 GAE mgg^{-1}) compared to fruit pulp (1.3 GAE mgg^{-1}) in freeze dried fruit sample (Soong and Barlow, 2004). Flavanol monomers, proanthocyanidins, hydroxycinnamic

acids, and flavonol glycosides were found to be the four polyphenol classes present in the extracts obtained from two varieties Hass and Sheperd (Kosinska *et al.*, 2012). Githinji (2014) studied the total phenolic content in avocado seeds in eastern Kenya and observed that the total phenol content varied from 5.63 to 18 mg/g GAE.

Vinha *et al.* (2013) observed that highest concentration of Vitamin C (4.1±2.7 mg/100g) was found in pulp and that of Vitamin E (5.36±1.77 mg/100g) in skin. The seeds contained the maximum total phenolic content (704.0±130.0 mg/100g) and flavonoids (47.97±2.69 mg/100g).

Gamble *et al.* (2010) analyzed the influence of three avocado quality parameters *viz.*, ripeness, dry matter content and internal bruising on consumer preferences using a consumer panel of 107 members of age group 20 to 40 years. An increasing trend in consumer liking and purchase decision was observed with increase in dry matter content. Higher purchase willingness and consumer liking was for avocados softened to a firmness of 6.5N or less. Incidence of bruising and levels of bruising had more influence on purchase decision rather than the price.

2.9 Post-harvest studies

Eaks (1976) conducted a study in Fuerte and Hass cultivars to determine the ripening days of fruits when stored at different temperatures. Fruits at 20 °C ripened after 8.7 days. Those at 10 ^{o}C were fully ripe after three weeks of storage and fruits stored at 5° and 0° showed no sign of ripening.

The storage life of avocado is relatively very low. Lutz and Hardenburg (1968) suggested that best storage temperature of cold-tolerant cultivars is 4.4 °C (40 °F) while cold-intolerant cultivars can be stored best at 12.8°C (55 °F) and for Fuerte, suitable temperature is 7.2 °C (45 °F). Low temperature storage induces

chilling injury with mesocarp discolouration (Chaplin *et al.,* 1982; Zauberman *et al.,* 1985).

Use of ethylene inhibitor 1-Methylcyclopropene (1-MCP) at different concentrations of 300 nlL^{-1} and 900 nlL^{-1} delayed ripening and retained better peel colour allowing normal ripening of avocado (Hofman *et al*., 2001; Lemmer *et al*., 2003; Pesis *et al*., 2003; Hershkovitz *et al.,* 2005; Jeong *et al*., 2003; Woolf *et al.,* 2005)

Gelatin- starch coatings increased the shelf life of Hass avocado by delaying the respiratory climacteric upto three days and retaining fresh-like characteristics (Aguilar-Méndez *et al*., 2008).

2.10 Pests, diseases and physiological disorders

The most severe and destructive disease of avocado worldwide is Phytophthora root rot caused by *Phytophthora cinnamomi.* It destroys the finer feeder roots and can even kill large trees. At advance stages, it leads to severe leaf and fruit abscission leaving the bare framework of branches (Zentmyer, 1953).

Avocado scab characterized by corky raised oval spots that coalesces to form large rough patches on fruit. It is caused by *Sphaceloma perseae* fungus and these necrotic lesions paves way for secondary infection (Jenkins, 1925, 1934).

Anthracnose is the most serious post-harvest disease of avocado. In some cultivars, it also causes significant losses during pre-harvest period (Fitzell, 1987). *Colletotrichum gloeosporioides* is the causative agent and results in dark circular spots with salmon coloured spore masses (Simmonds, 1965; Hartill, 1991).

Botryosphaeria spp. and *Colletotrichum spp.* were identified as the major fungal pathogens causing stem end and fruit rot (Hatril, 1991; Hopkirk *et al.,* 1994).

An integrated management system based on periodic removal of dried dead twigs and branches within the canopy combined with application of copper based fungicidal sprays can decrease the incidence of post-harvest rots (Hopkirk *et al*., 1994).

Hofshi and Arpaia (2002) reported several abnormalities such as cukes or double fruit, ring neck, crick side double fruit, carapace spots caused by mechanical injury affecting the external appearance of avocado fruits.

Materials and Methods

3. MATERIALS AND METHODS

1. MATERIALS

The study 'Characterisation of avocado (*Persea americana* Mill)' was carried out at Wayanad district, Kerala during 2018-19 under Department of Fruit Science, College of Horticulture, Kerala Agricultural University, Vellanikkara. This serves as a preliminary study to identify promising types to promote large scale cultivation of this introduced crop presently gaining slow recognition in Kerala. The various materials used and methods adopted during the course of the study are detailed in this chapter.

2. LOCATION

The study was conducted in Wayanad district situated in the high ranges of Kerala. Wayanad region is located between 11^0 60' North lattitude and 76^0 08' East longitude at an altitude of 1000m above mean sea level and has a mild sub-tropical climate. The collections of avocado maintained at Regional Agricultural Research Station (RARS) Ambalavayal were made use of for the study.

3. OBSERVATIONS

Each observation was recorded from individual tree. The observations on tree characters, inflorescence characters, fruit characters, seed characters and quality attributes were recorded as per descriptors for avocado (*Persea* spp) (IPGRI, 1995).

3.1 Observations on tree characters

The following tree characters were observed and recorded.

3.1.1 Age of the tree (years)

Age of the tree was recorded from the registers maintained at RARS Ambalavayal.

3.1.2 Tree height (m)

Height of the tree was measured from ground level to top using a graduated pole and expressed in metre (m).

3.1.3 Trunk girth (cm)

Girth of the tree was measured at 50 cm above the ground and expressed in centimetre (cm).

3.1.4 Crown shape

Crown shape of the tree was observed and recorded as columnar, pyramidal, obovate, rectangular, circular, semicircular, semielliptic, and irregular (IPGRI,1995).

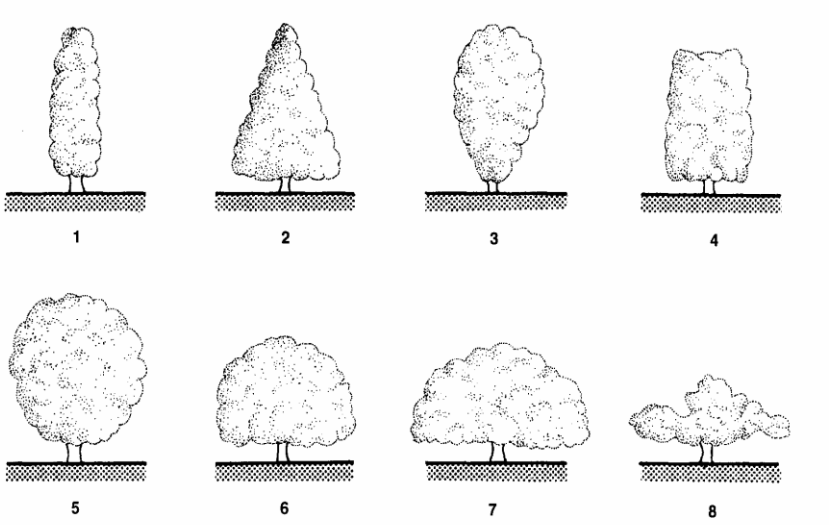


Fig. 1 Crown shape: (1)**Columnar, (2)Pyramidal, (3)Obovate, (4)Rectangular, (5)Circular, (6)Semicircular, (7) Semielliptic and (8)Irregular**

3.1.5 Branching pattern

Branching pattern of the tree was observed and recorded as ascendant, irregular, verticillate, axial and horizontal (IPGRI,1995).

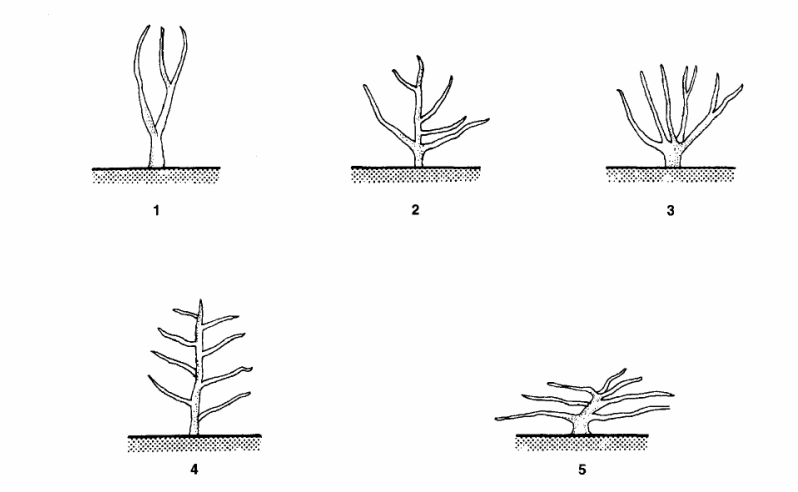


Fig. 2 Branching pattern: (1)Ascendant, (2)Irregular, (3)Verticillate, (4)Axial and (5)Horizontal

3.1.6 Leaf blade length (cm)

The length of fully expanded leaves was measured from base to tip of leaf blade at its centre. Average of ten representative leaves were taken and expressed in centimetre (cm).

3.1.7 Leaf width (cm)

The width of fully expanded leaves was measured at its broadest part. Average of ten representative leaves were taken and expressed in centimetre (cm).

3.1.8 Leaf blade shape

The shape of leaf blade was recorded as ovate, obovate, oval, roundish, cordiform, lanceolate, oblong, oblong-lanceolate as per the descriptor given by IPGRI (1995).

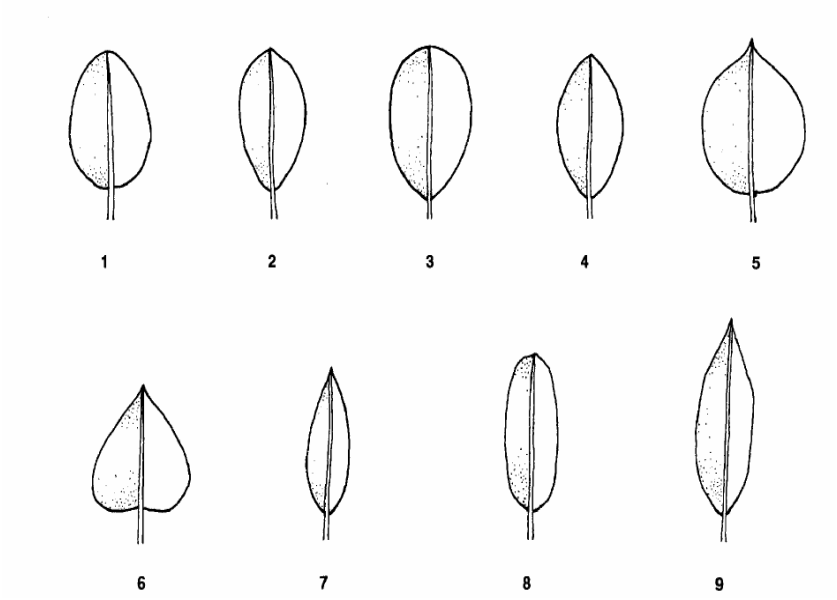


Fig. 3 Leaf blade shape: (1)Ovate, (2)Narrowly obovate, (3)Obovate, (4)Oval, (5)Roundish, (6)Cordiform, (7)Lanceolate, (8)Oblong, (9)Oblong-lanceolate

3.1.9 Leaf colour

The leaf colour of matured leaf was observed on the adaxial side and recorded as light green, green and dark green.

3.1.10 Shoot length (cm)

Shoot length was observed in randomly selected current season shoots in each tree and recorded from the base of primary leaf to collar region and the mean shoot length was expressed in centimetre (cm).

3.1.11 Internodal length (cm)

The internodal length between two successive nodes was measured and the mean internodal length was expressed in centimetre (cm).

3.2 Observations on inflorescence characters

3.2.1 Position of inflorescence

Position of inflorescence recorded as either terminal, subterminal or axillary.

3.2.2 Flowering type

Flowering type was recorded after five observations based on the flower opening order. Based on the observation, each tree was classified as A type or B type.

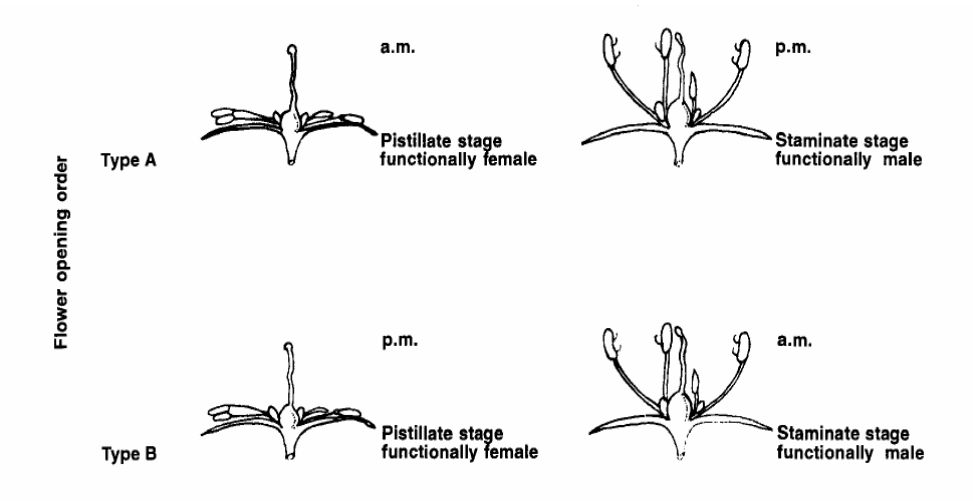


Fig. 4 Flowering type

3.2.3 Length of inflorescence (cm)

The average of five inflorescences length were measured from the base to tip of the inflorescence and expressed in centimetre (cm).

3.2.4 Width of inflorescence (cm)

The average of five inflorescences width were measured from the widest point of the same inflorescence and expressed in centimetre (cm).

3.2.5 Number of flowers per inflorescence

The number of flowers were counted in five inflorescences selected randomly on each tree and the average was calculated.

3.2.6 Flower colour

The colour of the flower petals were observed and recorded as cream, yellow or green.

3.3 Observations on phenological characters

3.3.1 Time of flushing (months)

The time of flushing recorded when the plant gave new extension growth and specified as months

3.3.2 Flowering season (months)

The time of flowering was noted, specifying the months**.**

3.3.3 Duration of flowering (days)

Total number of days from first flower opening to last flower opening in selected panicles were recorded and specified as days.

3.3.4 Number of days from flowering to fruit set (days)

Total number of days from flowering to fruit set was calculated.

3.3.5 Number of days from fruitset to harvest (days)

Total number of days from fruitset to harvest was calculated.

3.3.6 Season of fruiting (months)

The season of fruiting was noted from the first month of fruit development to harvest.

3.4 Observations on fruit characters

3.4.1 Number of fruits/tree

The total number of fruits harvested during each harvest was counted and total was number of fruits per tree for the season was calculated.

3.4.2 Yield (kg/tree)

The fruits harvested in each harvest were weighed using a weighing balance for each tree and total yield per tree per season were calculated.

3.4.3 Fruit weight (g)

Individual fruit weight was recorded in five random fully matured fruits collected from each tree using a weighing balance. The average was calculated and expressed in gram (g).

3.4.4 Fruit shape

The fruit shape was characterized as oblate, spheroid, high spheroid, ellipsoid, narrowly obovate, obovate, pyriform, clavate, rhomboidal and others (IPGRI, 1995).

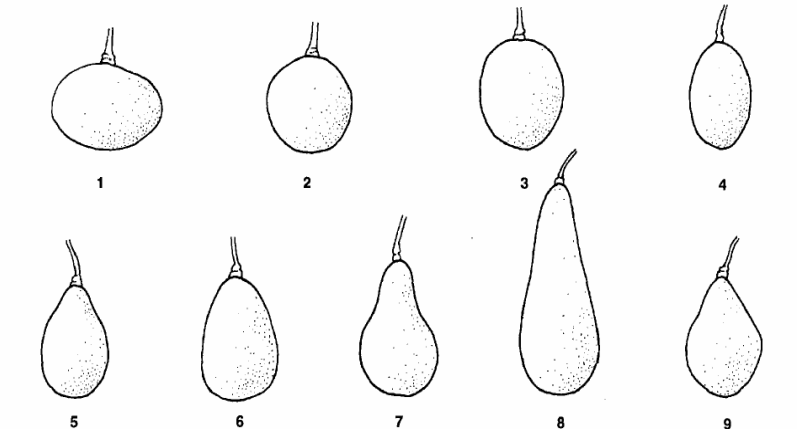


Fig. 5 Fruit shape: (1)**Oblate, (2)Spheroid, (3)High spheroid, (4)Ellipsoid, (5)Narrowly obovate, (6)Obovate, (7)Pyriform, (8)Clavate and (9)Rhomboidal**

3.4.5 Fruit length (cm)

Length of individual fruit was measured from base end to apex end using a scale and data was recorded in five random fully matured fruits collected from each tree. The average was calculated and expressed in centimetre (cm).

3.4.6 Fruit diameter (cm)

Diameter of individual fruit was measured at the broadest part using a scale and data was recorded in five random fully matured fruits collected from each tree. The average was calculated and expressed in centimetre (cm).

3.4.7 Fruit base shape

The fruit base shape was characterized as depressed, flattened, inflated and pointed (IPGRI 1995).

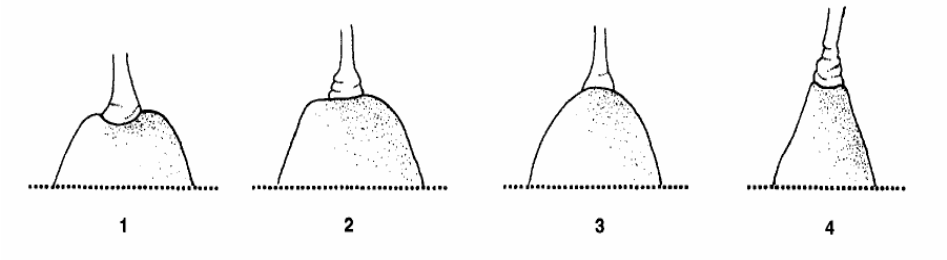


Fig. 6 Fruit base shape: (1)Depressed, (2)Flattened, (3)Inflated and (4)Pointed

3.4.8 Fruit apex shape

The fruit apex shape was characterized as deeply depressed, slightly depressed, flattened, rounded and pointed (IPGRI, 1995).

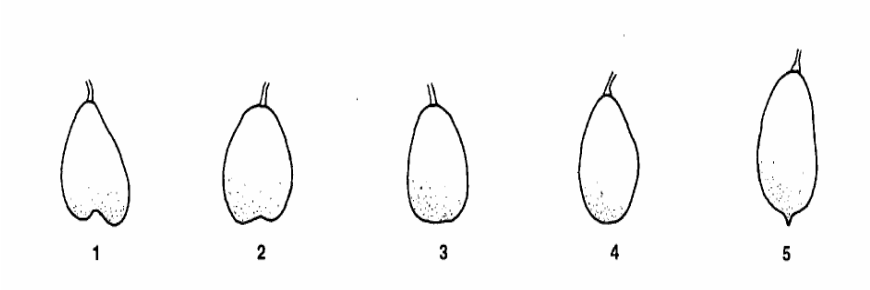


Fig. 7 Fruit apex shape: (1)**Deeply depressed, (2)Slightly depressed, (3)Flattened, (4)Rounded and (5)Pointed**

3.4.9 Fruit apex position

Fruit apex position was noted on individual fruits and recorded as central or asymmetric (IPGRI, 1995).

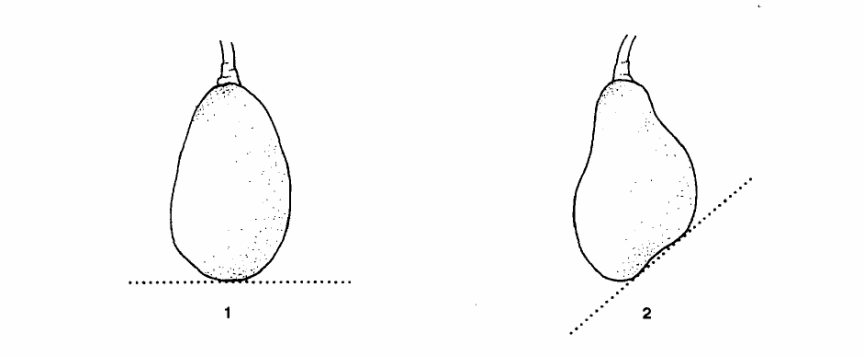


Fig. 8 Fruit apex position: (1)Central and (2)Asymmetric

3.4.10 Ridges on fruit

Presence or absence of ridges on fruit skin surface were observed and recorded as none, partial and entire (IPGRI,1995).

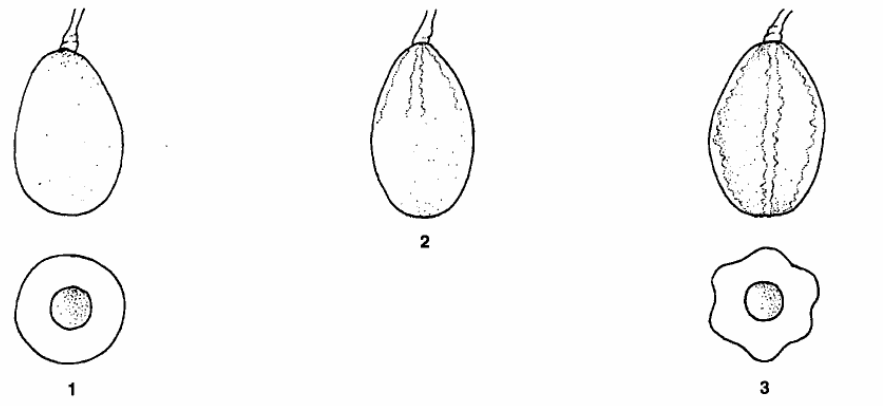


Fig. 9 Ridges on fruit: (1) None, (2)Partial and (3)Entire

3.4.11 Gloss on fruit skin

Glossiness on the fruit skin surface was observed and recorded as weak, intermediate and strong (IPGRI,1995).

3.4.12 Pedicel position on fruit

Pedicel position on fruit was noted and recorded as central, asymmetrical, very asymmetrical and extremely asymmetrical (IPGRI,1995).

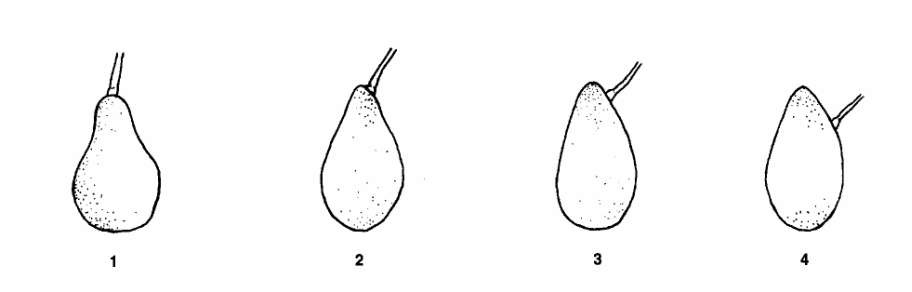


Fig. 10 Pedicel position on fruit: (1)Central, (2)Asymmetrical, (3)Very asymmetrical and (4)Extremely asymmetrical.

3.4.13 Fruit skin surface

Fruit skin surface was characterized as smooth, intermediate and rough (IPGRI, 1995).

3.4.14 Fruit skin colour

Fruit skin colour of ripe fruit was characterized as light green, green, dark green, yellow, red, purple, black, speckled and other (IPGRI, 1995).

3.4.15 Fruit skin thickness (mm)

The entire pulp was scooped out of the fruit and the thickness of the fruit skin was measured using a vernier calliper and accordingly classified into thin (1 mm) and thick (2 mm).

3.4.16 Colour of flesh next to skin

Colour of flesh next to fruit skin was characterized as ivory, light yellow, yellow, deep yellow, light green, green and other (IPGRI, 1995).

3.4.17 Colour of flesh next to seed

Colour of flesh next to seed was characterized as ivory, light yellow, yellow, deep yellow, light green, green and other (IPGRI, 1995).

3.4.18 Flesh texture

The flesh texture was characterized as watery, buttery, pastose, granular and other (IPGRI, 1995).

3.4.19 Degree of discolouration of open fruit after four hours

Fully ripe fruit was cut longitudinally into two halves and kept at room temperature. After four hours, the degree of discolouration was observed and recorded as low, intermediate and high.

3.4.20 Storage days of fruit (days)

Storage days refers to number of days taken from harvest to softening (ripening) of fruit at room temperature (20 ^{0}C) (IPGRI, 1995). Storage days was recorded for five fruits and mean was calculated.

3.4.21 Shelf life of fruit (days)

Number of days ripe fruit remain in good condition when stored under room temperature was recorded.

3.5 Observations on seed characters

3.5.1 Seed shape

Shape of the seed was characterized as oblate, spheroid, ellipsoid, ovate, broadly ovate, cordiform, base flattened and apex rounded, base flattened and apex conical (IPGRI, 1995)**.**

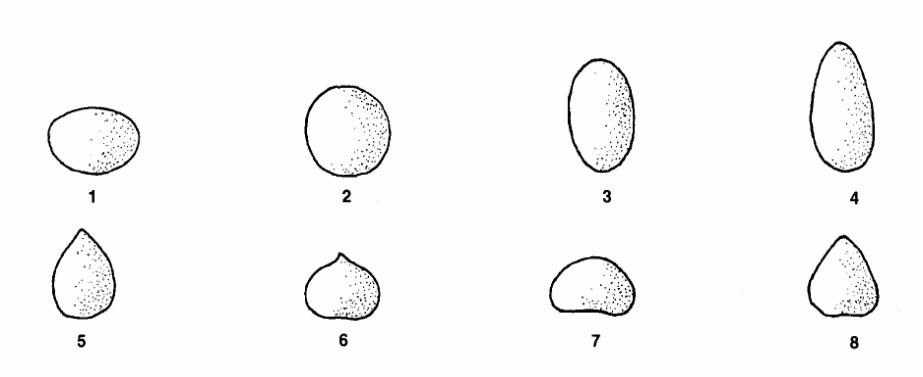


Fig. 11 Seed shape: (1)Oblate, (2)Spheroid, (3)Ellipsoid, (4)Ovate, (5)Broadly ovate, (6)Cordiform, (7)Base flattened and apex rounded and (8)Base flattened and apex conical

3.5.2 Seed weight (g)

Individual fresh seed obtained from five fully ripe fruits per tree were collected and weight was recorded using digital electronic balance. The average was calculated and expressed in gram (g).

3.5.3 Cotyledon surface

Seed cotyledon surface was observed after removal of seed coat and recorded as smooth, intermediate and rough (IPGRI,1995).

3.5.4 Attachment of cotyledons

The attachment of cotyledons are recorded as not attached or attached (IPGRI, 1995).

3.5.5 Cotyledon colour

Cotyledon colour was observed and noted as ivory, cream, yellow and pink (IPGRI, 1995).

3.5.6 Length of seed cavity (cm)

Fully ripe fruit was cut open into two halves longitudinally and seed was removed carefully from the seed cavity. Then the length at the centre place of seed cavity was measured using a scale and the data was recorded in five fruits for each accession studied. The average was calculated and expressed in centimetre (cm).

3.5.7 Diameter of seed cavity (cm)

Fully ripe fruit was cut open into two halves longitudinally and seed was removed carefully from the seed cavity. Then the width at the broadest part of seed cavity was measured using a scale and the data was recorded in five fruits for each accession studied. The average was calculated and expressed in centimetre (cm).

3.5.8 Length of seed (cm)

Length of five seeds from five randomly selected fruits was measured using vernier caliper. The average was computed and expressed in centimetre (cm).

3.5.9 Diameter of seed (cm)

Recorded on the same five seeds used for measuring seed length. Diameter was measured at the broadest point using vernier caliper. The average was computed and expressed in centimetre (cm).

3.5.10 Seed position in fruit

Position of seed within the fruit was observed for five fruits per accession and recorded as basal, central, to one side and apical (IPGRI, 1995).

3.5.11 Free space of the seed cavity

Fully ripe fruits were cut into two halves longitudinally and observed for the presence or absence of free space within the seed cavity. If free space present, it is recorded as space on seed apex, space on seed base, space on seed apex and base (IPGRI,1995).

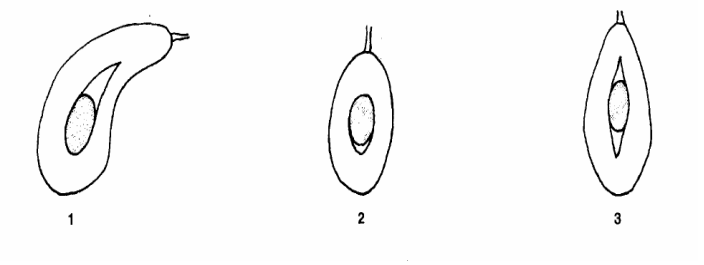


Fig. 12 Free space of the seed cavity: (1)Space on seed apex, (2)Space on seed base and (3)Space on seed apex and base

3.5.12 Total phenolic content (mg g^{-1})

The total phenolic content of avocado seed was estimated spectrophometrically by Folin-Ciocalteau method using Gallic acid standard

(Singleton *et al.*, 1999). Samples were prepared by extraction of 3g avocado seed powder with 100 ml of distilled water at 50^0C over stirring hot plate for one hour then cooled and filtrate was obtained. To 0.2 ml of extract/standard, 0.5 ml Folin-Ciocalteau reagent, 1.5 ml of 20% sodium carbonate and 7.8 ml of distilled water were added and the absorbace was read at 760 nm after two hours. The TPC of avocado seed extract were calculated and expressed as mg equivalents of Gallic acid equivalents (GAE)/g of dry weight of seed powder.

3.6 Quality attributes

3.6.1 Total soluble solids (^{0} Brix)

TSS of fruit pulp was recorded using 'ERMA' hand refractometer (range 0-32º brix) and expressed in degree brix (^{0} Brix).

3.6.2 Titrable acidity (%)

The titratable acidity was estimated by titrating a known weight/volume of the sample against 0.1N NaOH solution using phenolphthalein as an indicator. The acidity was calculated and expressed in percentage (AOAC, 1998).

3.6.3 TSS/acid ratio

TSS/acid ratio was computed by dividing obtained value of TSS by corresponding obtained value of titrable acidity.

3.6.4 Fats (%)

Fat content in avocado pulp was estimated using soxhlet extraction of a known quantity of pulp using petroleum ether (60-80^{0}C) for 6 hours without interruption by gentle heating. It is then distilled off completely, dried and the fat

is weighed and percenge of total crude fat is calculated and expressed in per cent (%) (Ranganna, 1997).

$$\text{Per cent total crude fat (\%)} = \frac{\text{Weight of fat (g)}}{\text{Weight of sample (g)}} \times 100$$

3.6.5 Total sugars, Reducing sugars (%), Non-reducing sugars (%)

Reducing sugars was determined using Lane and Eynon method (Ranganna, 1997). To 5 grams of fresh fruit pulp, 100 ml distilled water was added and then clarified with 2ml of neutral lead acetate solution. By adding potassium oxalate, excess lead acetate was removed and volume was made upto 250ml. The aliquot after filtration was titrated against mixture of Fehling solution A and B using methylene blue as indicator. To estimate total sugars, citric acid and water were added to 50 ml of the clarified solution and boiled and cooled. Then the volume was made upto 250 ml after neutralizing with NaOH and then titrated against mixture of Fehling solution A and B until the endpoint appears as red brick precipitate.

3.7 Organoleptic scoring of fruit

Fruit samples from different accessions were collected and randomly coded. Based on the nine point hedonic scale ranging from one to nine, a score chart was made wherein one denotes poor and nine stands for excellent qualities. The sensory evaluation for the coded samples was done by a panel of ten semi trained persons for various quality attributes like appearance, colour, flavour, taste,

after-taste, texture, odour and overall acceptability. The details of scorecard used for the sensory evaluation of fruits is given in Appendix I.

3.8 Statistical analysis

Principal Component Analysis and cluster analysis were done for variability assessment of quantitative characters of all the 25 accessions using the software MINITAB 17.1. Frequency distribution of qualitative characters were calculated. Data obtained by sensory evaluation was analyzed using a software called SPSS-K related.

3.9 Pest and disease incidence

Constant monitoring of experimental site was carried out to check the incidence of pests and diseases. If any occurrences were observed, they were recorded during the study period.

Results

4. RESULTS

This chapter comprises of results obtained from the study 'Characterisation of avocado (*Persea americana* Mill)' conducted at Wayanad during 2018-19. Characterisation was done for twenty five accessions of avocado and each character was recorded in accordance with the IPGRI (1995) crop descriptor. The results based on the observations for tree characters, inflorescence characters, phenological characters, fruit characters, seed characters and quality attributes are presented in this chapter.

4.1 Tree characters

Different tree characters observed for all the accessions include age of the tree, tree height, trunk girth, crown shape, branching pattern, leaf length, leaf width, leaf colour, shoot length and intermodal length. The data pertaining to the above observations are recorded in Table 1 and Table 2 represents the descriptive statistics of minimum, maximum, range, average, standard error of mean, standard deviation and coefficients of variation.

4.1.1 Age of the tree

Age of the tree ranged from 6 years to 51 years with a coefficient of variation of 55.99 per cent. Out of the 25 trees studied, the maximum age (51 years) were recorded in eight accessions *viz*. AV-2, AV-6, AV-8, AV-9, AV- 14, AV-19, AV-21 and AV-24 followed by 48 years in AV-3, 45 years in AV-11 and 42 years in AV-25. Six accessions *viz.*, AV-16, AV- 17, AV-18, AV-20, AV- 22, AV- 23 belonged to the age group of 28 years. There were three accessions in age group 11 to 20 years and five accessions were below ten years of age. One of the accessions (AV-1) was of only six years age.

4.1.2 Tree height (m)

Average tree height of the accessions was 9.01 m with a CV of 27.62 per cent. Maximum tree height of 14.50 m was observed in AV-11, whereas minimum tree height (5.87 cm) was observed in AV-6. The tree height of accessions AV-10, AV-25, AV- 7, AV-17, AV-12, AV-21, AV-23, AV-3 were in range of 10 to 14 m. Tree height of less than 10 m was recorded in sixteen accessions of which AV-13 had 9.94 m, followed by AV-1 and AV-20 in the range of 8 to 9 m. The accessions AV-19, AV-8, AV-5, AV-14, AV-16, AV-22 and AV-18 were in the range 7 to 8 m and accessions AV-2, AV-4, AV-15, AV-9 were in the range of 6 to 7 m.

4.1.2 Trunk girth (cm)

High variability in trunk girth was observed with coefficient of variation 55.58 per cent. Trunk girth ranged from 33.10 cm in AV-15 to 274 cm in AV- 21. Trunk girth of 215.60 cm was observed in AV-8 followed by AV-9 (207.00 cm). Accessions AV-2, AV-14, AV-21, AV- 19, AV- 6 and AV-11 had trunk girth in the range of 150 cm to 200 cm whereas trunk girth ranged from 100 cm to 150 cm in AV-11, AV-25, AV-3 and AV-16. There were 13 accessions with trunk girth below 100 cm.

4.1.4 Crown shape

Circular, columnar, obovate and irregular type of canopy were observed in the accessions studied. Circular type of canopy was observed in accessions AV-5, AV-10, AV-16, AV-18, AV-25 whereas columnar type of canopy was observed in AV-4, AV-6, AV-12, AV-17, AV-22 and AV- 23. Accesions AV- 15, AV-19 and AV-20 had obovate canopy. All the remaining accessions had irregular canopy.

4.1.5 Branching pattern

Branching pattern was observed to be axial in accessions AV-17 and AV-21, ascendant in AV-1, AV-4, AV-8, AV-10, AV-12, AV-15, AV-19 and AV-22. Accessions AV-7, AV-13, AV-23 had horizontal type of branching pattern whereas AV-14, AV-16, AV-18, AV-20, AV- 24 and AV-25.

4.1.6 Leaf blade length (cm)

Average leaf blade length was 19.49 cm with CV 27.78 per cent. Maximum leaf length was observed in AV-5 (23.47 cm) followed by AV-23 (23.46 cm) and AV-22 (23.20 cm). Accessions AV-2, AV-20, AV-12, AV-4, AV-1, AV-16 AV-17, AV-21, AV-25 and AV-11 had leaf blade length above the average value, whereas accessions AV-15, AV-14, AV-3, AV-9, AV-24, AV-7, AV-18, AV-8, AV-10, AV-19 and AV-13 had values below average leaf blade length. Minimum leaf blade length of 15.56 cm was recorded in AV-6.

4.1.7 Leaf width (cm)

Leaf width of the accessions varied from 5.54 cm to 13.15 cm with an average leaf width of 8.83 cm. Maximum leaf width (13.15 cm) was observed in AV- 5. Leaf width was above 10 cm in AV-23, AV-20, AV-22 and AV-11. Accessions AV-12, AV-17, AV-18, AV-4, AV-7, AV-2, AV-21, AV-13, AV-9, AV-1, AV-25 and AV-8 had leaf width in the range of 8 to 10 cm and AV-10, AV-19, AV-15, AV-24, AV-16, AV-3 and AV-14 had leaf width in the range of 6 to 8 cm. Minimum leaf width of 5.54 cm was recorded in AV-6 (Table 1).

Table 1: Tree characters of avocado

Accessions	Age of tree (years)	Tree height (m)	Trunk girth (cm)	Crown shape	Branching pattern	Leaf blade length (cm)	Leaf width (cm)	Leaf blade shape	Leaf colour	Shoot length (cm)	Internodal length (cm)
AV-1	6	8.87	39.00	Irregular	Ascendant	20.26	8.21	Lanceolate	Green	64.90	4.04
AV-2	51	6.87	180.00	Irregular	Verticillate	21.68	8.48	Lanceolate	Dark green	42.02	5.78
AV-3	48	10.27	122.00	Irregular	Verticillate	18.84	7.47	Lanceolate	Dark green	64.80	4.72
AV-4	7	6.81	35.50	Columnar	Ascendant	20.50	8.93	Lanceolate	Dark green	50.40	5.52
AV-5	9	7.34	50.00	Circular	Verticillate	23.47	13.15	Narrowly obovate	Green	76.60	4.20
AV-6	51	5.87	152.00	Columnar	Verticillate	15.56	5.54	Lanceolate	Dark green	58.80	1.82
AV-7	15	11.74	73.80	Irregular	Horizontal	18.51	8.69	Lanceolate	Dark green	65.50	4.78
AV-8	51	7.68	215.60	Irregular	Ascendant	17.77	8.00	Narrowly obovate	Dark green	58.90	4.20
AV-9	51	6.63	207.00	Irregular	Verticillate	18.74	8.38	Lanceolate	Green	76.96	3.74
AV-10	15	13.41	93.00	Circular	Ascendant	17.46	7.97	Lanceolate	Green	48.30	2.02
AV-11	45	14.50	136.00	Irregular	Verticillate	19.56	10.42	Narrowly obovate	Green	43.40	2.60
AV-12	12	11.17	72.00	Columnar	Ascendant	20.60	9.83	Narrowly obovate	Dark green	76.70	5.30
AV-13	8	9.94	41.00	Irregular	Horizontal	15.85	8.40	Lanceolate	Green	48.20	2.64
AV-14	51	7.34	168.00	Irregular	Verticillate	18.93	6.60	Narrowly obovate	Dark green	63.40	4.74
AV-15	7	6.67	33.10	Obovate	Ascendant	19.31	7.72	Lanceolate	Dark green	59.80	3.72
AV-16	28	7.34	120.00	Circular	Verticillate	19.96	7.70	Lanceolate	Green	64.30	3.66
AV-17	28	11.74	70.00	Columnar	Axial	19.77	9.54	Narrowly obovate	Dark green	76.40	3.14
AV-18	28	7.07	97.00	Circular	Verticillate	17.90	9.18	Narrowly obovate	Green	84.20	2.12
AV-19	51	7.80	156.80	Obovate	Ascendant	17.23	7.77	Narrowly obovate	Dark green	63.20	4.24
AV-20	28	8.46	70.00	Obovate	Verticillate	20.77	11.27	Narrowly obovate	Dark green	89.60	3.74
AV-21	51	11.17	165.00	Irregular	Axial	19.76	8.42	Lanceolate	Dark green	79.60	4.28
AV-22	28	7.12	80.70	Columnar	Ascendant	23.20	11.27	Narrowly obovate	Dark green	56.00	4.16
AV-23	28	10.74	75.00	Columnar	Horizontal	23.46	11.97	Narrowly obovate	Green	49.60	4.98
AV-24	51	6.56	274.00	Irregular	Verticillate	18.60	7.71	Lanceolate	Green	56.60	2.92
AV-25	42	12.17	134.00	Circular	Verticillate	19.66	8.16	Narrowly obovate	Green	74.20	4.24

Table 2. Descriptive statistics for quantitative traits of avocado tree characters

Descriptives	Age of tree (years)	Tree height (m)	Trunk girth (cm)	Leaf length (cm)	Leaf width (cm)	Shoot length (cm)	Internodal length (cm)
Range	45.00	8.63	240.90	7.91	7.61	47.58	3.96
Minimum	6.00	5.87	33.10	15.56	5.54	42.02	1.82
Maximum	51.00	14.50	274.00	23.47	13.15	89.60	5.78
Average	31.60	9.01	114.42	19.49	8.83	63.70	3.89
Standard error of mean	3.53	0.49	12.71	0.41	0.34	2.59	0.22
Standard deviation	17.69	2.46	63.59	2.05	1.71	12.97	1.08
Co-efficient of variation	55.99	27.26	55.58	10.55	19.35	20.37	27.78

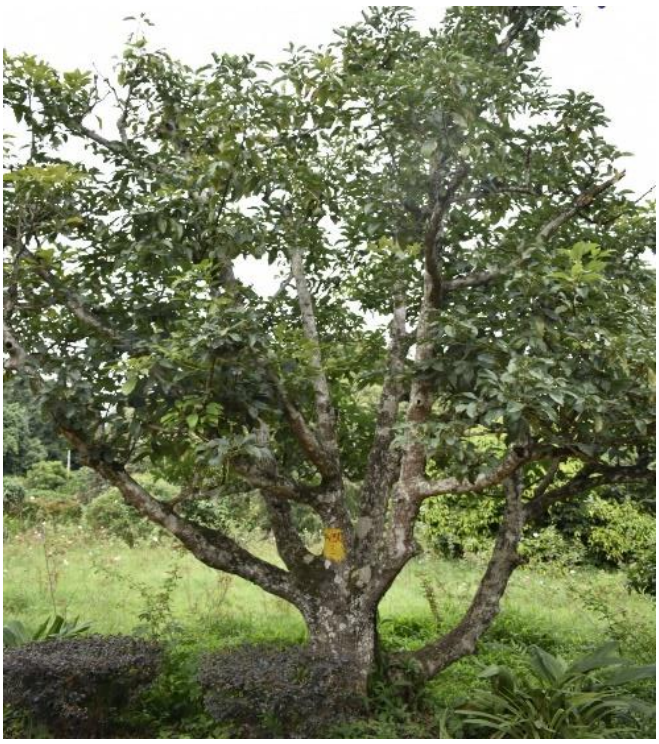
Columnar

Circular

Obovate

Irregular

Plate 1. Crown shape in avocado



Verticillate

Axial

Ascendant

Horizontal

Plate 2. Branching pattern of avocado tree

Lanceolate **Narrowly obovate**

Plate 3. Leaf shape

Green **Dark green**

Plate 4. Leaf colour of avocado

4.1.8 Leaf blade shape

Lanceolate and narrowly obovate type of leaf blade were observed in all the accessions. AV-1, AV-2, AV-3, AV-4, AV-6, AV-7, AV-9, AV-10, AV-13, AV-15, AV-16, AV-21 and AV-24 had lanceolate leaves whereas AV-5, AV-8, AV-11, AV-12, AV-14, AV-17, AV-18, AV-19, AV-20, AV-22, AV-23, AV-25 had narrowly obovate leaves.

4.1.9 Leaf colour

The leaf colour of matured leaf was observed to be either green as in accessions AV-1, AV-5, AV-9, AV-10, AV-11, AV-13, AV-16, AV-18, AV-23, AV-24 and AV-25 or dark green as in AV-2, AV-3, AV-4, AV-6, AV-7, AV-8, AV-12, AV-14, AV-15, AV-17, AV-19, AV-20, AV-21 and AV-22.

4.1.10 Shoot length (cm)

Shoot length recorded was maximum (89.60 cm) in AV-20 followed by AV-18 (84.20 cm), AV-21 (79.60 cm), AV-9 (76.96 cm), AV-12 (76.70 cm), AV-17 (76.40 cm) and AV-25 (74.20 cm). Out of the other accessions, 11 accessions had shoot length in the range of 55 to 65 cm and six accessions in the range 40 to 55 cm. Minimum shoot length (42.02 cm) was observed in AV-2. Average shoot length was 63.70 cm with CV 20.37 per cent.

4.1.11 Internodal length (cm)

Maximum internodal length was 5.78 cm in AV-2, followed by AV-4 (5.57 cm), AV-12 (5.30 cm), AV-23 (4.98 cm), AV-23 (4.78 cm), AV-7 (4.74 cm), AV-14 (4.74 cm) and in AV-3 (4.72 cm). Internodal length was in between 4 to 4.5 cm in AV-21, AV- 19, AV-25, AV-5, AV- 8, AV- 22 and AV-1 and in between 2 to 4 cm in AV-9, AV-20, AV-15, AV-16, AV-17, AV-24, AV-13, AV-11, AV-18 and AV-

10. Minimum internodal length was observed in AV-6 (1.82 cm). Average internodal length was 3.89 cm with CV 27.78 per cent.

4.2 Inflorescence characters

The inflorescence characters such as position of inflorescence, flowering type, length of inflorescence, width of inflorescence, number of flowers per inflorescence and flower colour were recorded and the results are presented in Table 3 and the descriptive statistics for quantitative characters is presented in Table 5.

4.2.1 Position of inflorescence

The inflorescence position was observed as terminal in all the accessions.

4.2.2 Flowering type

Out of the 25 accessions studied, flowering was observed in 23 accessions and both type A or type B flowering were observed. Flowering type A was noticed in accessions AV-3, AV-10, AV-11, AV-15, AV-17, AV-20, AV-24 and AV-25 whereas in accessions AV-1, AV-2, AV-4, AV-5, AV-6, AV-7, AV-8, AV-9, AV-12, AV-13, AV-14, AV-16, AV-18, AV-21 and AV-23 flowering type B was noticed.

4.2.3 Length of inflorescence (cm)

Average inflorescence length of 8.16 cm with coefficient of variation 22.69 per cent was observed. Length of inflorescence varied from 5.4 cm to 11.9 cm. Maximum inflorescence length was observed in AV-23 (11.9 cm), followed by 11.50 cm in AV-21. Inflorescence length ranged from 10 to 11 cm in AV-20, AV-11, AV-17; from 8 to 10 cm in AV-16, AV-18, AV-24 and AV-3. In accessions AV-12, AV-25, AV-2, AV-14, AV-10, AV-7, AV-9, AV-8, AV-5, AV-5, AV-1, AV-13, AV-

15 inflorescences were of length in the range of 6 to 8 cm and shortest inflorescences were found in AV-4 (5.4 cm).

4.2.4 Width of inflorescence (cm)

Average inflorescence width of 10.26 cm with coefficient of variation 28.94 per cent was observed. Width of inflorescence varied from 5.80 cm to 15.93 cm. Maximum inflorescence width was observed in AV- 23, followed by 14.73 cm in AV-3 and minimum inflorescence width was observed in AV-13 (5.80 cm). Inflorescence width was in the range of 5.50 to 10 cm and 10 to 12.50 cm in nine accessions each and above 12.50 cm in five accessions.

4.2.5 Number of flowers per inflorescence

Total number of flowers in each inflorescence varied from 65 as in AV-12 to 247.33 as in AV-6. On an average, 137.20 flowers were observed in a single inflorescence with CV value of 43.75 per cent. Among 23 accessions that borne inflorescences, 13 had flowers above the average number and other 10 accessions had below average number.

4.2.6 Flower colour

In all the accessions, the flowers were greenish yellow in colour.

4.3 Phenological characters

Observations on phenological parameters such as time of flushing, flowering season, duration of flowering, number of days from flowering to fruit set, number of days from fruit set to harvest and season of fruiting were recorded and presented in Table 4a, Table 4b and Table 5.

Table 3. Inflorescence characters in different avocado accessions

Accessions	Position of inflorescence	Length of inflorescence (cm)	Width of inflorescence (cm)	No. of flowers per inflorescence	Flowering type	Flower colour
AV-1	Terminal	6.53	12.67	90.67	Type B	Greenish yellow
AV-2	Terminal	7.43	7.83	178.33	Type B	Greenish yellow
AV-3	Terminal	8.53	14.73	150.33	Type A	Greenish yellow
AV-4	Terminal	5.40	9.33	76.33	Type B	Greenish yellow
AV-5	Terminal	6.60	8.80	116.00	Type B	Greenish yellow
AV-6	Terminal	5.93	11.50	247.33	Type B	Greenish yellow
AV-7	Terminal	7.30	11.77	166.33	Type B	Greenish yellow
AV-8	Terminal	7.03	10.93	84.67	Type B	Greenish yellow
AV-9	Terminal	7.30	13.07	150.67	Type B	Greenish yellow
AV-10	Terminal	7.	6.73	126.33	Type A	Greenish yellow
AV-11	Terminal	10.23	11.10	126.33	Type A	Greenish yellow
AV-12	Terminal	7.73	7.20	65.33	Type B	Greenish yellow
AV-13	Terminal	6.40	5.80	95.33	Type B	Greenish yellow
AV-14	Terminal	7.40	12.50	127.67	Type B	Greenish yellow
AV-15	Terminal	6.33	12.33	162.67	Type A	Greenish yellow
AV-16	Terminal	9.90	6.03	88.00	Type B	Greenish yellow
AV-17	Terminal	10.13	10.43	149.67	Type A	Greenish yellow
AV-18	Terminal	9.87	10.07	137.67	Type B	Greenish yellow
AV-19	-	-	-	-	-	-
AV-20	Terminal	10.77	13.10	148.33	Type A	Greenish yellow
AV-21	Terminal	11.50	6.27	133.67	Type B	Greenish yellow
AV-22	-	-	-	-	-	-
AV-23	Terminal	11.90	15.93	169.33	Type B	Greenish yellow
AV-24	Terminal	8.57	11.83	148.33	Type A	Greenish yellow
AV-25	Terminal	7.60	5.93	216.33	Type A	Greenish yellow

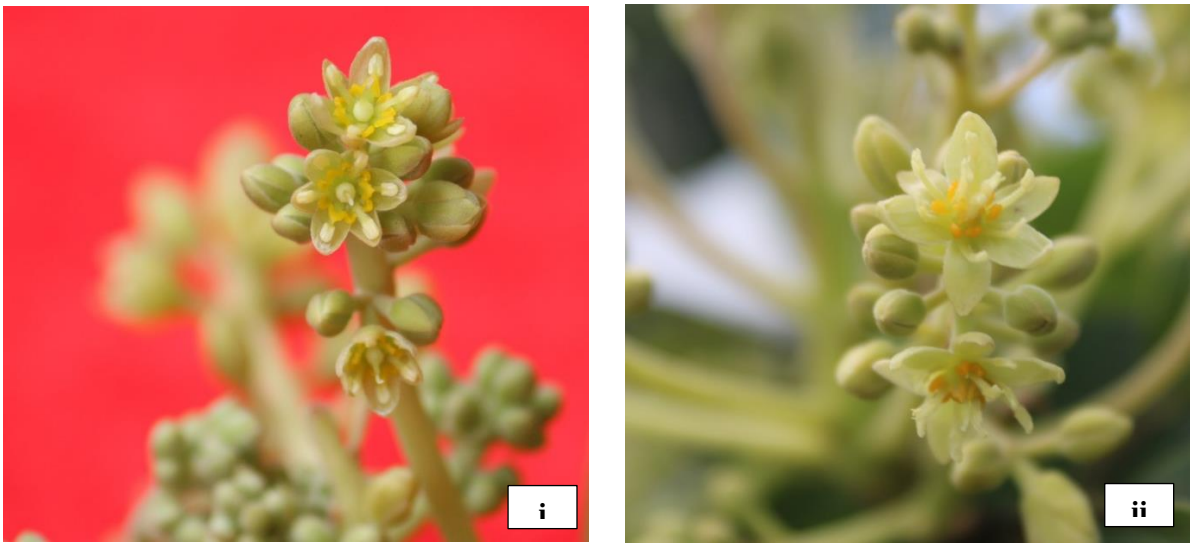


Plate 5a. Avocado flower (i) as functional female (ii) as functional male

Plate 5b. Avocado inflorescence

Plate 6: Terminal position of inflorescence

Plate 7. Flower colour of avocado - greenish yellow

4.3.1 Time of flushing

Two cycles of flushing was noticed in 18 accessions whereas only one cycle of flushing was recorded in 7 accessions (Table 4a). Season of flushing coincided with the months of August, September, February and March. In accessions AV-10, AV-4 and AV-14, flushing was observed in the month of February. Flushing coincided with month of March in two accessions *viz.,* AV-11, AV-15 and with September for accessions AV-13 and AV-22.

Two cycles of flushing in months of September and February was noticed in AV-2, AV-7, AV-8, AV-9, AV-21 and AV-24. Flushing was initiated in both September and March in accessions AV-5, AV-12, AV-16, AV-17, AV-18 and AV-23. Initiation of flowering for accessions AV-1, AV-3, AV-6, AV-19, AV-20 and AV-25 was in the months of August and February.

4.3.2 Flowering season (months)

Flowering was noticed in all accessions during September to October. However in majority of accessions, flowering was also observed during February to March as in accessions AV-1, AV-3, AV-6, AV-7, AV-8, AV-9, AV-10, AV-11, AV-12, AV-16, AV-17, AV-18, AV-21, AV-23, AV-24 and AV-25.

4.3.3 Duration of flowering (days)

Mean duration of flowering was recorded to be 32.17 days with a CV of 14.19 per cent. Duration of flowering was observed to be minimum (25.00 days) in AV-23 and maximum (45.00 days) in AV-6.

Table 4a. Time of flushing in avocado accessions

Accessions	Time of flushing
AV-1	August and February
AV-2	September and February
AV-3	August and February
AV-4	February
AV-5	September and March
AV-6	August and February
AV-7	September and February
AV-8	September and February
AV-9	September and February
AV-10	February
AV-11	March
AV-12	September and March
AV-13	September
AV-14	February
AV-15	March
AV-16	September and March
AV-17	September and March
AV-18	September and March
AV-19	August and February
AV-20	August and February
AV-21	September and February
AV-22	September
AV-23	September and March
AV-24	September and February
AV-25	August and February

Table 4b. Phenological characters in different avocado accessions

Accessions	Flowering season	Duration of flowering (days)		Number of days from flowering to fruit set (days)		Number of days from fruit set to harvest (days)		Season of fruiting
		Sept - Oct	Feb-Mar	Sept-Oct	Feb-Mar	Sept-Oct	Feb-Mar	
AV-1	September to October and February to March	25	32	No fruit set	18	-	120	March to September
AV-2	September to October	38	-	16	-	136	-	October to April
AV-3	September to October and February to March	42	37	18	17	125	134	October to April and March to September
AV-4	September to October	25	-	15	-	155	-	October to April
AV-5	September to October	29	-	15	-	162	-	October to April
AV-6	September to October and February to March	45	42	14	16	126		October to April and March to September
AV-7	September to October and February to March	36	33	25	No fruit set	155	-	October to April
AV-8	September to October and February to March	35	26	22	21	121	123	October to April and March to September
AV-9	September to October and February to March	35	33	17	18	143	152	October to April and March to September
AV-10	September to October and February to March	38	38	21	25	128	117	October to April and March to September
AV-11	September to October and February to March	31	31	14	15	135	132	October to April and March to September
AV-12	September to October and February to	35	29	12	16	146	147	October to April and

	March							March to September
AV-13	September to October	28	-	19	-	132	138	October to March
AV-14	September to October	27	-	15	-	158	-	October to April
AV-15	September to October	34	-	12	-	152	-	October to April
AV-16	September to October and February to March	29	31	No fruit set	25	-	144	March to September
AV-17	September to October and February to March	33	31	28	33	162	164	October to April and March to September
AV-18	September to October and February to March	29	28	No fruit set	17	-	147	March to September
AV-19	No flowering	-	-	-	-	-	-	No fruiting
AV-20	September to October	31	-	17	-	139	-	October to April
AV-21	September to October and February to March	37	33	20	23	143	137	October to April and March to September
AV-22	No flowering	-	-	-	-	-	-	No fruiting
AV-23	September to October and February to March	26	25	16	14	153	150	October to April and March to September
AV-24	September to October and February to March	37	28	29	27	127	126	October to April and March to September
AV-25	September to October and February to March	33	33	25	26	105	109	October to March and March to August

Table 5. Descriptive statistics of inflorescence and phenological traits of avocado

Descriptives	Length of inflorescence (cm)	Width of inflorescence (cm)	No. of flowers/ inflorescence	Duration of flowering (days)	Flowering to fruit set (days)	Fruit set to harvest (days)
Range	6.50	10.13	182.00	18.50	18.50	139.93
Minimum	5.40	5.80	65.33	25.00	12.00	105.00
Maximum	11.90	15.93	247.33	45.00	33.00	164.00
Average	8.16	10.25	137.20	32.17	26.35	139.93
Standard error of mean	0.38	0.61	9.12	0.95	1.05	3.12
Standard deviation	1.85	2.97	43.75	4.56	5.01	14.95
coefficient of variation	22.69	28.95	31.89	14.19	26.35	10.69

4.3.4 Number of days from flowering to fruit set (days)

It took an average of 19.02 days from flowering to reach fruit set. Maximum number of days from flowering to fruit set (5.01 days) was recorded in AV-17 and minimum (1.05 days) in AV-15 and coefficient of variation was 26.35 per cent.

4.3.5 Number of days from fruit set to harvest (days)

Fruits reached harvest maturity within a period of 139.93 days. Minimum days to harvesting was 105 days as in AV-25 and maximum days to harvesting was 164 days as in AV- 17.

4.3.6 Season of fruiting (months)

The time from fruit development to harvest was in October to March in AV-13. In accessions AV-2, AV-4, AV-5, AV-7, AV-14, AV-15 and AV-20 fruiting season was observed from months of October to April. The period from March to September marked the season of fruiting in AV-1, AV-16 and AV-18. Two fruiting seasons from October to April and March to September was recorded in AV-3, AV-6, AV-8, AV-9, AV-10, AV-11, AV-12, AV-17, AV-21, AV-23 and AV-24 whereas in accession AV-25, two fruiting seasons observed were from October to March and March to August.

4.4 Fruit characters

The observations on fruit characteristics were recorded and presented in Table 6, Table 7, Table 8a and Table 8b.

4.4.1 Number of fruits/tree

On an average, 291.60 fruits were obtained per tree. Highest number of fruits was recorded for AV- 3 (920 fruits per tree) followed by AV-25 (904 fruits per tree) and AV-11 (875 fruits per tree).

4.4.2 Yield (kg/tree)

On an average, the yield per tree recorded was 89.29 kg. Highest yield of 382.50 kg per tree was recorded in AV-6 and lowest yield of 6.27 kg per tree was recorded in AV-4.

4.4.3 Fruit weight (g)

Individual fruit weight was ranged from 152.40 g in AV-7 to 434.20 g in AV-17.The mean fruit weight was 282 g with a CV of 31.5 per cent.

4.4.4 Fruit shape

In accessions AV- 1, AV-3, AV-10, AV-11, AV-15, AV-16 and AV-25 fruits were narrowly obovate whereas in accessions AV-2, AV-6, AV-12 and AV-23 fruits were clavate. Accessions AV-8, AV-9 and AV-24 had obovate shaped fruits and AV-4, AV-5, AV-20 and AV- 21 had fruits with pyriform shape. Ellipsoid type of fruits were observed in AV-7 and spheroid fruits were observed in AV-13, AV-17, AV-18. In accession AV-14, both pyriform and narrowly obovate fruits were found.

Table 6. Quantitative fruit traits of avocado accessions

Accessions	Number of fruits	Yield (kg/tree)	Fruit weight (g)	Fruit Length (cm)	Fruit diameter (cm)	Fruit skin thickness (mm)	Storage days of fruit (days)	Shelf life of fruit (days)
AV-1	72	17.28	250.86	8.24	5.78	1	3.0	1.0
AV-2	168	67.20	407.18	14.66	7.46	1	3.5	2.0
AV-3	920	170.20	186.38	8.72	5.72	1	9.0	1.0
AV-4	23	6.27	188.99	7.84	8.14	1	4.0	1.0
AV-5	315	63.20	212.72	8.90	6.94	2	14.0	1.5
AV-6	450	382.50	191.80	9.70	5.50	1	6.0	1.5
AV-7	96	14.88	152.42	7.96	5.72	2	15.0	1.0
AV-8	85	31.87	387.82	10.98	7.90	1	6.0	1.0
AV-9	156	58.50	388.32	10.66	7.84	2	8.0	1.0
AV-10	127	34.92	270.05	9.20	6.52	2	7.0	2.0
AV-11	875	218.75	288.24	9.42	7.76	1	11.0	1.0
AV-12	235	52.87	239.62	12.50	6.02	1	8.0	1.0
AV-13	56	20.27	364.92	9.44	7.58	2	7.0	1.5
AV-14	183	50.32	281.06	9.96	6.64	1	9.0	1.5
AV-15	55	9.35	178.64	7.68	7.18	1	10.0	1.0
AV-16	150	47.25	315.07	10.38	5.98	1	7.0	2.0
AV-17	655	284.44	434.22	9.66	8.28	1	6.0	2.0
AV-18	276	106.26	391.76	9.70	8.42	1	7.0	1.0
AV-20	36	8.28	231.70	11.58	6.40	1	6.0	1.0
AV-21	678	115.26	170.96	9.50	5.30	1	6.0	1.5
AV-23	27	10.80	408.26	12.62	7.42	1	5.0	1.0
AV-24	155	42.62	276.94	9.74	6.60	2	8.0	1.5
AV-25	904	240.46	266.98	8.88	6.54	1	4.0	1.5

Table 7. Descriptive statistics of quantitative characters of avocado fruit

Descriptives	Number of fruits	Yield (kg/tree)	Fruit weight (g)	Fruit length (cm)	Fruit diameter (cm)	Storage days of fruit (days)	Shelf life of fruit (days)
Range	893.00	376.23	281.80	6.98	3.12	12.00	1.00
Minimum	27.00	6.27	152.40	7.68	5.30	3.00	1.00
Maximum	920.00	328.50	434.20	14.66	8.42	15.00	2.00
Average	291.60	89.29	282.00	9.91	6.85	7.37	1.32
Standard error of mean	62.47	21.21	18.50	0.35	0.20	0.63	0.08
Standard deviation	299.61	101.76	88.80	1.68	0.96	3.02	0.38
Coefficient of variation	102.44	113.80	31.50	16.94	14.02	41.03	29.23

Table 8a. Qualitative fruit characters of avocado

Accessions	Fruit shape	Fruit base shape	Fruit apex shape	Fruit apex position	Ridges on fruit	Gloss on skin	Pedicel position on fruit	Fruit skin surface
AV-1	Narrowly obovate	Depressed	Flattened	Asymmetric	None	Intermediate	Asymmetrical	Intermediate
AV-2	Clavate	Depressed	Rounded	Central	None	Intermediate	Central	Smooth
AV-3	Narrowly obovate	Depressed	Rounded	Central	None	Intermediate	Central	Intermediate
AV-4	Pyriform	Depressed	Rounded	Central	None	Weak	Asymmetrical	Intermediate
AV-5	Pyriform	Depressed	Rounded	Asymmetric	Entire	Intermediate	Asymmetrical	Rough
AV-6	Clavate	Depressed	Rounded	Central	None	Intermediate	Asymmetrical	Smooth
AV-7	Ellipsoid	Depressed	Rounded	Asymmetric	Entire	Weak	Central	Rough
AV-8	Obovate	Inflated	Flattened	Asymmetric	None	Weak	Asymmetrical	Smooth
AV-9	Obovate	Depressed	Flattened	Asymmetric	None	Weak	Central	Smooth
AV-10	Narrowly obovate	Inflated	Flattened	Central	None	Intermediate	Central	Smooth
AV-11	Narrowly obovate	Depressed	Flattened	Asymmetric	None	Intermediate	Asymmetrical	Smooth
AV-12	Clavate	Inflated	Rounded	Central	None	Weak	Asymmetrical	Smooth
AV-13	Spheroid	Depressed	Flattened	Asymmetric	None	Intermediate	Central	Smooth
AV-14	Pyriform and narrowly obovate	Depressed	Rounded	Central	None	Intermediate	Central	Smooth
AV-15	Narrowly obovate	Depressed	Flattened	Asymmetric	None	Weak	Asymmetrical	Smooth
AV-16	Narrowly obovate	Depressed	Rounded	Asymmetric	None	Intermediate	Asymmetrical	Smooth
AV-17	Spheroid	Inflated	Rounded	Central	None	Intermediate	Central	Intermediate
AV-18	Spheroid	Inflated	Rounded	Central	None	Intermediate	Central	Smooth
AV-20	Pyriform	Inflated	Rounded	Central	None	Weak	Central	Smooth
AV-21	Pyriform	Depressed	Rounded	Central	None	Intermediate	Asymmetrical	Smooth
AV-23	Clavate	Depressed	Rounded	Central	None	Weak	Asymmetrical	Smooth
AV-24	Obovate	Depressed	Rounded	Asymmetric	None	Intermediate	Asymmetrical	Smooth
AV-25	Narrowly obovate	Depressed	Rounded	Asymmetric	None	Intermediate	Asymmetrical	Smooth

Table 8b. Qualitative fruit characters of avocado

Accessions	Fruit skin colour	Colour of flesh next to seed	Colour of flesh next to skin	Flesh texture	Degree of discolouration of open fruit after 4 hours
AV-1	Purple	Light yellow	Light green	Buttery	Low
AV-2	Purple	Yellow	Light green	Buttery	Low
AV-3	Purple	Yellow	Light green	Buttery	Low
AV-4	Purple	Light yellow	Light green	Buttery	Low
AV-5	Purple	Yellow	Light green	Buttery	Low
AV-6	Light green	Light yellow	Light green	Buttery	Low
AV-7	Purple	Yellow	Light green	Buttery	Low
AV-8	Purple	Light yellow	Light green	Buttery	Low
AV-9	Purple	Light yellow	Light green	Buttery	Low
AV-10	Purple	Light yellow	Light green	Buttery	Low
AV-11	Purple	Yellow	Light green	Buttery	Low
AV-12	Purple	Light yellow	Light green	Buttery	Low
AV-13	Purple	Light yellow	Light green	Buttery	Low
AV-14	Purple	Light yellow	Light green	Buttery	Low
AV-15	Purple	Light yellow	Light green	Buttery	Low
AV-16	Purple	Light yellow	Light green	Buttery	Low
AV-17	Light green	Yellow	Light green	Buttery	Low
AV-18	Light green	Yellow	Light green	Buttery	Low
AV-20	Purple	Yellow	Light green	Buttery	Low
AV-21	Purple	Light yellow	Light green	Buttery	Low
AV-23	Purple	Light yellow	Light green	Buttery	Low
AV-24	Purple	Light yellow	Light green	Buttery	Low
AV-25	Purple	Light yellow	Light green	Buttery	Low

Spheroidal

Clavate

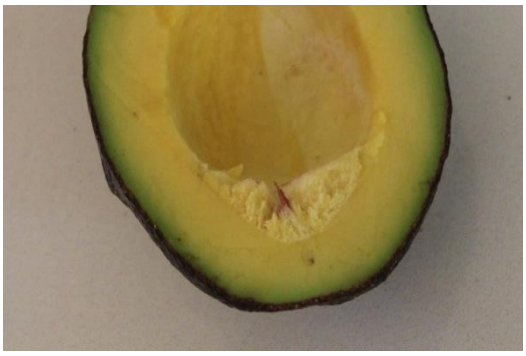
Narrowly obovate

Obovate

Pyriform

Ellipsoid

Plate 8. Fruit shape of avocado accessions

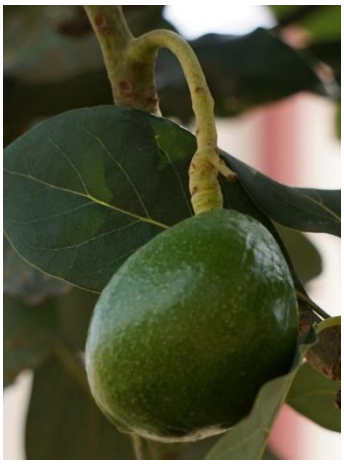


Rounded **Flattened**

Plate 9. Fruit apex shape

Inflated **Depressed**

Plate 10. Fruit base shape



Central **Asymmetrical**

Plate 11. Pedicel position on fruit

Rough **Intermediate** **Smooth**

Plate 12. Fruit skin surface

Entire **None**

Plate 13. Ridges on fruit

Light green

Plate 14. Colour of flesh next to skin

Yellow

Light yellow

Plate 15. Colour of flesh next to seed

1st day

2nd day

3rd day

Plate 16. Shelf life of fruits

Stem end rot

Anthracnose

Plate 17. Disorders in avocado during storage

Plate 18. Harvesting of avocado fruits

4.4.5 Fruit length (cm)

Length of the fruit varied from 7.68 cm as in AV-15 to 14.66 cm as in AV-2 with a CV of 16.94 per cent. Average fruit length was recorded as 9.91 cm.

4.4.6 Fruit diameter (cm)

Diameter of fruit ranged from 5.30 cm in AV-21 to 8.42 cm in AV-18. Average fruit diameter was recorded as 6.85 cm with a CV of 14.02 per cent.

4.4.7 Fruit base shape

Shape of fruit base in the accessions observed were found to be either depressed or inflated. Inflated fruit base was noticed in accessions AV-7, AV-10, AV-12, AV-17, AV-18 and AV- 20 and depressed fruit base was observed in AV-1, AV-2, AV-3, AV-4, AV-5, AV-6, AV-8, AV-9, AV-11, AV- 13, AV- 14, AV- 15, AV-16, AV- 21, AV- 23, AV- 24 and AV-25.

4.4.8 Fruit apex shape

Fruit apex was observed to be either flattened or rounded. In accessions AV-1, AV-8, AV-9, AV-10, AV-11, AV-13 and AV-15 fruit apex was rounded whereas fruit apex was flattened in accessions AV- 2, AV-3, AV-4, AV-5, AV- 6, AV-7, AV-12, AV-14, AV-16, AV-17, AV-18, AV- 20, AV-21, AV-23, AV-24 and AV-25.

4.4.9 Fruit apex position

Position of fruit apex was identified to be either asymmetric in accessions AV-1, AV-5, AV-7, AV-8, AV-9, AV-11, AV-13, AV-15, AV-16, AV-24, AV-25 or central in AV-2, AV-3, AV-4, AV-6, AV-10, AV-12, AV-14, AV-17, AV-18, AV-20, AV-21 and AV- 24.

4.4.10 Ridges on fruit

Generally ridges were not found on fruit skin except for accessions AV-5 and AV-7 in which it was recored as entire.

4.4.11 Gloss on fruit skin

Weak glossiness was observed on fruits obtained from accessions AV-4, AV-7, AV-8, AV-9, AV-12, AV- 15, AV-20 and AV- 23 whereas intermediate glossiness was noticed on fruits of accessions AV-1, AV-2, AV-3, AV-5, AV-6, AV-10, AV-11, AV-13, AV-14, AV-16, AV-17, AV-18, AV-21, AV-24 and AV-25.

4.4.12 Pedicel position on fruit

In accessions AV-1, AV-4, AV-5, AV-6, AV-8, AV- 11, AV-12, AV-15, AV-16, AV-21, AV-23, AV-24 and AV-25, the pedicel is located centrally whereas pedicel position was asymmetrical in accessions AV-2, AV-3, AV-7, AV-9, AV-10, AV-13, AV-14, AV-17, AV-18 and AV-20.

4.4.13 Fruit skin surface

Fruit skin surface was identified to be predominantly smooth in accessions AV-2, AV-6, AV- 8, AV-9, AV-10, AV-11, AV-12, AV-13, AV-14, AV-15, AV-16 AV-18, AV-20, AV-21, AV-23, AV-24 and AV-25. However in accessions AV-1, AV-3, AV-4 and AV-17, fruit skin surface was intermediate and in accessions AV-5 and AV-7 fruits were with rough skin.

4.4.14 Fruit skin colour

The fruit skin in ripe fruits were found to be either purple or light green. Accessions AV-1, AV-2, AV-3, AV-4, AV-5, AV-7, AV-8, AV-9, AV-10, AV-11,

AV-12, AV-13, AV-14, AV-15, AV-16, AV-20, AV-21, AV-23, AV-24 and AV-25 had purple skinned fruits, whereas accessions AV- 6, AV-17, AV-18 had light green skinned fruits.

4.4.15 Fruit skin thickness (mm)

Thickness of fruit skin was recorded as 1 mm (thin) in accessions AV-1, AV-2, AV-3, AV-4, AV-6, AV-8, AV-11, AV-12, AV-14, AV-15, AV-16, AV-17, AV-18, 20, AV-21, AV-23 and AV-25 and 2 mm (thick) in accessions AV-5, AV-7, AV-9, AV-13 and AV-24.

4.4.16 Colour of flesh next to skin

Colour of flesh next to skin was identified to be light green in all accessions.

4.4.17 Colour of flesh next to seed

The flesh colour of pulp next to seed was either yellow as in accessions AV-2, AV-3, AV-5, AV-7, AV-11, AV-17, AV-18 and AV-20 or light yellow as in accessions AV-1, AV-4, AV-6, AV-8, AV-9, AV-10, AV-12, AV-13, AV-14, AV-15, AV-16, AV-21, AV-23, AV-24 and AV-25.

4.4.18 Flesh texture

Texture of avocado flesh was buttery in all accessions.

4.4.19 Degree of discolouration of open fruit after four hours

Low degree of discolouration was observed in fruits of all accessions when cut and kept open at room temperature for four hours.

4.4.20 Storage days of fruit (days)

Storage days of fruit varied from 3 to 15 days. Average storage days was recorded as 7.37 days with a CV of 41.03 per cent. Least storage days were required for ripening was observed in accession AV-1 (3 days) followed by AV-2 (3.5 days) and AV-25 (4 days). Maximum storage days of fruit was recorded for AV-8 (15 days).

4.4.21 Shelf life of fruit (days)

Mean shelf life of ripe fruits was recorded to be 1.3 days. Fruits obtained from accessions AV-1, AV-3, AV-4, AV-7, AV-8, AV-9, AV-11, AV-12, AV-15, AV-18, AV-20 and AV-23 had shelf life of one day. Shelf life was recorded to be 1.5 days for 7 accessions *viz.,* AV-5, AV-6, AV-13, AV-14, AV-21, AV-24 and AV-25 whereas for accessions AV-2, AV-10, AV-16 and AV-17, the shelf life was observed for 2 days.

4.5 Seed characters

Various observations on seed characters such as seed shape, seed weight, cotyledon surface, attachment of cotyledons, cotyledon colour, length and diameter of seed cavity, length and diameter of seed, seed position in fruit, free space of seed cavity and total phenolic content were recorded and presented in Table 9, Table 10 and Table 11.

4.5.1 Seed shape

Various shape of seeds were observed in the accessions such as base flattened and apex conical, base flattened and apex rounded, ovate, broadly ovate and cordiform. Accessions AV-1, AV-3, AV-10, AV-12, AV-14, AV-16, AV-21 and AV-23 had seeds with base flattened and apex conical. Accessions AV-8, AV-11,

AV-13, AV-17, AV-18 and AV-25 had seeds with base flattened and apex rounded. Broadly ovate seeds were noticed in accessions AV-2, AV-4, AV-5 and AV-7 and ovate seeds were noticed in accessions AV-6 and AV-20. However accessions AV-9, AV-15 and AV-24 had seeds with cordiform in shape.

4.5.2 Seed weight (g)

Mean seed weight of avocado was 49.13 g with a CV of 41.64 per cent. Maximum seed weight (100.1 g) was observed in AV-17 and the minimum seed weight (26.2 g) in AV-6.

4.5.3 Cotyledon surface

Seed cotyledon surface were observed to be smooth, intermediate and rough. Accessions AV-2, AV-3, AV-6, AV-10, AV-12, AV-15, AV-16, AV-20, AV-21, AV-23 and AV-24 had smooth surface,while accessions AV-1, AV-4, AV-5, AV-7, AV-9, AV-11, AV-14 and AV-25 had intermediate surface and accessions AV-8, AV-13, AV-17 and AV-18 had cotyledons with rough surface.

4.5.4 Attachment of cotyledons

The seeds were found to possess attached cotyledons in all accessions.

4.5.5 Cotyledon colour

Cotyledon colour was noted as ivory in accessions AV-6, AV-8, AV-14, AV-17, AV-18 and AV-24. Yellow coloured cotyledons were found to be present in accessions AV-2, AV-4, AV-5, AV-7, AV-11, AV-12, AV-21 and AV-23. In accessions AV-1, AV-3, AV-9, AV-10, AV-13, AV-15, AV-16, AV-20 and AV-25,

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cotyledons were cream in colour.

4.5.6 Length of seed cavity (cm)

Minimum seed cavity length of 4.2 cm was recorded in AV-3 and AV-4, whereas maximum value of 6.6 cm was in AV-2. Mean value of seed cavity length was 5.04 cm with a CV of 13.72 per cent.

4.5.7 Diameter of seed cavity (cm)

Diameter of seed cavity recorded was minimum (3.03 cm) in AV-6 and maximum (5.70 cm) in AV-8. Average diameter of seed cavity was recorded as 4.47 cm with a CV of 15.57 per cent.

4.5.8 Length of seed (cm)

Maximum seed length of 5.57 cm was observed in AV-9 followed by 5.50 cm in AV-2. Minimum seed length was recorded in AV-1 (3.40 cm). Average value of seed length was 4.53 cm with a CV of 41.64 per cent.

4.5.9 Diameter of seed (cm)

Average diameter of seed was calculated as 4.53 cm with a CV of 13.36 per cent. Minimum seed diameter (2.37 cm) was recorded in AV-6 while maximum seed diameter (5.82 cm) was recorded in AV-9.

4.5.10 Seed position in fruit

Position of seed within the fruit was observed to be central in 16 accessions (AV-1, AV-3, AV-4, AV-5, AV-7, AV-8, AV-9, AV-10, AV-13, AV-15, AV-17, AV-18, AV-19, AV-20, AV-24 and AV-25) and apical in accessions AV-2, AV-6, AV-11, AV-12, AV-14, AV-16 and AV-22.

Table 9: Quantitative characteristics of avocado seed

Accession	Seed weight (g)	Length of seed (cm)	Diameter of seed (cm)	Length of seed cavity (cm)	Diameter of seed cavity (cm)	Total phenolic content of seed (mg/g)
AV-1	41.92	3.40	3.72	4.64	4.48	5.92
AV-2	32.90	5.50	2.60	6.60	3.83	37.37
AV-3	41.30	3.65	3.52	4.20	3.97	9.77
AV-4	27.60	4.17	3.59	4.20	4.90	30.94
AV-5	53.70	4.15	3.78	5.50	4.55	4.40
AV-6	26.20	5.05	2.37	5.27	3.03	7.67
AV-7	27.60	4.14	3.21	4.27	3.27	5.74
AV-8	70.40	4.58	5.49	5.60	5.70	2.40
AV-9	69.13	5.57	5.82	6.20	4.97	3.20
AV-10	58.87	4.95	4.55	5.12	4.44	4.26
AV-11	44.75	4.96	4.56	4.96	4.56	3.04
AV-12	38.14	3.62	3.42	4.32	4.18	11.21
AV-13	72.36	4.33	5.36	4.64	5.30	5.22
AV-14	29.40	4.33	3.59	5.80	3.80	11.75
AV-15	40.27	4.22	4.50	4.20	4.60	34.39
AV-16	63.05	5.05	5.22	5.05	5.17	11.93
AV-17	100.10	5.31	5.58	5.10	5.65	8.45
AV-18	87.63	4.81	5.16	4.90	5.30	28.58
AV-20	30.80	4.74	3.75	5.23	3.73	18.47
AV-21	31.50	3.80	2.77	4.48	4.40	21.62
AV-23	40.60	4.40	3.91	5.95	4.70	15.07
AV-24	62.45	5.17	4.82	5.60	4.10	20.32
AV-25	39.40	4.50	4.37	4.30	4.37	8.63

Table 10: Qualitative characteristics of avocado seed

Accessions	Seed Shape	Cotyledon surface	Attachment of cotyledons	Cotyledon colour	Seed position in fruit	Free space of the seed cavity
AV-1	Base flattened and apex conical	Intermediate	Attached	Cream	Central	Free space on seed apex
AV-2	Broadly ovate	Smooth	Attached	Yellow	Apical	Free space on seed apex
AV-3	Base flattened and apex conical	Smooth	Attached	Cream	Central	Absent
AV-4	Broadly ovate	Intermediate	Attached	Yellow	Central	Absent
AV-5	Broadly ovate	Intermediate	Attached	Yellow	Central	Absent
AV-6	Ovate	Smooth	Attached	Ivory	Apical	Absent
AV-7	Broadly ovate	Intermediate	Attached	Yellow	Central	Absent
AV-8	Base flattened and apex rounded	Rough	Attached	Ivory	Central	Absent
AV-9	Cordiform	Intermediate	Attached	Cream	Central	Absent
AV-10	Base flattened and apex conical	Smooth	Attached	Cream	Central	Absent
AV-11	Base flattened and apex rounded	Intermediate	Attached	Yellow	Apical	Free space on seed base
AV-12	Base flattened and apex conical	Smooth	Attached	Yellow	Apical	Absent
AV-13	Base flattened and apex rounded	Rough	Attached	Cream	Central	Absent
AV-14	Base flattened and apex conical	Intermediate	Attached	Ivory	Apical	Free space on seed apex
AV-15	Cordiform	Smooth	Attached	Cream	Central	Absent
AV-16	Base flattened and apex conical	Smooth	Attached	Cream	Apical	Absent
AV-17	Base flattened and apex rounded	Rough	Attached	Ivory	Central	Absent
AV-18	Base flattened and apex rounded	Rough	Attached	Ivory	Central	Absent
AV-20	Ovate	Smooth	Attached	Cream	Central	Absent
AV-21	Base flattened and apex conical	Smooth	Attached	Yellow	Central	Absent
AV-23	Base flattened and apex conical	Smooth	Attached	Yellow	Apical	Free space on seed base
AV-24	Cordiform	Smooth	Attached	Ivory	Central	Absent
AV-25	Base flattened and apex rounded	Intermediate	Attached	Cream	Central	Absent

Table 11. Descriptive statistics of quantitative characters of avocado seed

Descriptives	Seed weight (g)	Length of seed (cm)	Diameter of seed (cm)	Length of seed cavity (cm)	Diameter of seed cavity (cm)	Total phenolic content of seed (mg/g)
Range	73.90	2.17	3.45	2.40	2.66	34.97
Minimum	26.20	3.40	2.37	4.20	3.03	2.40
Maximum	100.10	5.57	5.82	6.60	5.70	37.37
Average	49.13	4.53	4.15	5.04	4.47	13.49
Standard error of mean	4.27	0.12	0.20	0.14	0.14	2.21
Standard deviation	20.46	0.61	0.99	0.69	0.69	10.61
Co-efficient of variation	41.64	13.36	23.86	13.72	15.57	78.67

Base flattened and apex conical

Base flattened and apex rounded

Cordiform

Broadly ovate

Ovate

Plate 19. Seed shape

Yellow

Cream

Ivory

Plate 20. Cotyledon colour

Smooth

Intermediate

Rough

Plate 21. Cotyledon surface

Free space absent

Space on seed base

Space on seed apex

Plate 22. Free space of the seed cavity

4.5.11 Free space of the seed cavity

In seed cavity, free space was found to be absent in accessions AV-3, AV-4, AV-5, AV-6, AV-7, AV-8, AV-9, AV-10, AV-12, AV-13, AV-15, AV-16, AV-17, AV-18, AV-20, AV-24 and AV-25. In accessions AV-1, AV-2 and AV-14 free space was found and recorded as space on seed apex whereas in accessions AV-11 and AV-23 free space was found and recorded as space on seed base.

4.5.12 Total phenolic content (mg g^{-1})

Average total phenolic content of avocado seeds was estimated to be 13.49 mg g^{-1} with a high CV of 78.67 per cent. The total phenolic content was estimated to be maximum (37.37 mg g^{-1}) in AV-2 and minimum (2.4 mg g^{-1}) in AV-8.

4.6 Quality attributes

The quality of avocado fruits was estimated using different parameters such as total soluble solids, titrable acidity, TSS/acid ratio, percentage content of fats, total sugars, reducing sugars and non-reducing sugars. Data pertaining to quality attributes are presented in Table 12 and Table 13.

4.6.1 Total soluble solids (^{0}B)

Average TSS of avocado fruits was estimated as 8.15 ^{0}B with a CV of 14.96 per cent. TSS was recorded to be highest in AV-14 (10.4 ^{0}B) and was on par with AV-9 (10.2 ^{0}B) which was followed by AV-5 (10.1 ^{0}B) and AV-17 (9.4 ^{0}B). Minimum value of TSS (6.3 ^{0}B) was recorded in accessions AV-4 and AV-7.

4.6.2 Titrable acidity (%)

Titrable acidity of avocado ranged from 0.64 per cent to 1.28 per cent and displayed a CV of 29.23 per cent. Average value of titrable acidity was recorded as 0.84 per cent. Accessions AV- 5, AV-6, AV-7, AV-11, AV-12, AV-16, AV-17, AV-18, AV-20, AV-23 and AV-25 had minimum titrable acidity of 0.64 per cent and in accessions AV-2, AV-8, AV-10 and AV-13 maximum value of titrable acidity (1.28 per cent).

4.6.3 TSS/acidity ratio

Maximum TSS/acidity ratio was recorded in accession AV-5 with a value of 15.78 and minimum value was recorded in accession AV-2 (5.92). Average value was estimated to be 10.30 with a CV of 28.63 per cent.

4.6.4 Fats (%)

Average fat content of avocado pulp was recorded as 3.75 per cent with a CV of 28.95 per cent. Maximum fat content of 6.78 per cent was recorded in AV-12 and minimum fat content of 2.63 per cent was recorded in accession AV-4.

4.6.5 Total sugars, reducing sugars and non-reducing sugars

Total sugars, reducing sugars and non-reducing sugars were found to be present in negligible quantity in fruits of all accessions. Hence these quality attributes were not recorded.

Table 12. Fruit quality parameters of avocado accessions

Accessions	TSS (^{0}Brix)	Titrable acidity (%)	Fats (%)	TSS/acid ratio
AV-1	6.6	0.96	3.54	6.88
AV-2	7.6	1.28	2.85	5.94
AV-3	7.4	0.64	6.18	11.56
AV-4	6.3	0.96	2.63	6.56
AV-5	10.1	0.64	3.36	15.78
AV-6	8.2	0.64	2.91	12.81
AV-7	6.3	0.64	3.24	9.84
AV-8	9.3	1.28	3.57	7.27
AV-9	10.2	0.96	3.72	10.63
AV-10	8.3	1.28	3.86	6.48
AV-11	9.1	0.64	4.78	14.22
AV-12	8.5	0.64	6.78	13.28
AV-13	8.1	1.28	3.43	6.33
AV-14	10.6	0.96	3.68	11.04
AV-15	7.2	0.96	2.76	7.50
AV-16	7.6	0.64	2.73	11.88
AV-17	9.4	0.64	3.04	14.69
AV-18	8.3	0.64	3.15	12.97
AV-20	6.8	0.64	3.89	10.63
AV-21	8.5	0.96	2.7	8.85
AV-23	7.1	0.64	5.19	11.09
AV-24	8.5	0.96	4.26	8.85
AV-25	7.6	0.64	4.06	11.88

Table 13. Descriptive statistics of fruit quality parameters of avocado

Descriptives	TSS (^{0}Brix)	Acidity (%)	Fats %	TSS/acid ratio
Range	4.30	0.64	4.15	9.84
Minimum	6.30	0.64	2.63	5.93
Maximum	10.60	1.28	6.78	15.78
Average	8.15	0.84	3.75	10.30
Standard error of mean	0.25	0.05	0.22	0.61
Standard deviation	1.22	0.24	1.08	2.95
Co-efficient of variation	14.96	29.23	28.95	28.63

4.7 Organoleptic scoring of fruit

Organoleptic scoring of fruits for eight quality attributes *viz.*, appearance, colour, flavour, taste, after taste, texture, odour and overall acceptability was carried out using nine point hedonic scale where in score nine denotes highest score and score of one denotes lowest score. The results pertaining to the sensory evaluation are presented in Table 14.

In terms of appearance, mean rank was highest in AV- 10 (20.10) followed by AV- 24 (18.75), AV-11 (17.30) and AV-17 (17.10). With respect to colour, highest mean rank was obtained for AV-2 (18.95) followed by AV-3 (18.15), AV-6 (18.00) and AV-17 (16.80). In terms of flavour, highest mean rank was in AV-13 (19.80) followed by AV-8 (17.40) AV-3 (17.20), AV-6 (16.95). Highest mean rank for taste was obtained for AV-2 (19.40) followed by AV-24 (19.10) and AV-3 (18.50) whereas highest mean rank for after taste was recorded in AV-24 (20.50) followed by AV-2 (19.95) and AV-3 (19.25). For texture, mean rank was highest in AV-10 (20.90) followed by AV-2 (19.75) and AV-25 (17.35). In case of odour, AV-17 had the highest mean rank of 19.80 followed by AV-3 (17.25) and AV-24 (17.00). Highest mean rank in terms of overall acceptability was accorded to accession AV-24 (19.30) followed AV-10 (19.25), AV-9 (19.10) and AV-17 (18.65).

Table 14. Mean Rank of Sensory Evaluation

Appearance	Mean Rank	Colour	Mean Rank	Flavour	Mean Rank	Taste	Mean Rank	After-taste	Mean Rank	Texture	Mean Rank	Odour	Mean Rank	Overall acceptibility	Mean Rank
AV-10	20.10	AV-2	18.95	AV-13	19.80	AV-2	19.40	AV-24	20.50	AV-10	20.90	AV-17	19.80	AV-24	19.30
AV-24	18.75	AV-3	18.15	AV-8	17.40	AV-24	19.10	AV-2	19.95	AV-2	19.75	AV-3	17.25	AV-10	19.25
AV-11	17.30	AV-6	18.00	AV-3	17.35	AV-3	18.50	AV-3	19.25	AV-25	17.35	AV-24	17.00	AV-9	19.10
AV-17	17.10	AV-17	16.80	AV-10	17.20	AV-10	17.45	AV-21	17.20	AV-13	14.90	AV-13	16.90	AV-17	18.65
AV-2	15.30	AV-8	15.60	AV-6	16.95	AV-11	15.10	AV-6	16.00	AV-21	14.60	AV-10	16.65	AV-18	14.55
AV-6	14.90	AV-10	15.50	AV-17	16.35	AV-9	15.00	AV-11	15.40	AV-17	14.25	AV-2	16.40	AV-21	13.80
AV-3	14.35	AV-14	14.10	AV-9	16.10	AV-17	14.55	AV-7	14.70	AV-3	14.20	AV-21	15.45	AV-6	13.70
AV-18	14.25	AV-16	13.50	AV-14	15.80	AV-13	14.05	AV-10	14.70	AV-15	13.80	AV-9	15.10	AV-25	13.65
AV-13	14.20	AV-11	13.45	AV-11	15.35	AV-14	13.75	AV-17	14.35	AV-8	13.75	AV-23	13.50	AV-3	13.10
AV-14	13.95	AV-24	13.15	AV-21	14.65	AV-6	13.65	AV-25	12.50	AV-6	12.70	AV-25	13.40	AV-13	13.10
AV-21	12.55	AV-21	12.75	AV-12	13.55	AV-21	13.50	AV-9	12.00	AV-14	11.55	AV-8	13.15	AV-11	12.85
AV-15	12.50	AV-9	12.55	AV-23	11.95	AV-8	12.95	AV-1	11.85	AV-4	11.35	AV-14	13.05	AV-14	12.20
AV-16	11.95	AV-25	12.35	AV-24	11.30	AV-7	12.80	AV-18	11.70	AV-18	11.15	AV-6	12.60	AV-8	11.60
AV-1	11.85	AV-23	11.90	AV-2	10.40	AV-18	12.35	AV-5	11.15	AV-1	11.00	AV-11	11.85	AV-2	10.80
AV-25	11.85	AV-15	11.15	AV-7	9.25	AV-25	11.90	AV-13	10.25	AV-24	11.00	AV-7	11.20	AV-5	10.35
AV-9	10.85	AV-13	11.00	AV-5	8.55	AV-16	10.05	AV-14	9.60	AV-16	10.30	AV-16	9.95	AV-15	9.45
AV-4	8.35	AV-5	9.70	AV-1	8.20	AV-4	10.00	AV-4	9.45	AV-5	10.05	AV-20	8.35	AV-12	9.30
AV-12	8.05	AV-7	9.50	AV-18	8.00	AV-5	8.25	AV-8	8.25	AV-11	9.95	AV-5	7.80	AV-23	9.00
AV-8	7.40	AV-20	8.20	AV-16	6.95	AV-1	7.05	AV-20	7.20	AV-23	9.55	AV-4	6.80	AV-7	8.80
AV-20	5.95	AV-1	6.95	AV-25	6.75	AV-12	5.40	AV-15	5.70	AV-7	8.05	AV-15	6.00	AV-16	7.20
AV-7	5.00	AV-18	5.85	AV-15	5.75	AV-15	5.05	AV-23	5.55	AV-9	7.35	AV-12	4.80	AV-4	6.25
AV-5	4.90	AV-4	3.55	AV-20	4.65	AV-20	3.55	AV-12	4.80	AV-20	4.80	AV-1	4.75	AV-1	5.90
AV-23	4.60	AV-12	3.35	AV-4	3.75	AV-23	2.60	AV-16	3.95	AV-12	3.70	AV-18	4.25	AV-20	4.10
Kendall's W	0.492	0.478		0.556		0.56		0.557		0.420		0.512		0.450	

4.8 Pest and disease incidence

No major incidence of pests was noticed in accessions during course of study. However visits by vertebrate pests like monkeys were observed at times. *Colletotrichum gloeosporioides* caused anthracnose which resulted in die back. Avocado scab caused by *Sphaceloma perseae* was also reported in fruits resulting in necrotic brown coloured patches on fruit surface. Anthracnose and stem-end rot was noticed in fruits during post- harvest storage. Advanced stages of phytophthora stem rot resulting in bare framework of dying branches was also noticed.

4.9 Qualitative evaluation

Qualitative characters of avocado were assessed using 29 parameters of which variability was noticed in accessions with respect to 23 parameters. However no variability was noted in case of position of inflorescence, flower colour, flesh texture of fruit, colour of flesh next to skin, degree of discolouration of open fruit after four hours, attachment of cotyledon and hence were not considered for further evaluation. For each variable parameter, percentage frequency distribution was calculated and the results were tabulated as in Table 15 and Table 16.

4.9.1 Frequency distribution of avocado tree and leaf characters

Variability was observed for all the qualitative tree and leaf parameters studied *viz.*, crown shape, branching pattern, leaf blade shape and leaf colour (Table 15).

Irregular crown shape was observed in 44 per cent of the accessions followed by columnar (24 %), circular (20 %) and obovate (12 %). Branching pattern observed were verticillate, ascendant, horizontal and axial of which predominant was verticillate pattern (44 %) followed by ascendant (32 %), horizontal type (12 %) and axial (8 %).

Phytophthora rot

Dieback

Sphaceloma scab

Anthracnose

Plate 23. Diseases of avocado

Fifty two per cent of accessions had leaves with lanceolate shape and the remaining 48 per cent had narrowly obovate leaves. With regard to leaf colour, dark green coloured leaves were observed in 56 per cent accessions and green coloured leaves were observed in 44 per cent accessions.

Table 15. Frequency distribution of avocado tree and leaf characters

Sl. No.	Character	Expression	Frequency percentage
1	**Crown shape**	Circular	20.0
		Columnar	24.0
		Irregular	44.0
		Obovate	12.0
2	**Branching pattern**	Ascendant	32.0
		Axial	8.0
		Horizontal	12.0
		Verticillate	48.0
3	**Leaf blade shape**	Lanceolate	52.0
		Narrowly obovate	48.0
4	**Leaf colour**	Dark green	56.0
		Green	44.0

Table 16. Frequency distribution of inflorescence and phenological characters

Sl. no.	Character	Expression	Frequency percentage
1	**Flowering type**	A type	34.8
		B type	65.2
2	**Time of flushing**	February	12.0
		March	8.0
		September	8.0
		August and February	24.0
		September and March	24.0
		September and February	24.0
3	**Flowering season**	September to October	30.4
		September to October and February to March	69.6
4	**Fruiting Season**	March to September	13.0
		October to April	30.4
		October to April and March to September	47.5
		October to March	4.3
		October to March and March to August	4.3

Table 17. Frequency distribution of avocado fruit and seed characters

Sl.no.	Character	Expression	Frequency percentage
1	**Fruit shape**	Clavate	17.4
		Ellipsoid	4.3
		Narrowly obovate	30.4
		Obovate	13.0
		Pyriform	17.4
		Pyriform and narrowly obovate	4.3
		Spheroid	13.0
2	**Fruit Base shape**	Depressed	73.9
		Inflated	26.1
3	**Fruit apex shape**	Flattened	30.4
		Rounded	69.6
4	**Fruit apex position**	Asymmetric	47.8
		Central	52.2
5	**Ridges on fruit**	None	91.3
		Present	8.7
6	**Gloss on skin**	Intermediate	65.2
		Weak	34.8
7	**Pedicel position on fruit**	Asymmetrical	56.5
		Central	43.5
8	**Fruit skin surface**	Intermediate	17.4
		Rough	8.7
		Smooth	73.9
9	**Fruit skin colour**	Light green	13.0
		Purple	87.0
10	**Colour of flesh next to seed**	Light yellow	65.2
		Yellow	34.8
11	**Seed shape**	Base flattened and apex conical	34.8
		Base flattened and apex rounded	26.1
		Broadly ovate	17.4
		Cordiform	13.0
		Ovate	8.7
12	**Cotyledon surface**	Intermediate	34.8
		Rough	17.4
		Smooth	47.8
13	**Cotyledon colour**	Intermediate	34.8
		Rough	17.4
		Smooth	47.8
14	**Seed position**	Apical	30.4
		Central	69.6
15	**Free space of seed cavity**	Absent	78.3
		Free space on seed base	8.7
		Free space on seed apex	13.0

4.9.2 Frequency distribution of inflorescence and phenological parameters

Inflorescence type was classified into two groups- A type and B type and of the 23 accessions which flowered, 34.8 per cent had type A and 65.2 per cent had type B inflorescences (Table 16).

Flowering season coincided with months of September to October in 30.40 per cent of the accessions and dual flowering season *viz*., September to October and February to March was observed in 69.60 per cent accessions.

Wide variability has been recorded in time of flushing and fruiting season as in Table 16. Single fruiting season was noted as March to September, October to April, October to March with frequencies 13.00 %, 30.40 % and 4.30 %, respectively. Two seasons of fruiting *viz.,* September to October and February to March with frequency distribution of 69.60 per cent and October to March and March to August with frequency distribution of 4.3 %. Frequency distribution of time of flushing is recorded as February (12%), March (8%), September (8%), September and March (24 %), September and February (24 %).

4.9.3 Frequency distribution of avocado fruit and seed characters

Five different fruit shapes such as clavate, ellipsoid, narrowly obovate, obovate and pyriform were identified among the accessions. Out of the 23 accessions, 30.40 per cent accessions had fruits of narrowly obovate shape and 17.40 per cent each had clavate and pyriform shaped fruits, 13 per cent of the accessions had obovate fruits and 4.30 per cent each of accessions had elliptic fruits. Both pyriform and narrowly obovate shaped fruits were found in 4.30 per cent accessions.

Fruit base shape was observed as depressed in 73.90 per cent accessions and inflated in 26.10 accessions. Fruit apex shape was flattened in 30.40 accessions and rounded in 69.60 per cent accessions. Fruit apex position was central in 52.20 per cent accessions while asymmetric in 47.80 per cent

accessions. In majority of accessions (91.30 %) no ridges were present on fruit surface while 8.70 per cent accessions possessed fruits with ridges on surface. With regard to glossiness, 65.20 per cent of accessions had fruits with intermediate glossiness and 34.80 accessions had weak glossiness on fruits. Pedicel was located asymmetrically in 56.50 per cent accessions and centrally in 43.50 per cent accessions. Fruit skin surface was smooth in 73.90 per cent accessions, intermediate in 17.40 per cent accessions and rough in 7.40 per cent accessions. Light green skinned fruits were found in 13 per cent accessions whereas purple skinned fruits were found in 87 per cent accessions. Colour of pulp next to seed was either light yellow (65.20 %) and yellow (34.80 %).

With regard to seed shape, frequency distribution was 34.80 percent with base flattened and apex conical, 26.10 per cent base flattened and apex rounded, 17.40 per cent broadly ovate, 13 per cent cordiform and 8.70 per cent ovate.

Cotyledon surface was identified to be smooth (47.8 %), intermediate (34.8 %) and rough (17.4 %).

Cotyledon colour was identified to be cream in 39.10 per cent accessions, yellow in 34.80 per cent accessions and ivory in 26.1 per cent accessions.

Among accessions, seed position was central in 30.4 per cent accessions and apical in 69.6 per cent accessions.

Free space of the seed cavity was on seed apex in 13 per cent accessions, on seed base in 8.70 per cent accessions, whereas 78.30 per cent accessions had no free space in seed cavity.

4.10 Principal Component Analysis

Principal Component Analysis (PCA) is basically a data reduction technique in which principal components are formed on subjection of the original variables to a linear transformation and the number of principal components to be

retained are determined by Kaiser's criterion (Eigen value >1) (Kaiser, 1958). PCA was performed for morphological traits of tree, inflorescence, fruit and seed as well as quality parameters of fruit.

4.10.1 PCA for Tree Characteristics:

Principal component analysis for tree characters was done based on seven morphological characters and the results are presented in Table 18a. PCA grouped the tree characters into seven main components of which eigen value was greater than one for first three components. These components accounted for 74.4 per cent of total variation.

PC1 was contributed mainly by leaf width, trunk girth and leaf length with PC loadings of 0.502, -0.486 and 0.467, respectively. Though leaf length and leaf width contributed positively, tree girth gave negative contribution to PC1. The component PC2 was contributed by internodal length, leaf length and age of tree with PC loadings of 0.559, 0.460 and 0.426 all contributing positively to the component. Shoot length, tree height and internodal length featured PC3 (Fig. 13a).Loading plot for tree characters depicted that there was a strong association of age of tree and tree girth with extreme acute angles. Leaf length and leaf width also showed acute angles between them indicating close association (Fig. 13b).

4.10.1.1 Clustering based on tree characters

Clustering was done based on score plot of first two principal components of the analysis. The 25 accessions were grouped into six clusters (Fig. 13c). Maximum number of accessions belonged to cluster V with nine accessions and cluster IV and VI were comprised of single accessions each (Table 18b). Mean performance of clusters show that cluster III recorded minimum age of tree while cluster VI recorded maximum tree girth and intermodal length. Leaf length was maximum in cluster I while leaf width had maximum value in cluster III (Table 18c).

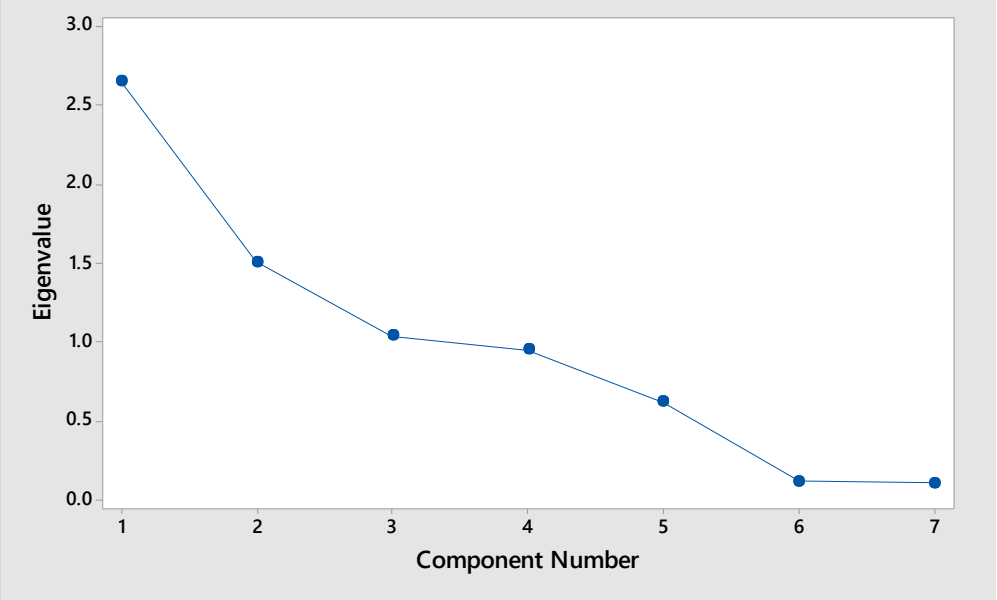


Fig. 13a Scree plot showing eigen values in response to number of components for estimated variables of avocado

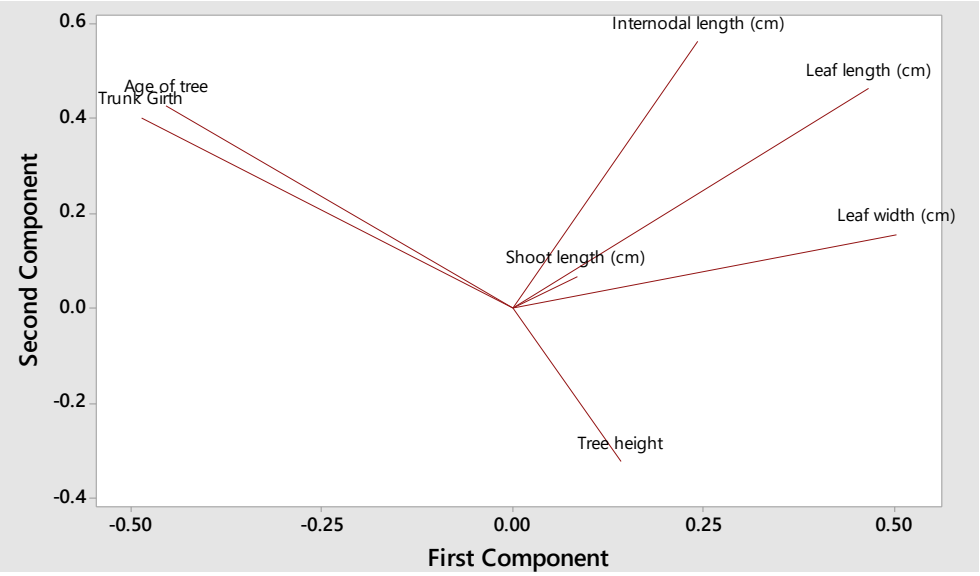


Fig. 13b Plot of first two PCA's showing showing relation among various quality traits of avocado

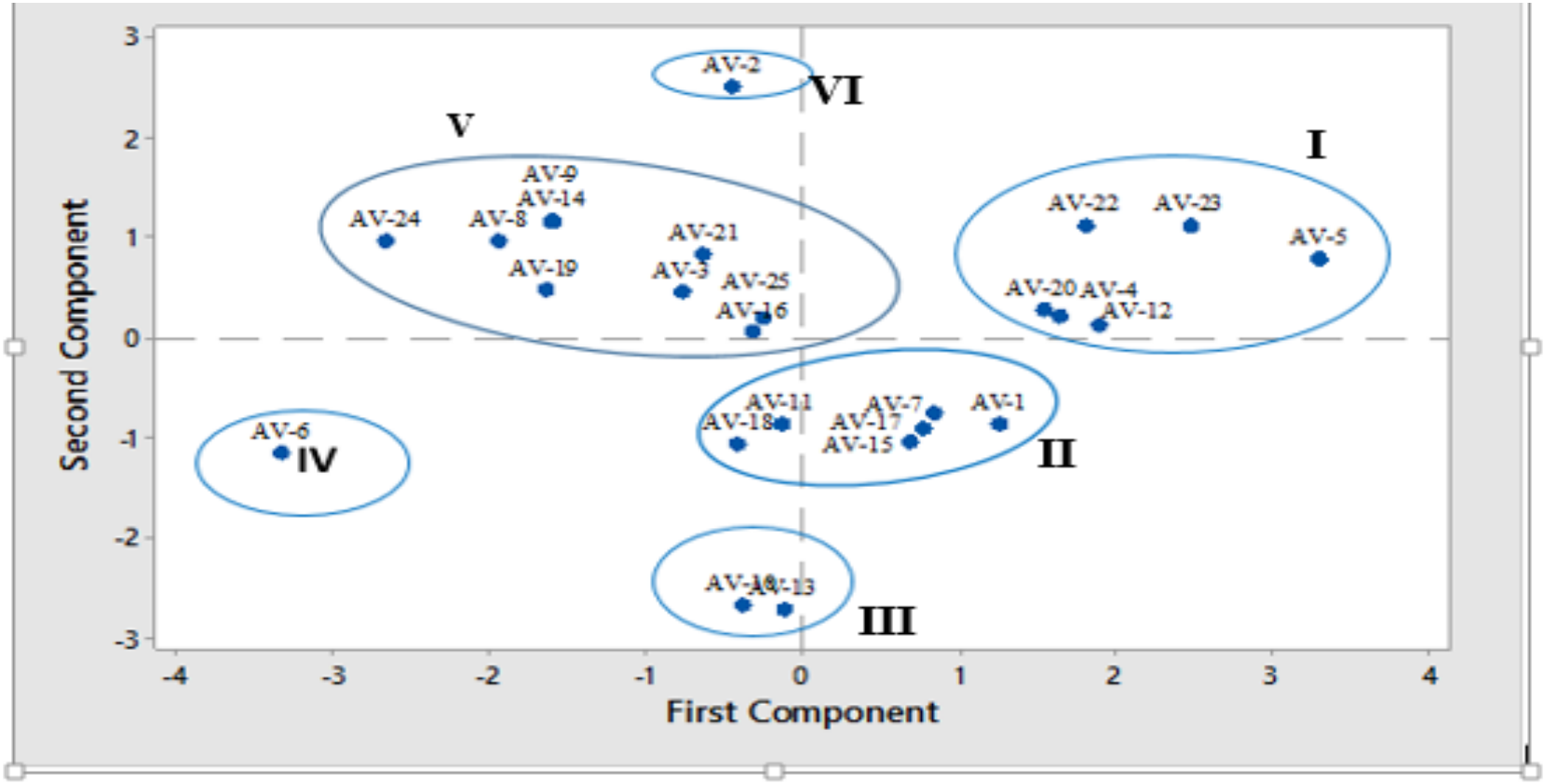


Fig. 13c Clustering of 25 accessions of avocado based on tree characters from first two components

Table 18a. Principal component analysis of avocado tree characters

Variable	Components						
	PC1	PC2	PC3	PC4	PC5	PC6	PC7
Age of tree (years)	-0.454	**0.426**	-0.012	0.36	-0.077	0.245	-0.645
Tree height (m)	0.142	-0.324	**-0.334**	0.79	0.349	0.065	0.115
Trunk girth (cm)	**-0.486**	0.401	-0.032	0.244	-0.167	-0.316	0.644
Shoot length (cm)	0.084	0.067	**0.906**	0.239	0.321	0.035	0.076
Internodal length (cm)	0.244	**0.559**	**-0.236**	-0.17	0.666	-0.305	-0.088
Leaf length (cm)	**0.467**	**0.46**	-0.068	0.079	-0.225	0.650	0.293
Leaf width (cm)	**0.502**	0.155	0.079	0.307	-0.498	-0.565	-0.236
Eigenvalue	2.656	1.506	1.041	0.953	0.618	0.119	0.104
Proportion	0.379	0.215	0.149	0.136	0.088	0.017	0.015
Cumulative	0.379	0.595	0.744	0.880	0.968	0.985	1.000

Table 18b. Clusterwise distribution of avocado accessions based on tree characters

Clusters	Size	Collections
I	6.00	AV-4, AV-5, AV-12, AV-20, AV-22, AV-23
II	6.00	AV-1, AV-7, AV-11, AV-15, AV-17, AV-18
III	2.00	AV-10, AV-13
IV	1.00	AV-6
V	9.00	AV-3, AV-8, AV-9, AV-14, AV-16, AV-19, AV-21, AV-24, AV-25
VI	1.00	AV-2

Table 18c. Mean performance of clusters based on tree characters

Cluster	Age of tree (years)	Tree height (m)	Trunk girth (cm)	Shoot length (cm)	Internodal length (cm)	Leaf length (cm)	Leaf width (cm)
I	18.67	8.61	63.87	66.48	4.65	22.00	11.07
II	20.20	10.70	70.38	62.00	3.66	19.48	8.92
III	11.50	11.68	67.00	48.25	2.33	16.66	8.19
IV	51.00	5.87	152.00	58.80	1.82	15.56	5.54
V	47.11	8.55	173.60	66.88	4.08	18.83	7.80
VI	51.00	6.87	180.00	42.02	5.78	21.68	8.48

4.10.2 PCA for inflorescence characters

Principal component analysis was done based on six inflorescence traits. The components PC1, PC2 and PC3 had eigen values greater than one and contributed maximum to the total variability in proportions of 31.2 per cent and 23.4 per cent respectively (Fig. 14a). PC1 comprised of duration of flowering, number of flowers per inflorescence and number of days from fruit set to harvest with PC loadings of 0.630, 0.540 and 0.491 respectively. Width of inflorescence, number of days from flowering to fruit set and number of flowers per inflorescence with PC loadings of 0.712, 0.486 and 0.410 contributed to PC2 (Table 19a).

Loading plot of first two components for inflorescence traits showed that there is a positive association between number of days from flowering to fruit set and duration of flowering indicated by the acute angle. Also length and width of inflorescence had a close linkage as indicated by the acute angle. However duration of flowering and length of inflorescence are nearly perpendicular to each other indicating that there is no linkage between these two characters (Fig. 14b).

4.10.2.1 Clustering of inflorescence traits

Clustering was done based on score plot of first two principal components of the analysis.Among the 23 accessions flowering occurred were grouped into eight clusters (Fig 14c). Maximum number of accessions belonged to cluster VII with six accessions and cluster IV comprised of five accessions (Table 19b). Mean performance of clusters show that cluster I recorded highest number of inflorescence per tree, duration of flowering and minimum length of inflorescence. Cluster VIII recorded maximum values for length of inflorescence, width of inflorescence and number of days from fruit set to harvest and minimum duration of flowering. Cluster II recorded highest number of days from flowering to fruit set and lowest number of days from fruit set to harvest (Table 19c).

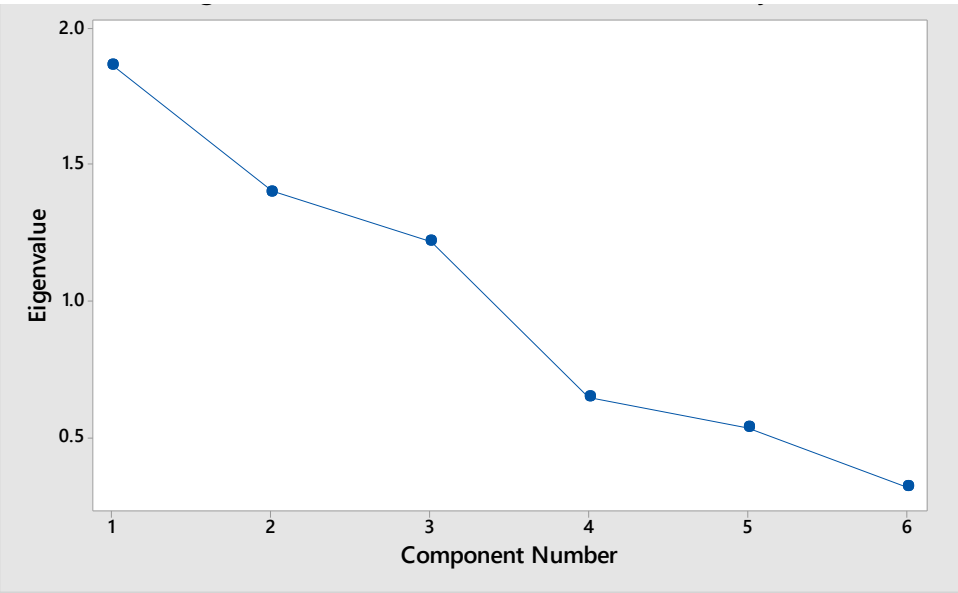


Fig. 14a Scree plot showing eigen values in response to number of components for estimated variables of avocado

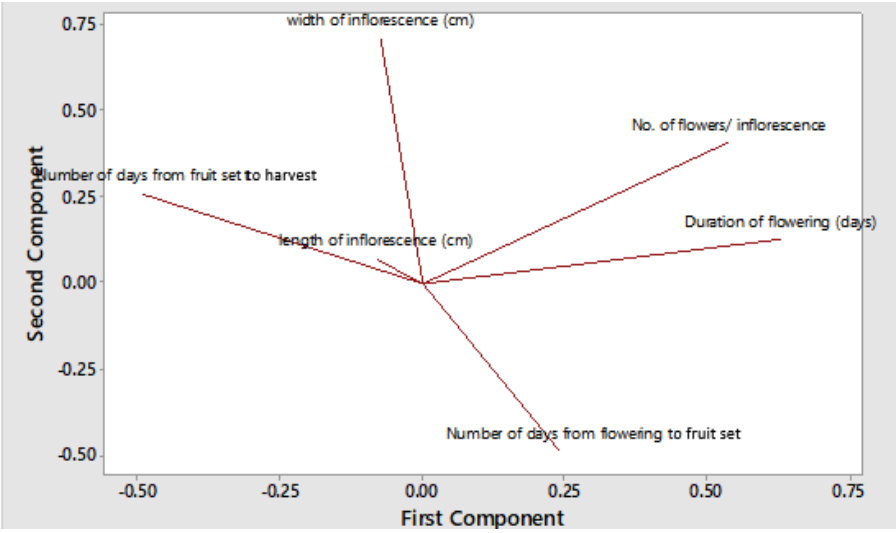


Fig. 14b Plot of first two PCA's showing relation among various quality traits of avocado

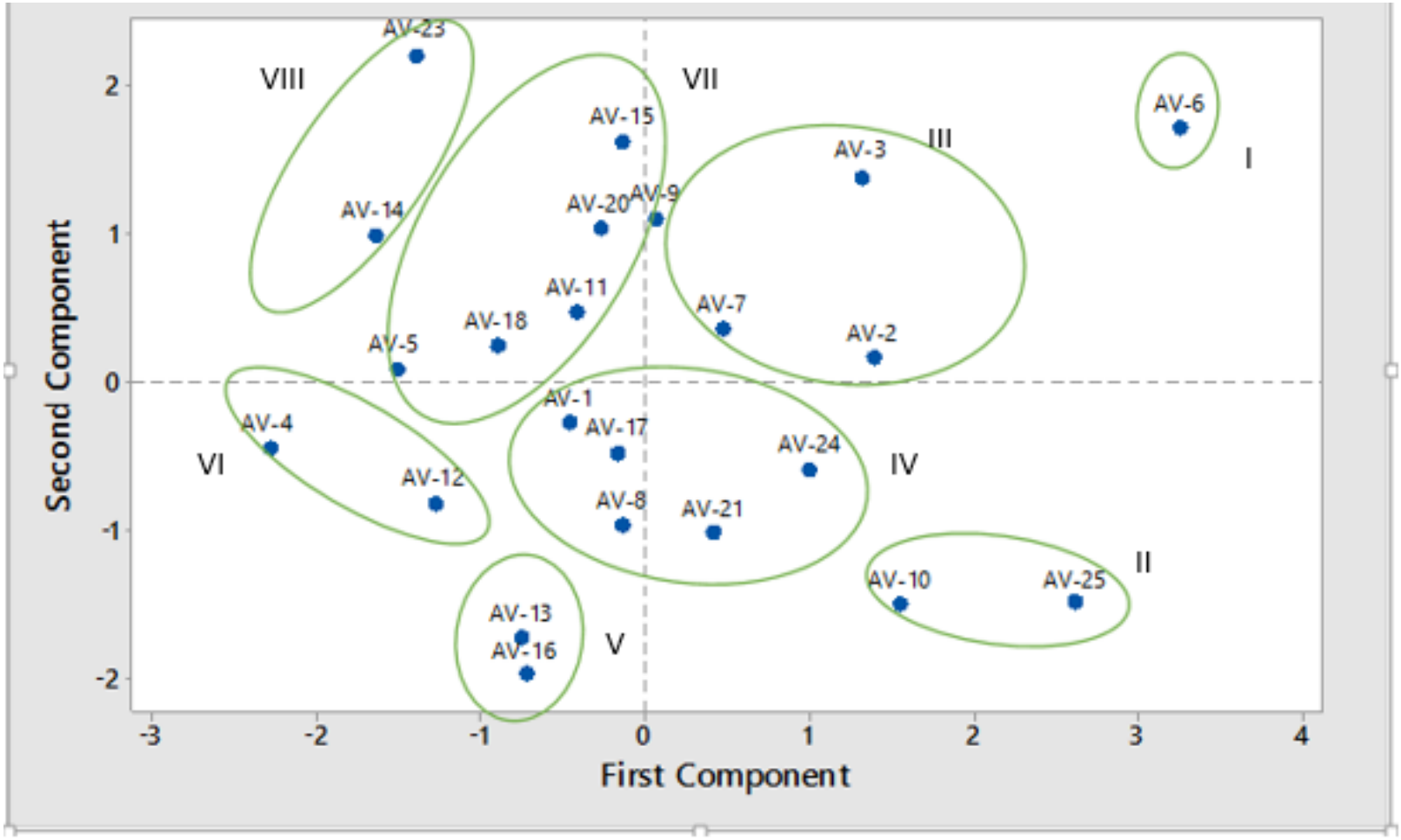


Fig. 14c Clustering of avocado accessions based on inflorescence characters from first two components

Table 19a. Principal component analysis of avocado inflorescence characters

Variables	Components					
	PC1	**PC2**	**PC3**	**PC4**	**PC5**	**PC6**
Length of inflorescence (cm)	-0.080	0.069	**-0.812**	-0.162	0.541	-0.106
Width of inflorescence (cm)	-0.073	**0.712**	-0.150	-0.387	-0.495	-0.265
No. of flowers/ inflorescence	**0.540**	**0.410**	-0.160	0.260	-0.003	0.669
Duration of flowering (days)	**0.630**	0.128	0.107	0.290	0.193	-0.674
Number of days from flowering to fruit set	0.240	**-0.486**	**-0.514**	0.137	-0.646	-0.075
Number of days from fruit set to harvest	**-0.491**	0.260	-0.134	0.808	-0.087	-0.109
Eigenvalue	1.869	1.404	1.220	0.648	0.536	0.321
Proportion	0.312	0.234	0.203	0.108	0.089	0.054
Cumulative	0.312	0.546	0.749	0.857	0.946	1.000

Table 19b. Clusterwise distribution based on inflorescence characters

Clusters	Size	Collections
I	1	AV-6
II	2	AV-10, AV-25
III	3	AV-3, AV-2, AV-7
IV	5	AV-24, AV-21, AV-8, AV-1, AV-17
V	2	AV-13, AV-16
VI	2	AV-4, AV-12
VII	6	AV-5, AV-18, AV-11, AV-20, AV-9, AV-15
VIII	2	AV-23, AV-14

Table 19c. Mean performance of clusters based on inflorescence characters

Clusters	Length of inflorescence (cm)	Width of inflorescence (cm)	No. of flowers/ inflorescence	Duration of flowering (days)	Number of days from flowering to fruit set	Number of days from fruit set to harvest
I	**5.93**	11.50	**247.33**	**45.00**	14.00	126.00
II	7.48	6.33	171.33	35.50	**23.00**	**116.50**
III	7.76	11.44	165.00	38.67	19.67	138.67
IV	8.75	10.43	121.40	33.40	23.40	134.60
V	8.15	**5.92**	91.67	28.50	22.00	138.00
VI	6.57	8.27	**70.83**	30.00	**13.50**	150.50
VII	8.52	11.41	140.28	31.50	15.33	146.33
VIII	**9.65**	**14.22**	148.50	**26.50**	15.50	**155.50**

4.10.3 PCA for fruit quantitative characters

Principal component analysis was done for fruit quantitative characters such as number of fruits, yield per tree, fruit weight, fruit length, fruit diameter, storage days of fruit and shelf life of fruit and the results obtained are presented in Table 20a. Scree plot showed that first three components showed eigen values above one which accounted for total variability of 75.3 per cent (Fig. 15a). PC1, PC2 and PC3 which made significant contribution had eigen values of 2.54, 1.57 and 1.14 respectively. Fruit length, fruit weight and fruit diameter contributed positively to PC1 with PC loadings of 0.505, 0.406 and 0.375 respectively. PC2 was composed mainly of fruit yield and number of fruits with PC loadings of -571 and -560. Factors contributing to PC3 were storage days of fruit, shelf life of fruit and fruit diameter with PC loadings -0.662, 0.598 and -0.264 respectively.

Loading plot of first two components depicts strong association of yield of tree with number of fruits which explains the extreme acute angle between them. Shelf life of fruit and storage days of fruit had negative association. Fruit weight showed close association with fruit length as well as fruit diameter (Fig. 15b).

4.10.3.1 Clustering of fruit quantitative traits

Clustering pattern was made based on score plot of first two principal components of the analysis and 23 accessions in which fruiting was observed were grouped into six clusters (Fig. 15c). Maximum number of accessions belonged to cluster II with 13 accessions and cluster IV and cluster VI comprised of single accession each (Table 20b). Mean performance of clusters demonstrated that cluster I showed maximum fruit weight, fruit length, fruit diameter and shelf life of fruit. Cluster IV consisting of single accession AV-7 had the minimum mean value for yield per tree, fruit weight, fruit length, fruit diameter but also recorded maximum storage days of fruit. Maximum yield was recorded in cluster V and maximum number of fruits per tree was recorded in cluster VI (Table 20c).

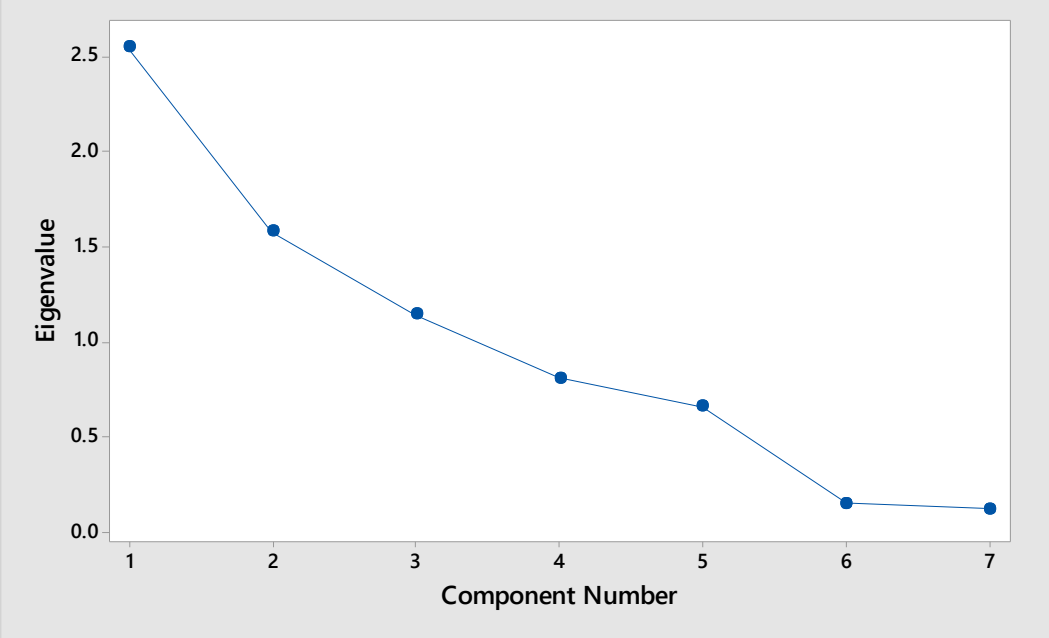


Fig. 15a Scree plot showing eigen values in response to number of components for estimated variables of avocado

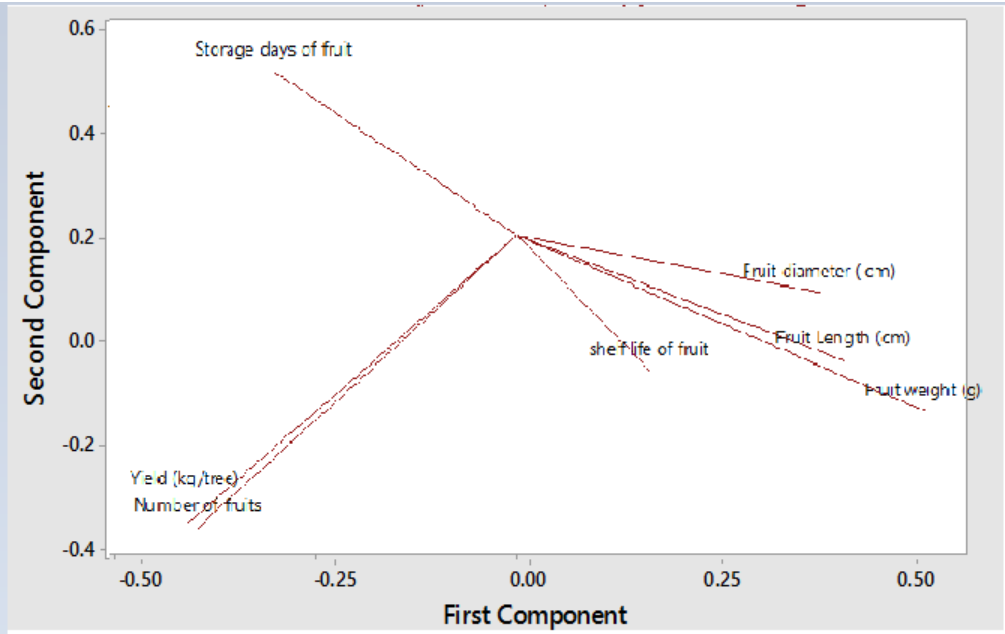


Fig. 15b Plot of first two PCA's showing showing relation among various quality traits of avocado

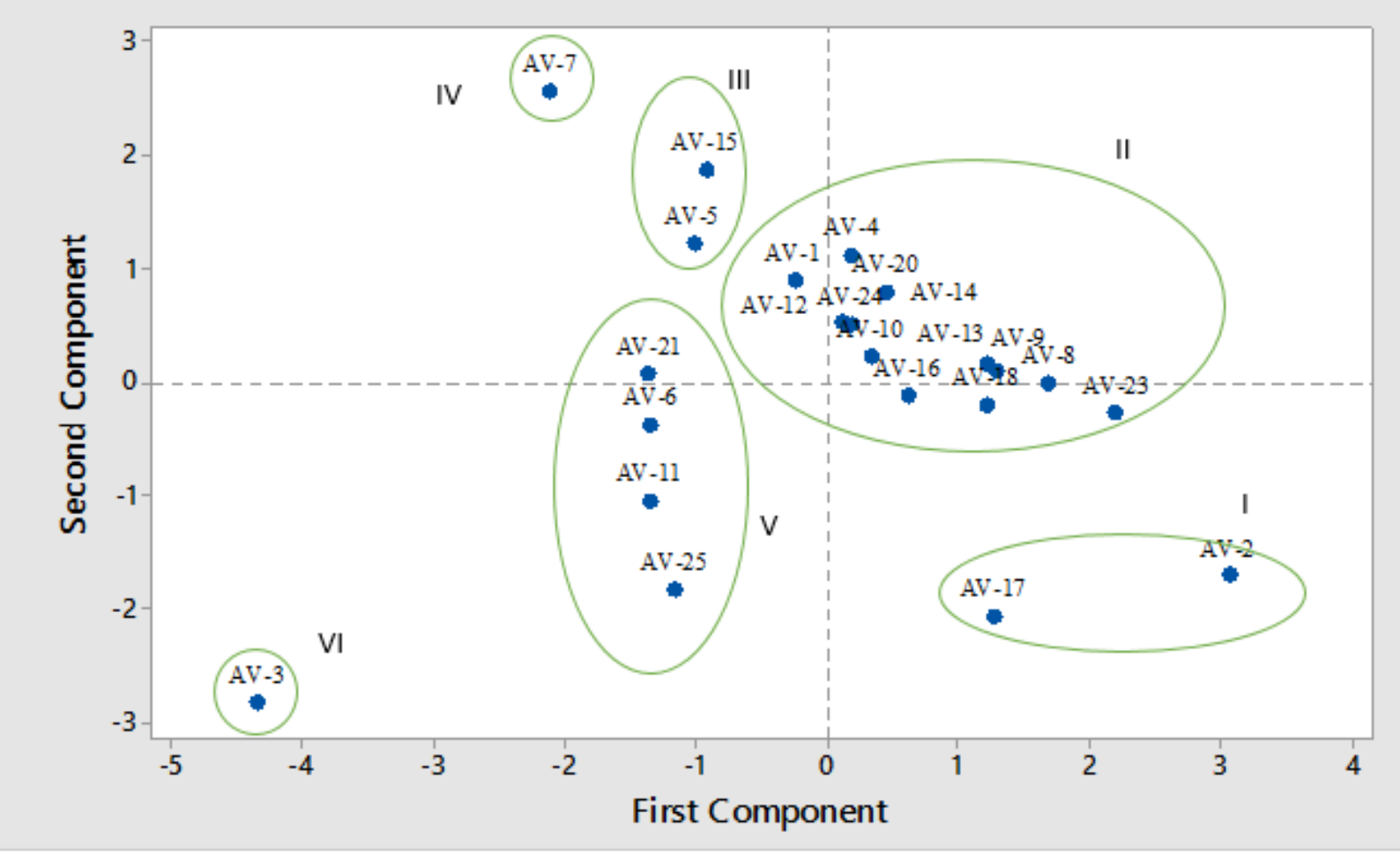


Fig. 15c Clustering of accessions of avocado based on quantitative fruit characters from first two components

Table 20a. Principal component analysis of quantitative characters of fruit

Variable	Components						
	PC1	PC2	PC3	PC4	PC5	PC6	PC7
Number of fruits	-0.396	**-0.571**	-0.136	-0.047	0.025	-0.357	0.607
Yield (kg/tree)	-0.407	**-0.560**	-0.114	0.067	0.081	0.302	-0.637
Fruit weight (g)	**0.505**	-0.342	-0.233	-0.157	0.091	0.658	0.327
Fruit length (cm)	**0.406**	-0.244	0.214	0.319	0.712	-0.328	-0.115
Fruit diameter (cm)	**0.375**	-0.113	**-0.662**	-0.251	-0.204	-0.466	-0.295
Storage days of fruit (days)	-0.300	0.320	**-0.269**	-0.559	0.647	0.071	0.016
Shelf life of fruit (days)	0.164	-0.264	**0.598**	-0.702	-0.133	-0.133	-0.134
Eigenvalue	2.5495	1.577	1.142	0.804	0.6576	0.149	0.118
Proportion	0.364	0.225	0.163	0.115	0.094	0.021	0.017
Cumulative	0.364	0.59	0.753	0.868	0.962	0.983	1

Table 20b. Clusterwise distribution of avocado accessions based on fruit characters

Clusters	Size	Collections
I	2	AV-17, AV-2
II	13	AV-1, AV-4, AV-12, AV-20, AV-24, AV-14, AV-13, AV-16, AV-18, AV-8,
III	2	AV-15, AV-5
IV	1	AV-7
V	4	AV-6, AV-21, AV-11, AV-25
VI	1	AV-3

Table 20c. Mean performance of clusters based on fruit characters

Clusters	Number of fruits	Yield (kg/tree)	Fruit weight (g)	Fruit length (cm)	Fruit diameter (cm)	Storage days of fruit (days)	Shelf life of fruit (days)
I	411.50	175.81	**420.70**	**12.16**	**7.87**	4.75	**2.00**
II	122.38	37.50	307.34	10.22	7.02	6.54	1.27
III	185.00	36.28	195.68	8.29	7.06	12.00	1.25
IV	**96.00**	**14.88**	**152.42**	**7.96**	**5.72**	**15.00**	1.00
V	726.75	**239.24**	229.50	9.38	6.28	6.75	1.38
VI	**920.00**	170.20	186.38	8.72	**5.72**	9.00	1.00

4.10.4 PCA for seed characters

The PCA grouped seed characters of avocado into 4 components of which PC1 and PC2 had eigen values of 2.19 and 1.51 and other two components had eigen values lower than one (Fig. 16a). PC1 mainly composed of seed weight, diameter of seed, and diameter of seed cavity with PC loadings of 0.547, 0.546 and 0.483. Length of seed cavity, length of seed and diameter of seed cavity contributed significantly to PC2 with PC loadings of 0.677, 0.595 and 0.287, respectively (Table 21a).

Loading plot of first two components shows that there is a strong association between seed weight with seed diameter and seed diameter with diameter of seed cavity. Acute angles between factors like length of seed and length of seed cavity indicated a positive association between these factors (Fig. 16b).

4.10.4.1 Clustering of seed characters

Clustering pattern was made based on score plot of first two principal components of the analysis and 23 accessions were grouped into six clusters (Fig. 16c). Maximum number of accessions belonged to cluster IV with 8 accessions and cluster VI comprised of single accession (Table 21b). Mean performance of clusters demonstrated that cluster I showed maximum seed weight, diameter of seed and least total phenolic content. Cluster VI recorded minimum value of seed diameter, diameter of seed cavity and maximum value of seed length, length of seed cavity and total phenolic content (Table 21c).

4.10.5 PCA for fruit quality attributes

The scree plot of PCA obtained showed that out of the 4 components extracted, PC1 and PC2 contributed significantly to total variation with eigen values of 2.06 and 1.09 (Fig. 17a). PC1 was contributed by acidity, TSS/acid

ratio and fat with PC loadings of 0.668, -0.608 and 0.369. TSS and acidity with PC loadings of -0.897 and -0.353 contributed negatively to PC2 (Table 22a).

In the loading plot of first two components, acidity and TSS/acid ratio was separated by acute angles indicating strong association. However acidity and fat % was separated by 180^0 indicating negative correlation (Fig. 17b).

4.10.5.1 Clustering of fruit quality attributes

Based on fruit quality attributes, the accessions were divided into 5 clusters (Fig. 17c). With cluster II having maximum number of accessions (8 accessions) (Table 22b). Cluster V recorded maximum value of titrable acidity and minimum value of TSS/acid ratio. Highest TSS was recorded in cluster IV and minimum TSS was recorded in cluster II. Cluster I had maximum value of fats and TSS/acid ratio (Table 22c).

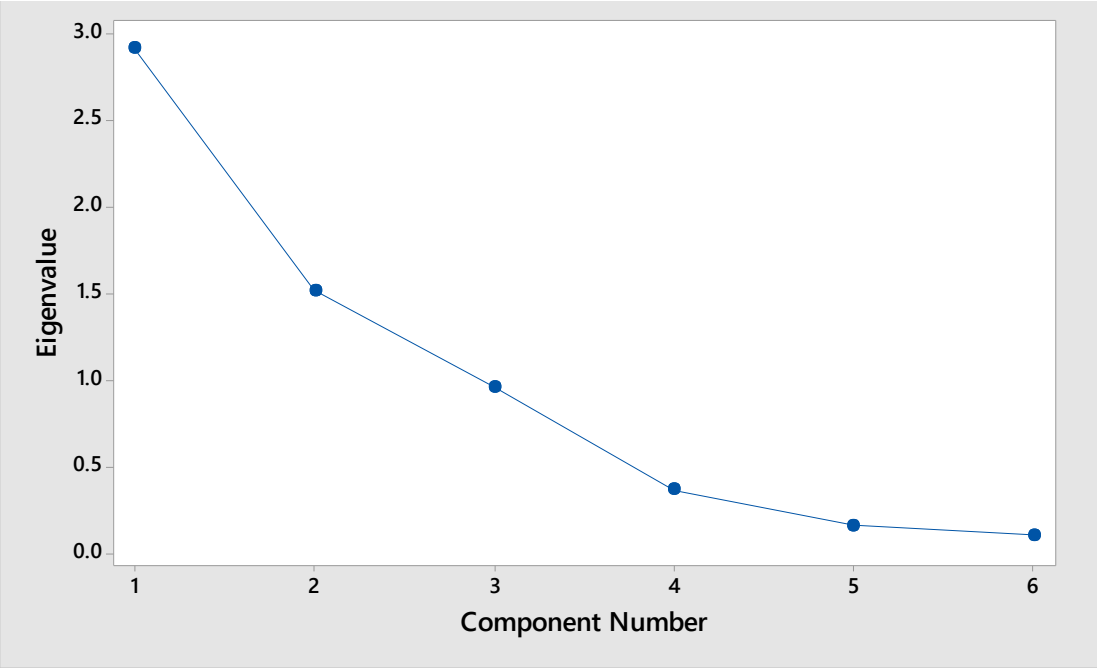


Fig. 16a Scree plot showing eigen values in response to number of components for estimated variables of avocado

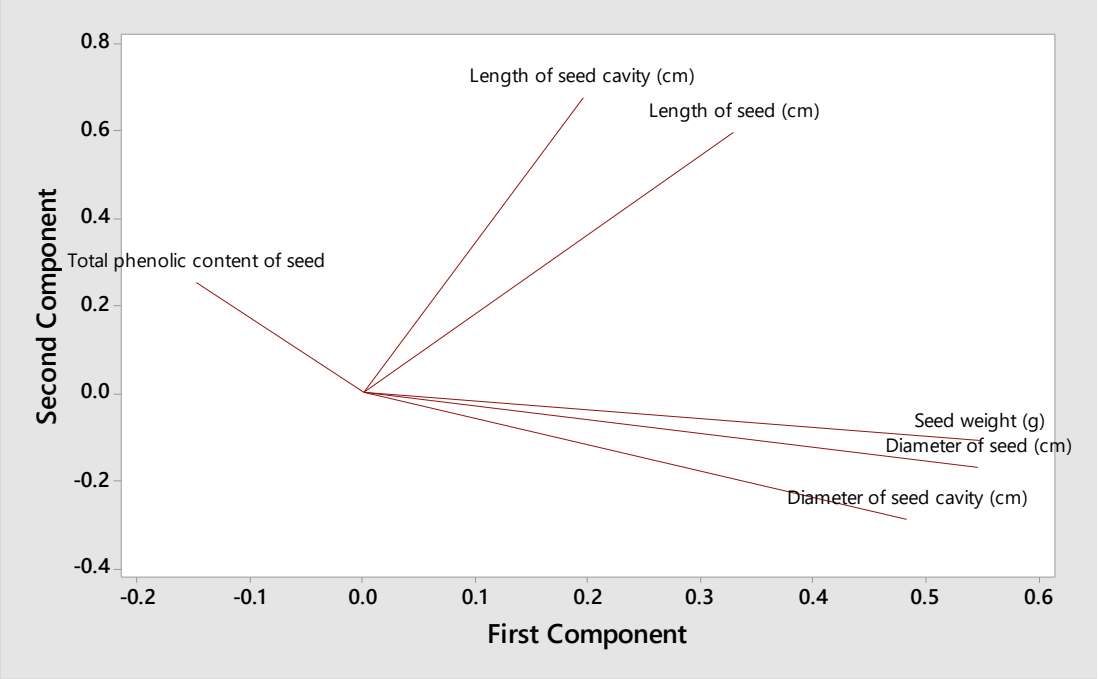


Fig. 16b Plot of first two PCA's showing relation among various quality traits of avocado

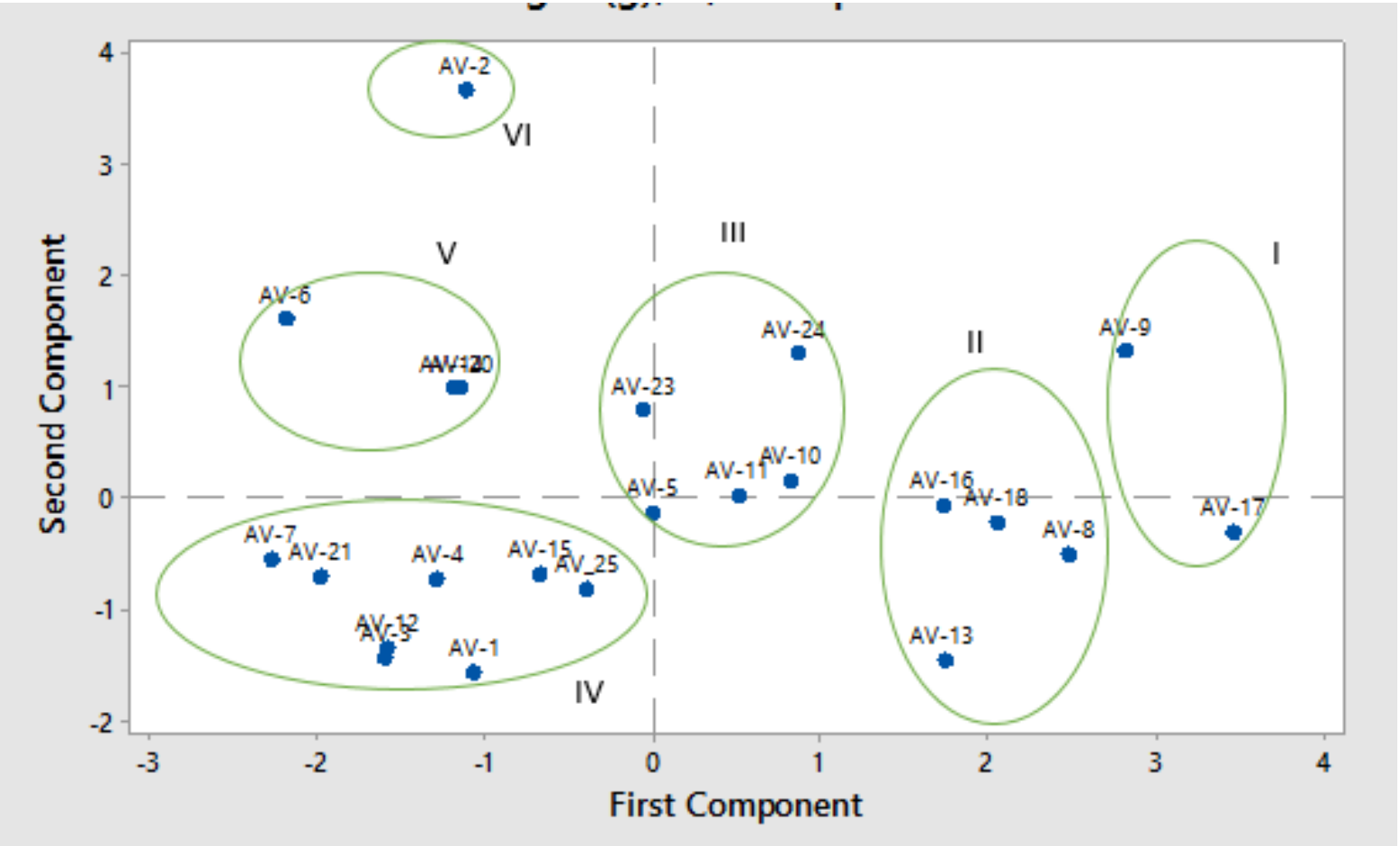


Fig. 16c Clustering of avocado accessions based on quantitative seed characters from first two components

Table 21a. Principal component analysis of quantitative characters of seed

Variable	Components					
	PC1	**PC2**	**PC3**	**PC4**	**PC5**	**PC6**
Seed weight (g)	**0.547**	-0.109	-0.059	-0.077	-0.821	0.066
Length of seed (cm)	0.33	**0.595**	0.012	-0.593	0.163	-0.398
Diameter of seed (cm)	**0.546**	-0.17	-0.014	-0.182	0.457	0.656
Length of seed cavity (cm)	0.196	**0.677**	0.2	0.647	-0.018	0.209
Diameter of seed cavity (cm)	**0.483**	**-0.287**	-0.291	0.437	0.294	-0.568
Total phenolic content of seed (mg g^{-1})	-0.147	0.252	-0.934	0.002	-0.049	0.202
Eigenvalue	2.910	1.514	0.959	0.360	0.154	0.099
Proportion	0.485	0.252	0.16	0.06	0.026	0.017
Cumulative	0.485	0.738	0.898	0.958	0.983	1

Table 21b. Clusterwise distribution of avocado accessions based on quantitative seed characters

Clusters	Size	Collections
I	2	AV-9, AV-17
II	4	AV-8, AV-18, AV-16, AV-13
III	5	AV-5, AV-11, AV-10, AV-23, AV-24
IV	8	AV-7, AV-3, AV-21, AV-12, AV-15, AV-25, AV-1, AV-4
V	3	AV-6, AV-14, AV-20
VI	1	AV-2

Table 21c. Mean performance of clusters based on quantitative seed characters

Clusters	Seed weight (g)	Length of seed (cm)	Diameter of seed (cm)	Length of seed cavity (cm)	Diameter of seed cavity (cm)	Total phenolic content of seed (mg/g)
I	**84.62**	5.44	**5.70**	5.65	5.31	**5.83**
II	73.36	4.69	5.31	5.05	5.37	12.03
III	**28.80**	4.71	3.24	5.43	3.52	12.63
IV	52.07	4.72	4.32	5.43	**4.47**	9.42
V	35.97	**3.94**	3.64	4.33	4.27	16.03
VI	32.90	**5.50**	**2.60**	**6.60**	**3.83**	**37.37**

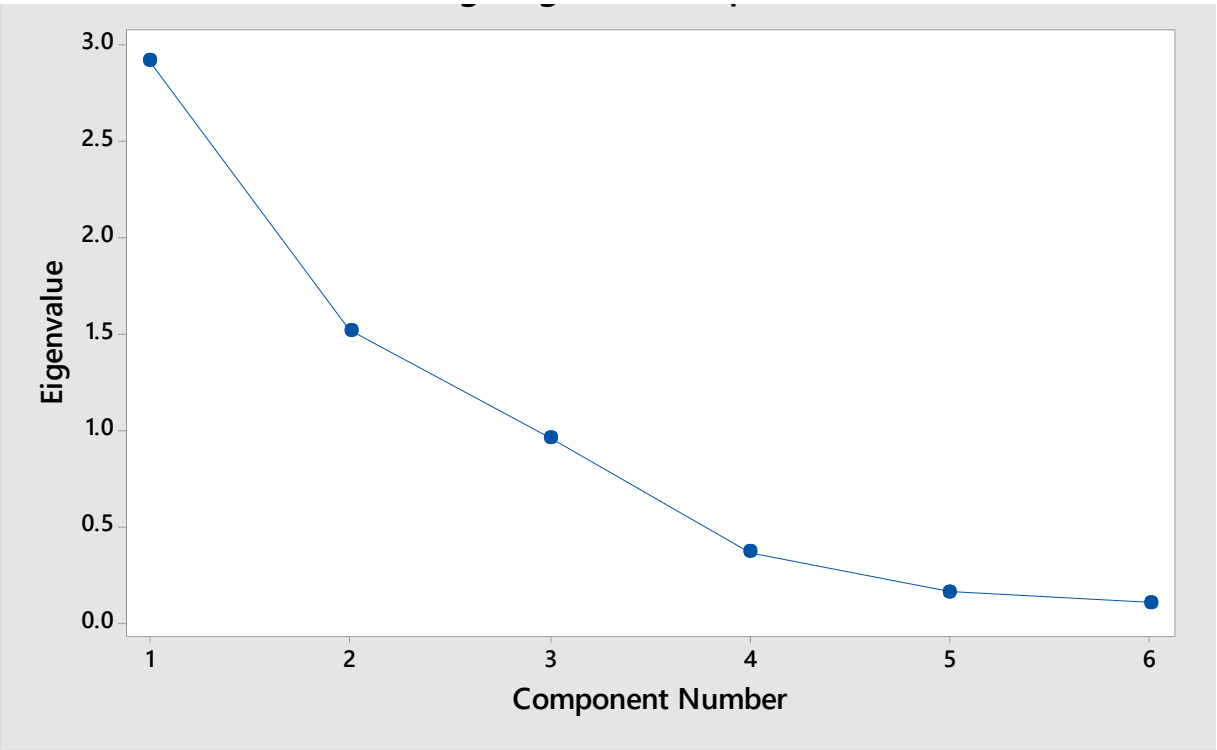


Fig. 17a Scree plot showing eigen values in response to number of components for estimated variables of avocado

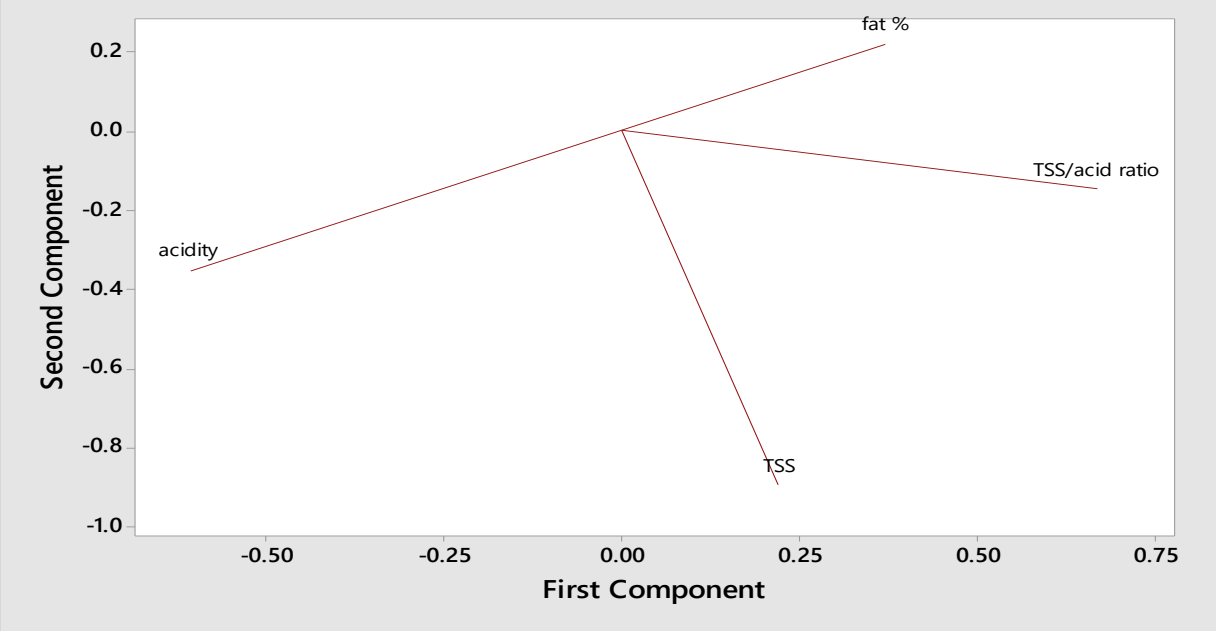


Fig. 17b Plot of first two PCA's showing relation among various quality traits of avocado

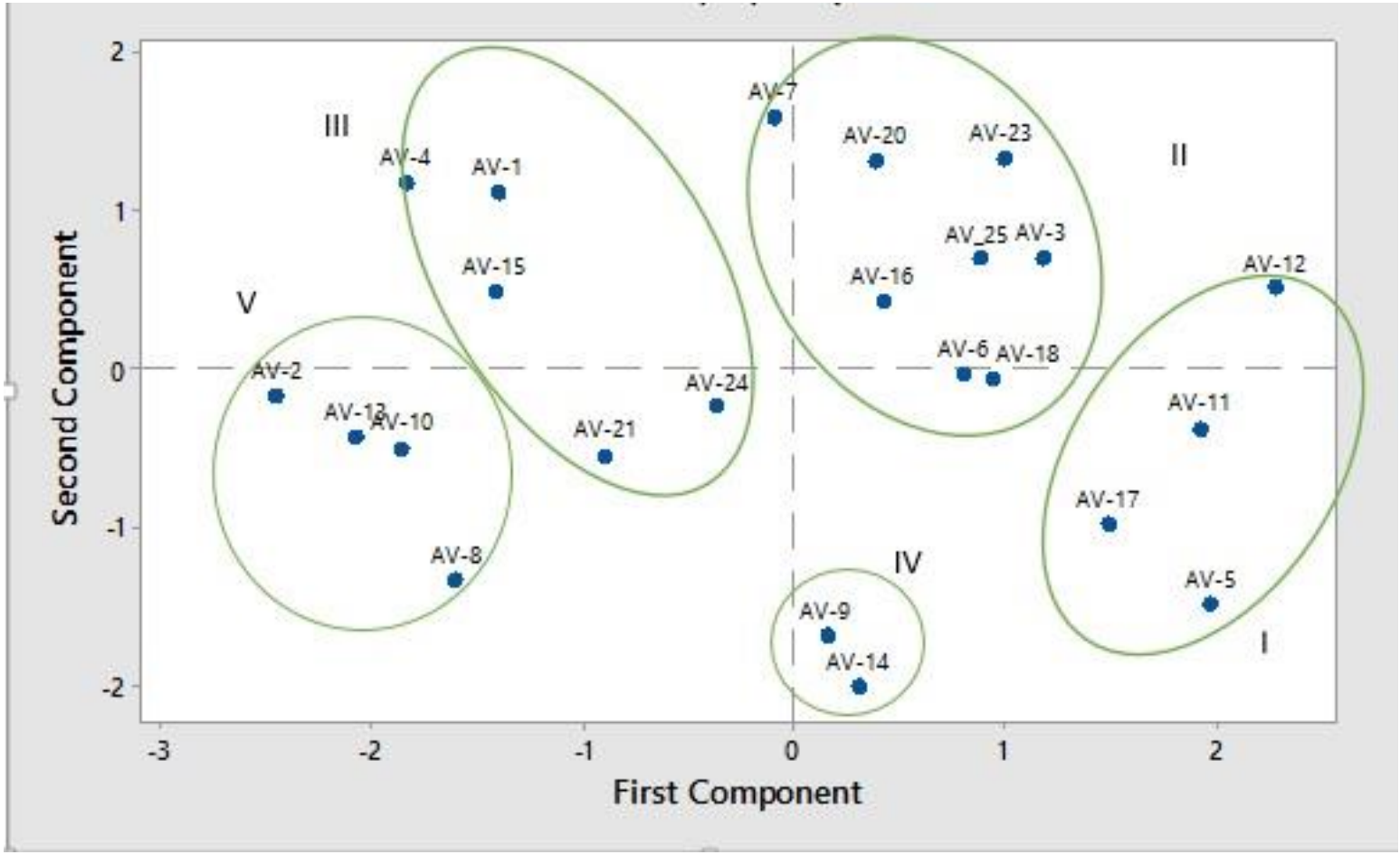


Fig. 17c Clustering of avocado accessions based on fruit quality attributes from first two components

Table 22a. Principal component analysis of fruit quality characters of avocado

Variable	Components			
	PC1	**PC2**	**PC3**	**PC4**
TSS (^{0}B)	0.219	**-0.897**	0.127	-0.361
Acidity (%)	**-0.608**	**-0.353**	0.336	0.627
Fat (%)	0.369	0.220	0.903	-0.003
TSS/acid ratio	**0.668**	-0.148	-0.235	0.690
Eigenvalue	2.067	1.098	0.816	0.017
Proportion	0.517	0.275	0.204	0.004
Cumulative	0.517	0.792	0.996	1

Table 22b. Clusterwise distribution of avocado accessions based on fruit quality characters

Clusters	Size	Collections
I	4	AV-12, AV-11, AV-17, AV-5
II	8	AV-6, AV-16, AV-18, AV-25, AV-7, AV-20, AV-23, AV-3
III	5	AV-24, AV-21, AV-1, AV-4, AV-15
IV	2	AV-9, AV-14
V	4	AV-2, AV-8, AV-10, AV-13

Table 22c. Mean performance of clusters based on fruit quality characters

Clusters	TSS (^{0}B)	Titrable acidity (%)	Fats (%)	TSS/acid ratio
I	9.28	0.64	**4.49**	**14.49**
II	**7.41**	0.64	3.92	11.58
III	7.42	0.96	**3.18**	7.73
IV	**10.40**	0.96	3.70	10.84
V	8.33	**1.28**	3.43	**6.51**

Discussion

5. DISCUSSION

Avocado (*Persea americana* Mill.) is a subtropical fruit that originated in tropical American regions. The fruit is highly nutritious and with great therapeutic value and of great demand in global fruit market.

In India, the cultivation of avocado has been limited to very few pockets of states of Tamil Nadu, Sikkim, Karnataka and Kerala (Ghosh, 2000). In Kerala, avocado cultivation has gained importance in high ranges of Wayanad and there is wide scope for its commercialization on a large scale.

The present study was conducted at Regional Agricultural Research Station, Ambalavayal in Wayanad district wherein 25 accessions of avocado were taken up for the study. Basic characterization of accessions were carried out with respect to tree, leaf, inflorescence, phenological, fruit and seed characteristics. The results of this study are discussed in this chapter

5.1.1 Tree characters

Age of the tree ranged from 6 years to 51 years with a high coefficient of variation of 55.99 per cent. Average tree height of the accessions was 9.01 cm with a CV of 27.62 per cent. High variability in tree girth was observed with coefficient of variation of 55.58 per cent. Girth of the trees ranged from 33.1 cm to 274 cm. Avocados are evergreen trees of height in the range 9m to 18m and the height can be maintained at lower levels for easy operations (Gaillard and Godefroy, 1995).

Circular, columnar, obovate and irregular type of canopy were observed in the accessions studied. Axial, ascendant, horizontal as well as verticillate branching patterns were noticed in the accessions. Branching pattern was predominantly

irregular (54.72 %) followed by ascendant (28.30 %) and then verticillate, axial, horizontal in equal proportions (5.66 %) (Abraham *et al.,* 2018).

Average leaf blade length recorded was 19.49 cm with CV 27.78 per cent. Leaf length ranged from 15.46 cm to 23.47 cm. **L**eaf width of the accessions varied from 5.540 cm to 13.15 cm with an average leaf width of 8.83 cm. Dark green or green leaves with lanceolate and narrowly obovate shape were observed in the accessions. However Nkansah (2013) and Abraham *et al.* (2018) observed five leaf shapes roundish, obovate, lanceolate, oblong- lanceolate in 100 accessions studied from four regions in Ghana.

Average shoot length was 63.695 cm with CV 20.37 per cent and average internodal length was 3.89 cm with CV 27.78 per cent. Similar results was recorded in avocado shoot and internodal length by Gregoriou and Kumar (1982).

5.2 Inflorescence characters

Out of 25 accessions, only 23 accessions flowered during the course of study. Inflorescence of avocado is greenish yellow and located terminally on the shoot. Flowering shoots of avocado are predominantly indeterminate (Schroeder, 1944). Avocado exihibits a unique flowering behaviour called protogynous diurnally synchronous dichogamy and accordingly the trees are classified into A type an B type (Stout, 1923; Bergh, 1974; Bergh 1975). A type flowering was observed in 34.8 % accessions and B type flowering in 65.2 % accessions.

Average inflorescence length of 8.16 cm with coefficient of variation 22.69 per cent was observed. Length of inflorescence varied from 5.40 cm to 11.90 cm. Average inflorescence width of 10.25 cm with coefficient of variation 28.94 per cent was observed. Width of inflorescence varied from 5.8 cm to 15.93 cm. On an average, 137.202 flowers were observed in a single inflorescence with CV value

43.75 per cent. Out of the 23 accessions that borne inflorescences, 13 had flowers above the average number and other 10 accessions had below average number. Tripathi *et al.* (2016) observed that length of panicle was minimum (5.16 cm) in CHESA-IX-3 and maximum (18.4 cm) in CHESPA-VIII-3.

5.3 Phenological characters

Avocado grows constantly by repeated flushing of which first flushing coincides with the beginning of flowering season .and each flushing lasts for three to four weeks (Davenport, 1982). Flushing in avocado occurred in months of August, September, February and March. Two seasons of flushing was recorded in September and March (4 %), September and February (24 %), September and March (20 %) and August and February (24 %). Flowering was noticed in all accessions during September to October and in addition February to March time flowering could be noticed in 17 accessions.

Mean duration of flowering was 32.17 days with a CV of 14.19 per cent and ranged from 25 to 45 days. Fruit reached harvest maturity within an average of 139.93 days from fruit setting. Harvesting was done within 107 to 163 days in the accessions. Alcaraz *et al*. (2013) observed that avocado fruits became ready for harvest within 31 to 37 weeks after flowering.

Single fruiting season was noted as March to September, October to April, October to March with frequencies 13 %, 30.4 % and 4.3 % respectively. Two seasons of fruiting *viz.*, September to October and February to March with frequency distribution 69.6 per cent and October to March and March to August with frequency distribution of 4.3 %.

5.4 Fruit characters

On an average, 291.6 fruits were obtained per tree. Highest number of fruits was recorded on AV- 3 (920 fruits per tree) followed by AV-25 (904 fruits per tree) and AV-11 (875 fruits per tree). An average yield of 89.29 kg per tree was obtained. Highest yield of 382.5 kg per tree was recorded in AV-6 and lowest yield of 6.27 kg per tree was recorded in AV-4. Average fruit yield is an interaction of tree age, environmental factors, cultivar and rootstock (Anon,1985). Though there is heavy flowering, the fruitset in avocado is as low as 1.5 % in Fuerte (Lahav and Zamet, 1999). This flower and fruit abscission is so as to reduce carbohydrate competition. (Scholefield, 1982; Buchholtz, 1986).

Individual fruit weight ranged from 152.4 g in AV-7 to 434.2 g in AV-17.The mean fruit weight was 282 g with a CV of 31.5 %. Length of the fruit varied from 7.68 cm in AV-15 to 14.66 cm in AV-2 with a CV of 16.94 per cent. Average fruit length was recorded as 9.91 cm. Diameter of fruit ranged from 5.3 cm in AV-21 to 8.42 as in AV-18. Average fruit diameter was recorded as 6.85 cm with a CV of 14.02 per cent.

Variability was noticed with regard to fruit shape *viz.,* narrowly obovate, clavate, obovate pyriform, ellipsoid types. Fruit base shape was observed as depressed in 73.9 per cent accessions and inflated in 26.1 accessions. Fruit apex shape was flattened in 30.4 accessions and rounded in 69.6 per cent accessions. Fruit apex position was central in 52.2 per cent accessions while asymmetric in 47.8 per cent accessions. In majority of accessions (91.3 %) no ridges were present on fruit surface while 8.7 per cent accessions possessed fruits with ridges on surface. 65.2 per cent of accessions had fruits with medium glossiness and 34.8 accessions had weak glossiness on fruits. Pedicel was located asymmetrically in 56.5 per cent accessions and centrally in 43.5 per cent accessions. Fruit skin surface was smooth in

73.9 per cent accessions, intermediate in 17.4 per cent accessions and rough in 7.4 per cent accession. Fruit skin thickness was recorded as 1 mm or 2 mm.

The fruit skin in ripe fruits were either purple or light green. Light green skinned fruits were found in 13 per cent accessions whereas purple skinned fruits were found in 87 per cent accessions. Colour of pulp next to seed was either light yellow (65.2 %) and yellow (34.8 %). External characterisation of avocado from Venezuela also showed that fruit peel was either rough or smooth and the peel colour was either purple or green (Gomez- Lopez, 1998). Avocado belongs to different horticultural races wherein the morphology of fruits vary greatly within races and hence wide variability can be observed with respect to fruit skin, size, shape and seed characters (Scora *et al.,* 2002).

Flesh texture of avocado was buttery in all accessions. Avocado fruits contain specialized parenchyma cells called idioblasts resulting in buttery texture (Platt-Aloia and Thomson, 1981). Only low degree of discolouration was observed upto 4 hours in fruits cut and kept at room temperature.

Avocado is climateric in nature and do not ripen unless it is harvested (Lee *et al.,* 1983;.Lewis, 1978). Ripening on tree is inhibited by low levels of ethylene and ACC.(Sitrit and Blumenfield,1986). On abcission of matured fruits from tree ethylene production increases and triggers climateric rise in respiration thereby inducing respiration (Chen *et al*.,1993; Rice *et al.,* 1993; Samson, 1980). Number of days to ripening from harvest varied from 3 to 15 days. Average storage days was recorded as 7.37 days with a CV of 41.03 per cent. Least storage days were required for ripening in accession AV-1 (3 days) followed by AV-2 (3.5 days), AV-25 (4 days). Maximum storage days of fruit was recorded for AV-8 (15 days). Hatton and Campbell (1959) observed ripening of avocado under normal conditions took 3 to 15

days. Similarly Gomez Lopez (1998) also reported that in cultivars Linda, Booth 8, River, Russell and Secundino, days to ripening ranged between 4 to 12 days.

The shelf life of avocado at room temperature is very low. Mean shelf life of ripe fruits was recorded to be 1.3 days. Maximum shelf life recorded was 2 days in accessions AV-2, AV-10, AV-16 and AV-17. At room temperature, the storage life of avocado is minimum and gets deteriorated by over-ripeness and fruit decay (Kosiyachinda and Young, 1976). Incidence of fungal pathogens as well as mechanical and frictional damages or internal disorders like grey pulp, change in pulp texture, vascular leaching also hampers the quality of fruits (Swarts, 1984).

5.5 Seed characters

Various shape of seeds were observed in the accessions such as base flattened apex conical, base flattened apex rounded, ovate, broadly ovate and cordiform.

Mean seed weight of avocado was 49.13g with a CV of 41.64 per cent. Maximum seed weight was observed to be 100.1g as in AV-17 and the minimum seed weight was 26.2g as in AV-6.

Seed cotyledon surface was classified as smooth, intermediate and rough. Accessions AV-2, AV-3, AV-6, AV-10, AV-12, AV-15, AV-16, AV-20, AV-21, AV-23 and AV-24 had smooth surface, accessions AV-1, AV-4, AV-5, AV-7, AV-9, AV-11, AV-14, AV-25 had intermediate surface and accessions AV-8, AV-13, AV-17and AV-18 had cotyledons with rough surface. The seeds were found to possess attached cotyledons in all accessions. Cotyledon surface was identified to be smooth (47.8 %), intermediate (34.8 %) or rough (17.4 %).

Cotyleon colour was identified to be cream in 39.1 per cent accessions, yellow in 34.8 per cent accessions and ivory in 26.1 per cent accessions.

Among accessions studied, seed position was central in 30.4 per cent accessions and apical in 69.6 per cent accessions. Free space in seed cavity was towards seed apex in 13 per cent accessions, at seed base in 8.7 per cent accessions whereas 78.3 per cent accessions had no free space in avocado. Similar variability in seed morphology was observed in avocado by Abraham *et al.* (2018).

Seed cavity length ranged from 4.2 cm to 6.6 cm with a CV of 13.72 per cent. Mean value of seed cavity length was recorded as 5.049 cm. Diameter of seed cavity ranged from 3.03 cm to 5.07 cm with a CV of 15.57 per cent. Average value of diameter of seed cavity was recorded as 4.478 cm. Maximum seed length of 5.57 cm was observed in AV-9 followed by 5.50 cm in AV-2. Minimum seed length was recorded in AV-1 (3.40 cm). Average value of seed length was 4.53 cm with a CV of 41.64 per cent. Diameter of seed ranged from 2.37 cm to 5.82 cm. Average diameter of seed was calculated as 4.53 cm with a CV of 13.36 per cent.

Average total phenolic content of avocado seeds was estimated to be 13.49 mg g^{-1} with a high CV of 78.67 per cent. The total phenolic content of avocado accessions ranged from 2.4 to 37.37 mg g^{-1}. Githinji (2014) reported that maximum phenolic content was observed in Fuerte (18.45 mg g^{-1} GAE).

5.6 Quality attributes

The quality of avocado fruits was estimated using different parameters such as total soluble solids, titrable acidity, TSS/acid ratio, percentage content of fats, total sugars, reducing sugars and non-reducing sugars. Total sugars, reducing sugars and non-reducing sugars were found to be present in negligible quantity in fruits of all

accessions. In comparison to other fruits, avocado contains very little sugar. It is as low as 0.2 g per one-half avocado (USDA, 2011).

Average TSS of avocado fruits was estimated as 8.15 ^{0}B with a CV of 14.96 per cent. TSS was recorded to be highest in AV-14 (10.4 ^{0}B) followed by AV-9 (10.2 ^{0}B), AV-5 (10.1 ^{0}B) and AV-17 (9.4 ^{0}B). Minimum value of TSS (6.3 ^{0}B) was recorded in accessions AV-4 and AV-7. Similar observations were made in avocado by Kaplankiran and Tuzcu, 1994; Toplu *et al.*, 1998, Ozdemir *et al.*, 2009 and Arias *et al*., 2012.

Titrable acidity of avocado ranged from 0.64 per cent to 1.28 per cent and displayed a CV of 29.23 per cent. Average value of titrable acidity was recorded as 0.84 per cent. Vinha *et al.* (2013) reported titrable acidity in Hass avocado was 1.07 $\pm$ 0.02 per cent.

Maximum TSS/acidity ratio was recorded in accession AV-5 with a value of 15.78 and minimum TSS/acidity ratio was recorded in accession AV-2 (5.92). Average value was estimated to be 10.30 with a CV of 28.63 per cent.

Average fat content of avocado pulp was recorded as 3.75 per cent with a CV of 28.95 per cent. Maximum fat content of 6.78 per cent was recorded in AV-12 and minimum fat content of 2.63 per cent was recorded in accession AV-4.

5.7 Organoleptic scoring of fruit

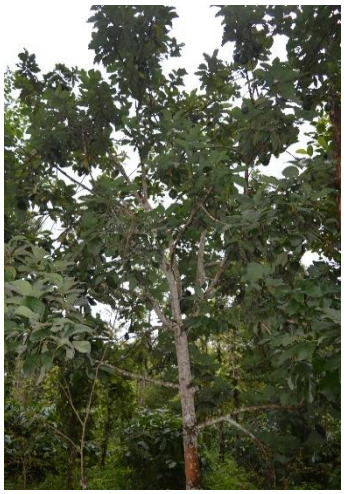
Organoleptic scoring of fruits gives a light on consumer reference in market thereby indicating marketability of fruits. Appearance is a major factor affecting consumer picking behaviour. In terms of appearance, mean rank was highest in AV-10 (20.10) followed by AV- 24 (18.75), AV-11 (17.30) and AV-17 (17.10). With respective to colour, AV-2 (18.95), AV-3 (18.15), AV-6 (18.00) and AV-17 (16.80)

AV-1

AV-2

AV-3

AV- 4



AV-5

AV-6

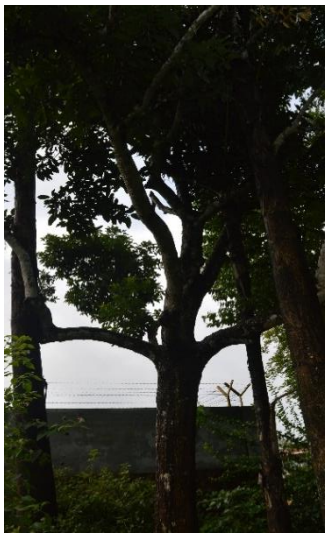
AV-7

AV-8

AV-9

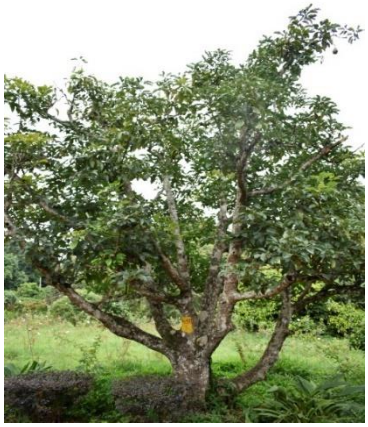
Plate 24a. Avocado accessions from AV-1 to AV-9

AV-10



AV-11

AV-12



AV-13

AV-14

AV-15

Plate 24b. Avocado accessions from AV-10 to AV-15

AV-16

AV-17

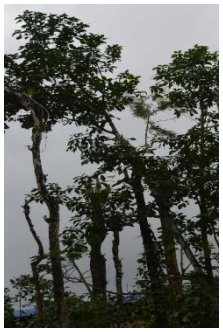
AV-18

AV-19

AV-20

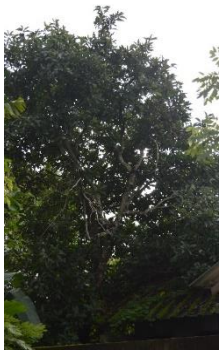
AV-21

AV-22



AV-23

AV-24

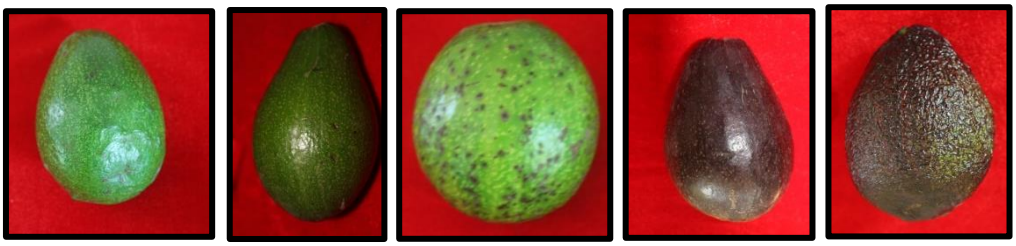


AV-25

Plate 24c. Avocado accessions from AV-16 to AV-25

AV-1 AV-2 AV-3 AV-4 AV-5

AV-6 AV-7 AV-8 AV-9 AV-10



AV-11 AV-12 AV-13 AV-14 AV-15

AV-16 AV-17 AV-18 AV-20

AV-21 AV-23 AV-24 AV-25

Plate 25. Fruits of different avocado accessions

had highest preference. In terms of flavour, highest mean rank was in AV- 13 (19.80) and for taste AV-2 (19.40) AV-24 (19.30) followed AV-10 (19.25), AV-9 (19.10), AV-17 (18.65) had the highest overall acceptability.

5.8 Pest and disease incidence

Fruit quality and appearance was severely affected by incidence of avocado scab and anthracnose. *Colletotrichum gloeosporioides* caused anthracnose which resulted in die back. Anthracnose occurs both in field and post harvest conditions and affects marketability of fruits (Hartill,1991) Avocado scab caused by *Sphaceloma perseae* was also reported in fruits resulting in necrotic brown coloured patches on fruit surface (Jenkins,1925). Apart from this, there was also occurence of red rusts. Phytophthora root rot resulted in complete dying of trees and shedding of leaves leaving behind a bare framework (Zentmyer, 1953). Anthracnose and stem-end rot was noticed in fruits during post- harvest storage. Advanced spore development on fruits hamperes the palatability of fruits and as a result decreases the shelf life of fruits. There was internal greying, degradation of pulp texture and occurrence of vascular streaks affectingthe quality and storability of ripen fruits.

5.9 Principal Component Analysis

To study the contribution of each character to variability principal component analysis was done. Similar analysis has been performed in crops of litchi, rambutan grown in Wayanad region and factors associated with variability was determinedand it was observed that the first three componenets accounted for maximum variability. (Chavaradar, 2016; Muhamed, 2016)

PCA was performed for morphological traits of tree, inflorescence, fruit and seed as well as quality parameters of fruit. PCA grouped the tree characters into seven main components of which first three components accounted for 74.4 per cent

of total variation. PC1 was contributed mainly by leaf width, tree girth and leaf length with PC loadings of 0.502, -0.486 and 0.467 respectively. Though leaf length and leaf width contributed positively, tree girth gave negative contribution to PC1. The component PC2 was contributed by internodal length, leaf length and age of tree with PC loadings of 0.559, 0.460 and 0.426 all contributing positively to the component. Shoot length, tree height and internodal length featured PC3. Loading plot for tree characters depicted that there was a strong association of age of tree and tree girth with extreme acute angles. Leaf length and leaf width also showed acute angles between them indicating close association. Clustering was done and 25 accessions were grouped into six clusters. Maximum number of accessions belonged to cluster V with nine accessions and cluster IV and VI were comprised of single accessions each. Mean performance of clusters show that cluster III recorded minimum age of tree while cluster VI recorded maximum tree girth and internodal length. Leaf length was maximum in cluster I while leaf width had maximum value in cluster III.

In case of inflorescence traits, the components PC1, PC2 and PC3 had eigen values greater than one and contributed maximum to the total variability in proportions of 31.2 per cent and 23.4 per cent respectively. PC1 comprised of duration of flowering, number of flowers per inflorescence and number of days from fruit set to harvest.Width of inflorescence, number of days from flowering to fruit set and number of flowers per inflorescence contributed to PC2. A positive association between number of days from flowering to fruit set and duration of flowering indicated by the acute angle. Out of 23 accessions those which flowering occurred were grouped into eight clusters. Maximum number of accessions belonged to cluster VII with six accessions and cluster IV comprised of five accessions. Mean performance of clusters show that cluster I recorded highest number of inflorescence per tree, duration of flowering and minimum length of inflorescence. Cluster VIII recorded maximum values for length of inflorescence, width of inflorescence and number of days from fruit set to harvest and minimum duration of flowering. Cluster

II recorded highest number of days from flowering to fruit set and lowest number of days from fruit set to harvest.

Principal component analysis was performed using quantitative characters of fruit such as number of fruits, yield per tree, fruit weight, fruit length, fruit diameter, storage days of fruit and shelf life of fruit. First three components showed eigen values above 1 which accounted for total variability of 75.3 per cent. Fruit length, fruit weight and fruit diameter contributed positively to PC1. PC2 was composed mainly of fruit yield and number of fruits. Factors contributing to PC3 were storage days of fruit, shelf life of fruit and fruit diameter. Loading plot of first two components depicts strong association of yield of tree with number of fruits which explains the extreme acute angle between them. Shelf life of fruit and storage days of fruit had negative association. Fruit weight showed close association with fruit length as well as fruit diameter. The 23 fruiting accessions were grouped into six clusters. Maximum number of accessions belonged to cluster II with 13 accessions and cluster IV and cluster VI comprised of single accession each. Cluster I showed maximum fruit weight, fruit length, fruit diameter and shelf life of fruit. Cluster IV consisting of single accession AV-7 had the minimum mean value of yield per tree, fruit weight, fruit length, fruit diameter but also recorded maximum storage days of fruit. Maximum yield was recorded in cluster V and maximum number of fruits per tree was recorded in cluster VI.

The PCA grouped seed characters of avocado into 4 components of which PC1 and PC2 had eigen values greater than 1. PC1 mainly composed of seed weight, diameter of seed, and diameter of seed cavity. Length of seed cavity, length of seed and diameter of seed cavity contributed significantly to PC2. Loading plot of first two components shows that there is a strong association between seed weight with seed diameter and seed diameter with diameter of seed cavity. Also, length of seed and length of seed cavity had a positive association.

Six clusters were formed wherein maximum number of accessions belonged to cluster IV with 8 accessions and cluster VI comprised of single accession. Mean performance of clusters demonstrated that cluster I showed maximum seed weight, diameter of seed and least total phenolic content. Cluster VI recorded minimum value of seed diameter, diameter of seed cavity and maximum value of seed length, length of seed cavity and total phenolic content.

In case of fruit quality attributes, PC1 and PC2 contributes significantly to total variation. PC1 was contributed by acidity, TSS/acid ratio and fat whereas TSS and acidity with PC loadings contributed to PC2. Acidity and TSS/acid ratio had strong association but acidity and fat % had negative correlation.

Based on fruit quality attributes, the accessions were divided into 5 clusters. With cluster II having maximum number of accessions (8 accessions). Cluster V recorded maximum value of titrable acidity and minimum value of TSS/acid ratio. Highest TSS was recorded in cluster IV and minimum TSS was recorded in cluster II. Cluster I had maximum value of fats and TSS/acid ratio.

5.11 Promising Accessions

Wide variability was observed with respect to morphological and phenological variation in the accessions. AV-3, AV-11 and AV-25 are accessions with high yield potential. In terms of quality, accessions AV-2, AV-10, AV-11, AV-24 and AV-3 can be regarded as superior among the collections and can be made use in breeding programmes.

Summary

6. SUMMARY

The project entitled “Characterization of Avocado (*Persea americana* Mill)” had been conducted in the Department of Fruit Science in the year 2018-19 as a preliminary investigation of basic characterisitcs of avocado accessions prevailing in the high ranges of Kerala. During the course of study, 25 accessions of avocado maintained at Regional Agricultural Research Station, Ambalavayal in Wayanad district. Basic characterization of accessions were carried out by evaluation of morphological characters in terms of tree, leaf, inflorescence, fruit, seed characteristics and phenological characters in terms of time of flushing, flowering, fruiting were recorded. The results of the study are summarized as follows.

Age of the tree ranged from 6 years to 51 years with a high coefficient of variation of 55.99 per cent.

Average tree height of the accessions was 9.01 cm with a CV of 27.62 per cent. High variability in trunk girth was observed with coefficient of variation 55.58 per cent and it ranged from 33.10 cm to 274.00 cm.

Circular, columnar, obovate and irregular type of canopy were observed in the accessions studied. Axial, ascendant, horizontal as well as verticillate branching patterns were noticed in the accessions.

Average leaf blade length was 19.49 cm with CV 27.78 per cent. Leaf length ranged from 15.46 cm to 23.47 cm. Leaf width of the accessions varied from 5.540 cm to 13.15 cm with an average leaf width of 8.83 cm. Dark green or green leaves with lanceolate and narrowly obovate shape were observed in the accessions..

Average shoot length was 63.695 cm with CV 20.37 per cent and average internodal length was 3.892 cm with CV 27.784 per cent.

Out of 25 accessions, only 23 accessions flowered during the course of study. Inflorescence of avocado is greenish yellow and located terminally on the shoot. A type flowering was observed in 34.8 % accessions and B type flowering in 65.2 % accessions.

Average inflorescence length of 8.16 cm with coefficient of variation 22.69 per cent was observed. Length of inflorescence varied from 5.40 cm to 11.90 cm. Average inflorescence width of 10.25 cm with coefficient of variation 28.94 per cent was observed. Width of inflorescence varied from 5.80 cm to 15.93 cm. On an average, 137.20 flowers were observed in a single inflorescence with CV value 43.75 per cent. Out of the 23 accessions that borne inflorescences, 13 had flowers above the average number and other 10 accessions had below average number.

Flushing in avocado occurred in months of August, September, February and March. Two seasons of flushing was recorded in September and March (4 %), September and February (24 %), September and March (20 %) and August and February (24 %). Flowering was noticed in all accessions during September to October and in addition February to March time flowering could be noticed in 17 accessions.

Mean duration of flowering was 32.17 days with a CV of 14.19 per cent and ranged from 25 to 45 days. **F**ruit reached harvest maturity within an average of 139.93 days from fruit setting. Harvesting was done within 107 to 163 days in the accessions.

Single fruiting season was noted as March to September, October to April, October to March with frequencies 13 %, 30.4 % and 4.3 % respectively. Two seasons of fruiting *viz.*, September to October and February to March with frequency distribution of 69.6 per cent and October to March and March to August with frequency distribution of 4.3 %.

On an average, 291.60 fruits were obtained per tree. Highest number of fruits was recorded in AV- 3 (920 fruits per tree) followed by AV-25 (904 fruits per tree) and AV-11 (875 fruits per tree). Average tree yield of 89.29 kg was obtained. Highest yield of 382.5 kg per tree was recorded in AV-6 and lowest yield of 6.27 kg per tree was recorded in AV-4.

Individual fruit weight ranged from 152.40 g in AV-7 to 434.20 g in AV-17. The mean fruit weight was 282.00 g with a CV of 31.50 %. Length of the fruit varied from 7.68 cm in AV-15 to 14.66 cm in AV-2 with a CV of 16.94 per cent. Average fruit length was recorded as 9.91 cm. Diameter of fruit ranged from 5.3 cm in AV-21 to 8.42 as in AV-18. Average fruit diameter was recorded as 6.85 cm with a CV of 14.02 per cent.

Variability was noticed with regard to fruit shape viz., narrowly obovate, clavate, obovate pyriform, ellipsoid types. Fruit base shape was observed as depressed in 73.9 per cent accessions and inflated in 26.1 accessions. Fruit apex shape was flattened in 30.4 accessions and rounded in 69.6 per cent accessions.

Fruit apex position was central in 52.2 per cent accessions while asymmetric in 47.8 per cent accessions. In majority of accessions (91.3 %) no ridges were present on fruit surface while 8.7 per cent accessions possessed fruits with ridges on surface. 65.2 per cent of accessions had fruits with medium glossiness and 34.8 accessions had weak glossiness on fruits. Pedicel was located asymmetrically in 56.5 per cent accessions and centrally in 43.5 per cent accessions. Fruit skin surface was smooth in 73.9 per cent accessions, intermediate in 17.4 per cent accessions and rough in 7.4 per cent accession. Fruit skin thickness was recorded as 1 mm or 2 mm.

The fruit skin in ripe fruits were either purple or light green. Light green skinned fruits were found in 13 per cent accessions whereas purple skinned fruits

were found in 87 per cent accessions. Colour of pulp next to seed was either light yellow (65.2 %) and yellow (34.8 %).

Flesh texture of avocado was buttery in all accessions. Low degree of discolouration was observed upto 4 hours in cut fruits. .

Number of days to ripening from harvest varied from 3 to 15 days. Average storage days was recorded as 7.37 days with a CV of 41.03 per cent. Least storage days were required for ripening in accession AV-1 (3 days) followed by AV-2 (3.5 days), AV-25 (4 days). Maximum storage days of fruit was recorded for AV-8 (15 days).

Mean shelf life of ripe fruits was recorded to be 1.3 days. Maximum shelf life of 2 days was recorded in accessions AV-2, AV-10, AV-16 and AV-17.

Wide variability in shape of seeds were observed in the accessions such as base flattened apex conical, base flattened apex rounded, ovate, broadly ovate, and cordiform.

Mean seed weight of avocado was 49.13 g with a CV of 41.64 per cent. Maximum seed weight was observed to be 100.10 g as in AV-17 and the minimum seed weight was 26.20 g as in AV-6.

Seed cotyledon surface was classified as smooth, intermediate and rough. Accessions AV-2, AV-3, AV-6, AV-10, AV-12, AV-15, AV-16, AV-20, AV-21, AV-23 and AV-24 had smooth surface, accessions AV-1, AV-4, AV-5, AV-7, AV-9, AV-11, AV-14, AV-25 had intermediate surface and accessions AV-8, AV-13, AV-17 and AV-18 had cotyledons with rough surface. Attached cotyledons was recorded in all accessions. Cotyledon surface was identified to be smooth (47.8 %), intermediate (34.8 %) or rough (17.4 %). Cotyledon colour was identified to be

cream in 39.10 per cent accessions, yellow in 34.80 per cent accessions and ivory in 26.10 per cent accessions.

Among accessions, seed position was central in 30.4 per cent accessions and apical in 69.6 per cent accessions. Free space in seed cavity was towards seed apex in 13 per cent accessions, at seed base in 8.70 per cent accessions whereas 78.30 per cent accessions had no free space in seed cavity.

Seed cavity length ranged from 4.20 cm to 6.60 cm with a CV of 13.72 per cent. Mean value of seed cavity length was recorded as 5.04 cm. Diameter of seed cavity ranged from 3.03 cm to 5.07 cm with a CV of 15.57 per cent. Average value of diameter of seed cavity was recorded as 4.47 cm. Seed length ranged from 5.57 cm (AV-9) to 3.40 cm (AV-1). Average value of seed length was 4.53 cm with a CV of 41.64 per cent. Diameter of seed ranged from 2.37 cm to 5.82 cm. Average diameter of seed was calculated as 4.53 cm with a CV of 13.36 per cent.

Average total phenolic content of avocado seeds was estimated to be 13.49 mg g^{-1} with a high CV of 78.67 per cent. The total phenolic content of avocado accessions ranged from 2.4 to 37.37 mg g^{-1}.

Total sugars, reducing sugars and non-reducing sugars were found to be present in negligible quantity in fruits of all accessions.

Average TSS of avocado fruits was estimated as 8.15 ^{0}B with a CV of 14.96 per cent. TSS was recorded to be highest in AV-14 (10.4 ^{0}B) followed by AV-9 (10.2 ^{0}B), AV-5 (10.1 ^{0}B) and AV-17 (9.4 ^{0}B). Minimum value of TSS (6.3 ^{0}B) was recorded in accessions AV-4 and AV-7.

Titrable acidity of avocado ranged from 0.64 per cent to 1.28 per cent and displayed a CV of 29.23 per cent. Average value of titrable acidity was recorded as 0.84 per cent.

Maximum TSS/acidity ratio was recorded in accession AV-5 with a value of 15.78 and minimum TSS/acidity ratio was recorded in accession AV-2 (5.92). Average value was estimated to be 10.30 with a CV of 28.63 per cent.

Average fat content of avocado pulp was recorded as 3.75 per cent with a CV of 28.95 per cent. Maximum fat content of 6.78 per cent was recorded in AV-12 and minimum fat content of 2.63 per cent was recorded in accession AV-4.

In terms of appearance, mean rank was highest in AV- 10 (20.10) followed by AV- 24 (18.75), AV-11 (17.30) and AV-17 (17.10). With respective to colour, AV-2 (18.95), AV-3 (18.15), AV-6 (18.00) and AV-17 (16.80) had highest preference. In terms of flavour, highest mean rank was in AV- 13 (19.80) and for taste in AV-2 (19.4). Aftertaste of AV-24, texture of AV-10 and odour of AV-17 was considered to be most acceptable by the judges. AV-24 (19.30) followed by AV-10 (19.25), AV-9 (19.10) had the highest overall acceptability.

No major incidence of pests were recorded. However there was an occurence of anthracnose both in field and storage conditions. Other diseases noticed were avocado scab and minor incidence of pink disease and red rusts.

PCA was performed for morphological traits of tree, inflorescence, fruit and seed as well as quality parameters of fruit. PCA grouped the tree characters into seven main components of which first three components accounted for 74.4 per cent of total variation. Clustering was done and 25 accessions were grouped into six clusters.

In case of inflorescence traits, the components PC1, PC2 and PC3 had eigen values greater than one and contributed maximum to the total variability in proportions of 31.2 per cent and 23.4 per cent, respectively. The 23 accessions in which flowering occurred were grouped into eight clusters based on the first two PCs.

For fruit characters, first three components showed eigen values above 1 which accounted for total variability of 75.3 per cent. The 23 fruiting accessions were grouped into six clusters.

The PCA grouped seed characters of avocado into 4 components of which PC1 and PC2 accounted for 73.80 per cent of variability. Six clusters were formed wherein maximum number of accessions belonged to cluster IV with 8 accessions and cluster VI comprised of single accession

In case of PCA of fruit quality attributes, PC1 and PC2 contributed 79.20 per cent of total variation. Based on fruit quality attributes, the accessions were divided into 5 clusters.

From the present study, it could be inferred that accessions AV-3, AV-11 and AV-25 have high yield potential and in terms of quality, while accessions AV-2, AV-10, AV-24, AV-3 can be regarded as superior among the collections. Hence these accessions can be subjected to further studies and developed into farmer preferred varieties.

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Appendices

Score card for organoleptic evaluation

Name of the judge:

Date :

	T1	**T2**	**T3**	**T4**	**T5**	**T6**	**C1**	**C2**
Appearance								
Colour								
Body								
Flavour								
Taste								
After taste								
Odour								
Overall acceptability								

9 point Hedonic scale

Like extremely	9
Like very much	8
Like moderately	7
Like slightly	6
Neither like nor dislike	5
Dislike slightly	4
Dislike moderately	3
Dislike very much	2
Dislike extremely	1

Signature:

CHARACTERIZATION OF AVOCADO

by

ANU ANN AUGUSTINE
(2017-12-003)

Abstract of the Thesis

Submitted in partial fulfilment of the requirement for the degree of

Master of Science in Horticulture
(FRUIT SCIENCE)

Faculty of Agriculture
Kerala Agricultural University

DEPARTMENT OF FRUIT SCIENCE
COLLEGE OF HORTICULTURE
KERALA AGRICULTURAL UNIVERSITY
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KERALA, INDIA

2020

Abstract

Avocado (*Persea americana* Mill.) popularly known as butter fruit, is a subtropical fruit belonging to family Lauraceae. The present work undertaken in the Department of Fruit Science during the period 2018-19 to study the morphology, flowering pattern and fruit set in avocado (*Persea americana* Mill.) grown in high ranges of Kerala is the pioneer study done in avocado. Basic characterization of 25 accessions of avocado maintained at Regional Agricultural Research Station, Ambalavayal in Wayanad district was carried out. Morphological and phenological characters of tree, leaf, inflorescence, fruit and seed were evaluated as per the IPGRI descriptor for avocado (*Persea* spp.).

The age of accessions ranged from 6-51 years and hence wide variability with respect to tree characters such as tree height (5.87 to 14.50 cm), trunk girth (33.10 to 274 cm), crown shape (circular, columnar, obovate and irregular), branching pattern (axial, ascendant, horizontal and verticillate), leaf blade length (15.46 to 23.47 cm), leaf width (5.54 to 13.15 cm), leaf blade colour (dark green and green), leaf shape (lanceolate and narrowly obovate), shoot length (89.60 to 42.02 cm) and internodal length ((1.82 to 5.78 cm) were observed among the accessions.

Out of the 25 accessions studied, 23 accessions flowered during the period of study. Avocado is known to exhibit a distinct flowering pattern and both A type (in 8 accessions) and B type (in 15 accessions) flowering pattern were noticed. Greenish yellow inflorescence were found to be borne terminally on shoots. Average number of flowers per inflorescence was 137.20 with average inflorescence length of 8.16 cm and width of 10.25 cm. Flushing in avocado occurred during the months of February (3 accessions), March (2 accessions) and September (2 accessions) and flushing was noticed twice in a year during August and February (6 accessions), September and February (6 accessions) and September and March (6 accessions). All the 23 accessions flowered during September to October and 18 out of 23 accessions

flowered again in February to March. Flowering continued from 25 to 45 days and flowers were found to set fruits in 12 to 35 days and fruits reached harvest maturity in 109 to 164 days. Both single fruiting season (47.7 %) and double fruiting season (51.8 %) were observed.

On an average, yield per tree was 89.29 kg and number of fruits per tree was 904. Variability was observed in fruit characters such as fruit weight (152.40 to 434.20g), fruit shape (narrowly obovate, clavate, obovate, ellipsoid, spheroid and pyriform), fruit length (7.68 to 14.66 cm), diameter (5.30 to 8.42 cm), base shape (depressed and inflated), apex shape (flattened or rounded), apex position (asymmetric or central) and pedicel position (central or asymmetrical). Fruit skin characters observed were thickness (1 mm and 2 mm), ridges (absent or entire), glossiness (weak or intermediate), surface (smooth, intermediate and rough) and colour (purple or light green). Fruit pulp was buttery in texture with light green colour near to skin and yellow or light yellow near to seed in all the 23 accessions. The fruits ripened in 3 to 15 days and had short shelf life of 1 to 2 days.

Avocado seeds showed variability in terms of weight (26.20 to 100.10g), length (3.40 to 5.57 cm), diameter (2.37 to 5.82 cm) and total phenolic content (2.4 to 37.37mg g^{-1}). Variability was also observed for qualitative characters of seeds such as seed shape, cotyledon surface, cotyledon colour, seed position and free space of cavity.

Quality attributes such as TSS (6.3 ^{0}Brix to 10.4 ^{0}Brix), titrable acidity (0.64 to 1.28 %), TSS/acidity ratio (5.92 to 15.78) and fats (2.63 to 6.78 %) were estimated. When organoleptic evaluation of the fruits were conducted, the accessions AV-24 and AV-10 were found to be more acceptable.

Principal Component Analysis (PCA) was done for different characters and the first three components accounted for variability in tree, inflorescence and fruit

characters, whereas first two components accounted for variability in seed and quality characters. Clustering based on first two components for tree, inflorescence, fruit, seed and quality characters led to the grouping of accessions into six, eight, six, six ad five clusters respectively.

From the present study, accessions AV-3, AV-11, AV-25, AV-2, AV-10 and AV-24 were identified to be the most promising accessions in terms of yield, quality and sensory attributes.