ASSESSMENT OF VARIABILITY IN *Annona* spp.

By

Jyolsna M

(2014-12-108)

DEPARTMENT OF POMOLOGY AND FLORICULTURE

COLLEGE OF HORTICULTURE

KERALA AGRICULTURAL UNIVERSITY

VELLANIKKARA, THRISSUR – 680 656

KERALA, INDIA

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THESIS

Submitted in partial fulfillment of the requirement for the degree of

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COLLEGE OF HORTICULTURE

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2016

DECLARATION

I hereby declare that the thesis entitled **"Assessment of variability in *Annona* spp."** is a bonafide record of research work done by me during the course of research and this thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

Vellanikkara
22-09-2016

Jyolsna M.
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CERTIFICATE

Certified that this thesis entitled **"Assessment of variability in *Annona* spp."** is a record of research work done independently by Ms. Jyolsna M under my guidance and supervision and that it has not previously formed the basis for award of any degree, fellowship or associateship to her.

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We the undersigned, members of the advisory committee of **Ms. Jyolsna M**, a candidate for the degree of **Master of Science in Horticulture**, agree that the thesis entitled **"Assessment of variability in *Annona* spp."** may be submitted by her in partial fulfillment of the requirement of the degree.

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Jyolsna M

Dedicated to

My loving

Family

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Introduction

1. INTRODUCTION

Annonaceae is a family consisting of about 2300 to 2500 species and more than 130 genera. It is concentrated in the tropics, with few species in temperate regions. About 900 species are from Neotropical, 450 are from Afrotropical, and other species are from Indo-malayan region (Wunderlin and Hansen, 2008).

Annona is one of the important genus in this family. The genus name, '*Annona*' is derived from a Latin word 'anon', meaning 'yearly produce' and it refers the production of fruits. Due to its adaptability to varied soil and climatic conditions, hardy nature, freed from pests and diseases, and escape from animal damage *Annona* spp. is found common in India. In this genus there are 120 species, out of which five have been selected as important under-utilized species with pomological significance (ICUC, 2002). Among these the most important and common species found in Kerala are *A. reticulata*, *A. squamosa* and *A. muricata*.

The most common species of Annona found in homesteads of Kerala is bullock's heart or ramphal, *i.e*, *Annona reticulata.* It is distributed in tropical and subtropical regions and is native to South America and West Indies (Pinto *et al*., 2005). It is mainly distributed in Burma, Bengal, and Southern regions of India. Besides, it is widely cultivated in Bangladesh and Pakistan (Zaman and Pathak, 2013). In Ayurveda, ramphal fruits are considered as a good tonic which enriches blood, increases muscular strength, act as a sedative to heart and relieves from vomiting (Padhi *et al*., 2011). Bark of this tree is a powerful astringent, antidysentric and vermifuge (Suresh *et al*., 2011). The leaves, bark of roots, and stem are rich in isoquinoline alkaloids. Thus phytochemical and pharmacological activities of ramphal root as well as fruit components advocate many clinical applications including cancer chemotherapy.

Among the Annonaceous fruits, *A. squamos*a, commonly called as custard apple, sithaphal or sweetsop is one of the most delicious arid fruit known mostly for its dessert and confectionery values. This tree is native to Central

America and North-Eastern part of South America (Purseglove, 1968). It is a small evergreen tree seen in India and widely cultivated in Thailand (De Leon, 1917; Carangal *et al*., 1961). The area and production is highest in Maharashtra with 8,660 ha and 59,330 MT. Custard apples are used mainly for fresh consumption or for preparation of juice and ice cream (Maurya and Singh, 2006; Nath *et al*., 2008). Oil extracted from seeds of sithaphal is used as pesticide. (Khalequzzaman and Sultana, 2006). The bark and roots are highly astringent, hence the bark decoction is used to halt diarrhoea. Root and leaf of sithaphal are used for drastic treatment of dysentery and other ailments due to its strong purgative action (Singh *et al*., 2005).

The species *A. muricata* is gaining popularity due to its potent anticancer property. It is an evergreen, typical tropical tree commonly known as soursop, graviola, guanabana. It is native to the Caribbean, Mexico and Central and South America (Leon, 1968).This species is widely distributed throughout the tropical and subtropical regions in the world, including India, Malaysia and Nigeria. Its fruits are consumed as fresh and other plant parts are utilised for medicinal purposes. Fruits are also used for preparation of products such as jam, jellies, beverages, wine, fruit-butter preserves and pure (Abbo *et al.,* 2006; Heenkenda *et al.,* 2011). Soursop contains 'acetogenin' which has wide variety of biological activities. These compounds are useful medicines since some of them have anti-tumoral, immuno-suppressant, antibacterial, insecticidal, pesticidal and antihelminthic properties (Kim *et al*., 1998; Yu *et al*., 1998).

A wide range of natural variability is seen in Kerala in all the three species. This variability is mainly due to the seed propagation and cross pollination nature of the crop. As this crop is having tremendous medicinal property there would be an increasing demand in the near future. No attempts are seen for the study of variability of these three species and any promising types in Kerala. It is in this context the present investigation on Assessment of variability in *Annona* spp. was undertaken aiming to assess the natural variability of *Annona reticulata, A. squamosa* and *A. muricata* existing in central parts of Kerala and also to identify promising types for commercial cultivation for Kerala condition.

Review of literature

2. REVIEW OF LITERATURE

Annonaceous fruits are closely associated with Ramayana. Some of the species are named after the legends that are involved in it. Eventhough it is native to South American continent it is widely and used by Indians from ancient times. *Annona* is a multipurpose tree having a commercial life of about 15 years. The trees require comparatively little care and are free from serious pests and diseases.

Among different annonaceous fruits, *A. squamosa, A.reticulata* and *A. muricata* are commonly found in homesteads of Kerala. The varying climatic conditions, soil factors, cross pollination and seed propagation of these species lead to wide natural variability in these crops. Such variability indicates the scope for crop improvement and selection of improved genotypes. Considering the importance of these fruits, identification and development of improved varieties will be of immense potential for commercial cultivation.

2.1. Variability in Annona

Cheema (1928) noticed that due to heterozygosity and cross pollination nature of *Annona*, there exists large genetic variation in some characters like leaf, inflorescence and fruit. Thus the selection from seedling population offers a scope for improvement in natural hybrids by utilising these variations.

Morphological variations were observed in vegetative, floral and fruit characters of *Annona squamosa* from central and southern India as well as from exotic introductions. The fruit characters were considered to be the most useful parameters for determining this variation. (Venkataratnam and Satyanarayana-swamy, 1959).

Variability was noticed in quantitative and qualitative characters by analysing fruit weight, fruit size, edible portion, brix reading and taste in *Annona squamosa* [*A. reticulata*] landraces collected from eight districts in Bangladesh

(Islam *et al.,* 1991). Variability in *Annona* spp. in different states of India was reported by Singh, 1992.

Sousa *et al*. (2006) evaluated thirty genotypes of sugar apple and characterized their length and fruit diameter, fruit mass, pulp mass, seed mass, rind mass, pulp yield, number of seeds, thickness of the rind, pH, total soluble solids (TSS), total titratable acidity (TTA), reducing and non-reducing sugars. There was variability in the traits like fruit, pulp, and rind mass and number of seeds. This had lead to the differentiation of evaluated genotypes.

Folorunso and Olorode (2006) conducted a morphological study of four species of *Annona* found in Nigeria and characterized it as important under-utilized species. Live plants, fruits, flowers and seeds were studied from mature plants in the experimental garden. Both qualitative and quantitative characters were recorded.

Yield, quality and genetic parameters of fruits were evaluated for 20 half-sibling custard apple tree progenies in home orchards (Lima e Silva *et al.,* 2007). Among that the progeny JG2 was having a high yield and fruit size and the progeny FE4 was having higher total titratable acidity in the fruit pulp. Besides there was variability between progenies, with higher number of fruits ha^{-1} (80 %) and also fruit yield (78 %). A positive genotypic and phenotypic correlation were present between fruit diameter (FD) and fruit height, FD and mean fruit weight, and number of fruits ha^{-1} and fruit yield.

Islam *et al.* (2010) conducted a study on fruits of 20 genotypes of bullock's heart from different locations of Bangladesh in respect of fruit size, shape, composition, colour of fruits and quality. Considerable genetic variability was observed and the genotype AR002, AR006 and AR0ll were found superior and hence selected for multiplication.

In Sri Lanka, a study revealed morphological variation of Soursop germplasm. Fruits weighing 3.35 kg and 3.48 kg were collected from

Giradurakotte germplasm centre and fruits with lesser number of seeds were also observed. Such fruits with higher size and lower fruit weight: seed ratio is essential for breeding programmes and also for conservation of germplasm (Padmini *et al*., 2013).

2.2. Tree characters

According to Leon (1987), *Annona* spp. consists of shrubs or small trees with a height of 4 to 8 m. They are erect spreading in habit. It may vary based on several factors such as climate, soil, crop management strategies and species.

2.2.1. A. reticulata

A. reticulata is having an erect growth with a spreading crown (Morton, 1987). Chopra *et al*. (1998) observed that it is a small deciduous or semi deciduous tree which grows up to a height of 10 meters. According to Pinto *et al.* (2005) the height of *A. reticulata* is nearly about 6.0 to 7.5 m. It is a small tree with glabrous branches. The stems are cylindrical having lenticels and very short coffee coloured hairs. *A. reticulata* is a small, semi-deciduous tree, 3-7m in height, with a broad, open crown or irregularly spreading branches and light brown bark with visible leaf scars (Surendra *et al.,* 2013).

2.2.2. A. squamosa

Custard apple is a small semi evergreen well branched shrub which grows up to 7 meters in height (Chopra *et al*., 1998). Farre *et al*. (1999) reported that custard apple is a small tree or a large shrub with spherical or a flattened ball crown. It comes up to a height of 3 to 5m, but under suitable environment it grows to a height of 6 or 8m. Leal (2000) noticed that sugar apple tree is smaller than soursop which is having a maximum height of 6m. They possess many lateral branches, among that young shoots are pubescent and older ones are smooth. On evaluation of various types, Rao and Subramanyan (2011) reported that the plant height per tree (3.2 m) was the highest in Phythota-3 followed by

MMR-9 (2.91 m). Maximum plant spread was recorded in Bangalore (9.5 m^3) followed by Atemoya x Balanagar (7.9 m^3).

2.2.3. A. muricata

According to Popenoe (1952), soursop is a low branching tree with upright growth habit. It comes up to a height of 10m. Melo *et al.* (1983) reported that soursop is an evergreen tree, bushy, with upright growth and low branching. It grows up to 25 to 30 feet height and has drooping branches (Morton, 1987). Besides wide adaptability and genetic diversity was seen in seedling population. Depending on the factors like climate, soil and crop management the height of soursop tree varied between 4 to 8 m (Nakasone and Paull, 1998).

On screening soursop accessions which are high yielding and early bearing it was observed that 'Moxoto 20.2' was having a height of 3.8 m. The diameter of canopy varied from 3.42 to 4.75 m among different accessions (Silva *et al*., 1999). Manigandan (2014) observed that among the 22 trees studied, 12 trees was having one branch (54.54 %), 7 trees were having two branches (31.82 %) and 3 trees were having three or more branches (13.64 %). The pubescence was uniformly absent in young branches of all the trees. No difference in pubescence of young branches was noticed. Canopy diameter of the accessions was in the range of 3.14to 4.95m. In case of tree shape, it was noticed that 14 trees were having conical shape (63.63 %), 2 were semi-spreading (9.09 %) and 6 were spreading types (27.27 %).

2.3. Leaf characters

Folorunso and Modupe (2006) observed that shape of leaf was elliptic in *A. reticulata* and *A. squamosa* but in *A. muricata* it was obovate. Similarly leaf apex was acute in *A. muricata* and *A. squamosa* whereas in *A. reticulata* it is attenuate. In case of leaf base it was obtuse in *A. muricata* while it was acute in *A. reticulata* and *A. squamosa*. It was also noticed that margin of leaves was entire in all the three species.

2.3.1. A. reticulata

According to Chopra *et al*. (1998), the leaves of *A. reticulata* are oblong, lanceolate, glabrous above and pubescent beneath when they are at young stage. Nirmal *et al*. (2010) observed that leaves of *A. reticulata* are oblong, acute, lanceolate, and leaf base is rounded. The upper surface of leaves was glabrous and lower surface had few hairs. *A. reticulata* leaves were light green in colour and oblong-lanceolate shape. Leaves were 4-15 cm long and 2-5.5 cm wide. Leaf margin was entire and acute base. (Zaman and Pathak, 2013).

Surendra *et al.* (2013) reported that *A. reticulata* leaves were having a length of 6-17 cm and width of 3-6 cm. They were usually pale green lanceolate or oblong lanceolate, glabrous leaves. Leaf margin was slightly unequal and its edges were without teeth. Leaf base was short pointed or rounded and its apex was short or long pointed.

2.3.2. A. squamosa

Ochse *et al*. (1974) observed that *Annona squamosa* leaves were oblong-elliptical shape with obtuse or acuminate apex and brilliant green in colour. Their length and width ranged from 2 to 17 cm and 2 to 7 cm. Custard apple leaves were dark green and its shape was oblong-lanceolate. The leaf was having a length of about 25 to 30 cm and width of 7 cm (Leon, 1987). Chopra *et al*. (1998) reported that the leaves were simple, alternative, oblong, lanceolate or elliptic in shape. They were 5.0 to 15.0 cm long and 1.9 to 3.8 cm wide.

2.3.3. A. muricata

Soursop had green leaves of oblong-ovate to cylindrical shape. The leaf length and width varied from 14 to 16 cm and 5 to 7 cm respectively (Morton, 1987).The leaves were leathery and broadly elliptic to obovate with 5.8 – 19.0 cm in length and 3.7 -8.1 cm width. Sometimes they were slightly unequal. Pinto *et al*. (2005) reported that leaves of soursop were oblong-obovate to oblong in

shape with 2-15 cm length, pointed, and smooth. Soursop leaves were 7.6 to 15.2 cm long and 2.5 to 7.6cm wide. The leaves were obovate to elliptic, glabrous on lower surface and with oblanceolate leaf blade (Orwa *et al*., 2009).

Manigandan (2014) observed that leaf length exhibited a good variation. Minimum leaf length of 112.21 mm was in accession AM 2, followed by 112.36 mm and 112.90 mm in AM 17 and AM 20. The maximum leaf length observed was 155.36 mm (AM 15) and 145.27 mm (AM 15) with a mean 131.69 mm. The coefficient of variation for the length of leaf was 8.80 per cent. Similarly, leaf width of all accessions was studied. It varied from minimum of 42.55 mm in AM 9 which was followed by 45.21 mm in AM 9 to a maximum of 63.21 mm (AM 11) which was followed by61.80 mm (AM 15) with mean leaf width of 53.85 mm. The coefficient of variation for the width of leaf was 9.90 per cent.

2.4. Floral characters

2.4.1. A. reticulata

Mowry *et al.* (1941) observed that under Florida conditions *A. reticulata* matured during late winter and early spring (dry to wet season). In Mexico, its flowering was observed during the transition from wet to dry season (August to November) and fruiting from March to April *i.e.* the dry season (Pinto *et al*., 2005).

2.4.2. A. squamosa

Mowry *et al.* (1941) reported that in Florida, the sugar apple fruiting season started in midsummer (wet season) and its ripening was irregular, which last for three months. Fruiting occurred during the beginning of the rainy season (summer) in Philippines. Whereas in India, fruiting occurred during the wet season (August to mid September). It was also noticed during October to November *i.e.* the end of the wet season (Coronel, 1994). In Mexico, flowering was observed at the end of the dry season (March to May) and fruiting at the end of the wet season (September to November). In Brazil, towards the end of the dry season (March to

Table 1. Variability of flowering in *Annona* spp.

Species	Flowering	Fruiting	Country	References
Annona reticulata	-	Late winter and early spring	Florida	(Mowry *et al*., 2014)
	August to November	March to April	Mexico	(Pinto *et al*., 2005)
A. squamosa	-	Wet season (Midsummer)	Florida	(Mowry *et al*., 1941)
	-	Rainy season (Summer)	Philippines	
	-	Wet season (August to mid September) End of wet season (October-November)	India	(Coronel, 1994)
	End of dry season (March-May)	End of wet season (September-November)	Mexico	(Pinto *et al*., 2005)
	End of dry season (March-May)	Wet season (December-January)	Brazil	
	Wet season (December)	Dry season (May)	Brasilia	
A. muricata	Wet season (November-February)	Beginning of dry season (April-July)	Brazil	(Bueso, 1980)
		From dry to wet season (February- September)	Puerto Rico	

May) flowering was observed. Thus fruiting is seen during the wet season (December to January). In Brasília, in the wet season (December) flowering can be induced thereby fruiting is attained during the dry season (May) (Pinto *et al*., 2005).

2.4.3. A. muricata

According to Bueso (1980) in Brazil, flowering occurred from November to February *i.e,* in the wet season and fruiting was at the beginning of the dry season *i.e,* April to July. In Puerto Rico and the Caribbean region, the soursop fruiting season commenced from February and March (dry season) to September (wet season) and peak was observed in the wet season (June to August). This Annona requires around six months for fruit development. Morton (1987) noticed that in soursop flowering started at the age of three years. Soursop flowers emerged from branches and trunk in groups of two or four flowers (Leon, 1987).

2.5. Fruit characters

2.5.1. A. reticulata

Leon (1987) observed that the fruits were heart shaped, may be ovate, conical or irregular. It weighs about 0.1 to 1 kg and length of 10 to 12 cm. The fruits are reddish-yellow in colour with impressed lines. The fruit contained about 40 seeds which are oblong. Seeds were smooth, glossy, shining, blackish or brownish-black with 1-2 cm length and 0.5 cm width (Zaman and Pathak, 2013).

According to Surendra *et al*. (2013), fruit was round, ovate or conical and heart shaped with many round protuberances. It was about 5-10 cm in diameter. When ripe it was greenish-yellow and its pulp was edible, sweetly aromatic and white in colour. Each carpel was embedded with a seed which were oblong, shiny and smooth. They were found numerous inside the fruit with 1.3-1.6 cm length and blackish or dark brown in appearance. *A. reticulata* fruits were edible, heart shaped and rough. It was yellow in colour at maturity and change to yellowish red on ripening (Jamkhande and Wattamwar, 2015).

2.5.2. A. squamosa

Studies conducted in a sugar apple orchard with 417 trees/ha at the age of six years revealed that the trees produce 60 fruits/plant. Thus the yield of fruits was 25,000 fruits/ha (Lucas, 1994). Andrade *et al*. (2001) observed that *Annona squamosa* produced edible fruits which are typically globular or heart-shaped. They were having a diameter of 12 cm and weigh about 150 g.

Franco and Janzantii (2005) observed that *A. squamosa* fruits were rounded and heart shaped, ovate or conical. Based on cultivar, pollination, nutrition and many other factors the fruit size varied. The fruits were having a diameter of 5 to 7.5cm, length 6 to 10cm and weight about 120 to 330 g. The fruits were usually yellowish green, oval in shape and with rough skin (Folorunso and Modupe, 2006). Lima e Silva *et al*. (2007) reported that the mean number of seeds per fruit varied from 31.0 to 41.4 in custard apple progenies.

Hernandez *et al.* (2011) reported that the highest value of fresh biomass of the fruit was 162.1 g, seed biomass was found to be 17.2 g and the equatorial diameter was found to be 6.4 cm in second harvest of custard apple. The fruits of first harvest showed a higher polar diameter of 5.3 cm. Rao and Subramanyam (2011) reported that the number of fruits was the highest (51.4) in Balanagar SR followed by Phythota-3 (45.3). The fruit yield was the highest (15.7 kg) in Ramaphal followed by MMR-10 (15 kg). The highest fruit weight per tree was observed (278.9 g) in Atemoya X Balanagar followed by Y. Palli – 12 (270.6 g). Besides highest seed weight (22.6 g) was recorded in Balanagar SR followed by Bellary (20.9 g). The custard apple fruit collected from different locations were having a gross weight ranging from 131.3 g to 184.5 g and the mean weight was 160.45 g. Similarly, the percent seed weight also varied from 18.9 to 26.4 with 22.45 percent as mean per cent weight of the seed. (Hashmi and Pawar, 2012)

Bhatnagar (2012) observed variations in shape of custard apple as round and cordate, fruit colour as yellowish green, light green, pale green, pulp colour as pale white, creamy white and areole shape as rounded, rounded and fused,

mummiform in the fruits. The pulp colour was pale white to creamy white. Besides maturity of these fruits were observed to be from first week of November to first week of December. Fruit weight was minimal in germplasm collected from Chittorgarh which was 89.5 g and maximum from Baran which was 149.8 g. The fruit weight was genetically controlled character and it has shown significant variation in different landraces. The minimum seed weight observed was 11.5 g in Jhalawar landrace and maximum was 13.3 g from Deola and Udaipur sites. The seed number per fruit had also exhibited variability which was 35.3 to 42.0 in different collections. The shelf life of fruits was 5 to 6 days at ambient temperature. The maximum shelf life of 6 days was noticed in fruits from Baran, Dara and Kota sites due to thin leathery rind in these landraces.

The main harvesting season of fruits was from October to November. The average weight of 50 fruits of *Annona squamosa* fruits was 155.02 g. The maximum and minimum weight of fruit was 231.64 and 114.8 g. The size of fruits varied from 58.92 to 74.15 mm. Thus average size of fruits was 66.15 mm with standard deviation 4.12. It was found that the maximum and minimum number of seeds per fruit was 89 and 8, respectively with an average of 40.06. In case of total flakes, maximum and minimum number was found to be 106 and 42 and average of 72.62. In the custard apple fruits, average seed percent was 10.30 per cent (Bakane *et al*., 2015).

2.5.3. A. muricata

Soursop fruits were ovoid with scattered spine like structures in its surface. It weighed about 0.9 to 10 kg and 18 cm long (Leon, 1987). According to Bora *et al*. (1987) the fruit contained about 127 to 170 seeds and they were scattered throughout its pulp. Seed weight was 0.33 to 0.59 g and its size varied from 1 to 2 cm. Morton (1987) reported that soursop fruit skin is leathery, covered with curved, soft, pliable spines. It had cream coloured pulp inside which is divided into segments. Seeds were usually black in colour, oval and with smooth finishing surface.

Pinto and Silva (1996) noticed that soursop fruits were ovate, conical or heart shaped with short, fleshy spines. They were dark green at unripe stage and changes to light green when they are ripe. It weighed about 0.9 to 10 kg and average was around 4 kg. Silva *et al*. (1999) reported that at the age of seventh year a soursop ecotype 'Morada' produced about 50-60 kg of fruits/plant.

Soursop fruits were having 14-40 cm length and 10-18 cm width. It weighed about 7 kg. The fruits were ovoid, oblong heart shaped. Seeds were dark brown or black, oblong which are 2 cm long and 0.7 cm wide (Oinimawo, 2002). According to Franco and Janzantii (2005), in soursop sporadic flowering and fruiting was observed all year round under favourable conditions. Its fruiting started from 2nd year and a 5 year old tree produced about 10-15 fruits.

Manigandan (2014) reported that out of 22 soursop accessions, shape of the fruit was broadly cordate in 20 accessions (90.91 %) and cordate in 2 accessions (9.09 %). The fruit surface was uniformly tuberculata (medium protrusions). Fruit colour also varied among the accessions. It was observed that about 11 accessions were having light green fruits (50 %), 9 accessions were having green surface (40.91 %), 1 accession was having dark green (4.54 %) and one was having yellowish green surface (4.54 %).fruit length varied from 132.52to 225.23 mm and diameter was in the range of 99.58 and 145.20 mm. Mean average yield was 99.05 kg per tree and lowest fruit yield was 20.47 kg per tree. Number of fruits per tree was in the range of 19 to 36 fruits. Average fruit weight varied from 0.89 to 3.05 kg and its mean fruit weight was 1.77 kg.

There was variability in seed characters also, it was noticed that a fruit contain about 44.34 to 95.34 seeds. The weight of fresh seeds/fruit was 14.19 to 37.29 g and individual seeds were weighing from 0.22 to 0.44 g. Besides seed length and width was varying. Minimum seed length noticed was 12.97 mm and maximum of 17.50 mm. Seed width among accessions varied from a minimum of 6.01 mm to a maximum of 7.94 mm.

2.6. Quality parameters

2.6.1. TSS

2.6.1.1. A. squamosa

Lima e Silva *et al*. (2007) observed that the total soluble solids content of custard apple progenies varied from 23.9 to 25.7 °Brix. Girwani *et al*. (2011) reported that TSS of custard apple fruits ranged from 22 to 28 °Brix and was found to be maximum in Hybrid-2 ('15/2 Red Sitaphal' × 'Pondapple'). The TSS of custard apple fruits exhibited a variation from 16.12 to 18.07 °Brix. Rao and Subramanyam (2011) observed a maximum T.S.S (25.9 %) in NLD – 8 followed by NLD – 10 (25 %). The maximum was 18.07 °Brix in landraces collected from Kelwara and Rajsamand sites followed by those from Baransite with 17.87 °Brix (Bhatnagar *et al*., 2012).

Hashmi and Pawar (2012) reported that per cent total soluble solids (TSS) content of custard apple fruits were more than 22 ^{o}Brix in all samples. The mean value of total soluble solids content was found to be 24.3 ^{o}Brix and it indicates the processable quality of pulp. The highest Total Soluble Solids (TSS) was recorded in the *Annona* genotype, SG-8 which was 26.95 °Brix followed by SG-12 and was 26.55 °Brix. The lowest TSS was found in PT-1 18.73 °Brix (Saitwal *et al*., 2015).

2.6.1.2. A. muricata

Ripe soursop fruits exhibited a variation in TSS from 13.5 to 19.0 °Brix (Lima *et al*., 2003). Manigandan (2014) reported an enormous variability in TSS which was in the range of 12.10 to 18.07 °Brix. It was also observed that the TSS was 24.5 °Brix.

2.6.2. Total titratable acidity

2.6.2.1. A. squamosa

Lima e Silva *et al.* (2007) noticed that TTA of custard apple progenies varied from 0.16 to 0.25 per cent with a mean of 0.21 per cent. A slight variation was observed in acidity of custard apple pulp at different locations. The TTA varied from 0.23 to 0.28 per cent (Hashmi and Pawar, 2012).

2.6.2.2. A. muricata

The highest value of TTA was 0.07 per cent and lowest was 0.04 per cent in soursop accessions (Manigandan, 2014).

2.6.3. Reducing sugar, non reducing sugar and total sugar

2.6.3.1. A. squamosa

According to Hashmi and Pawar (2012), the important factor notifying the quality of fruit is total sugar content of the pulp. Custard apple exhibited a variation in total sugar from 18.1 to 22.0 per cent with average value of 19.5 per cent. The marginal difference seen in total sugars may be due to the change in location and cultivars. The highest total sugars were in SG-8, *i.e.* 24.96 per cent followed by SG-12 with 24.00 per cent. The lowest TSS was found in PT-1 18.73 ^{0}Brix and a lowest total sugar was in AJ-2 *i.e.*17.01 per cent (Saitwal *et al*., 2015).

2.6.3.2. A. muricata

Singh *et al.* (2014) reported that the reducing sugar varied from 6.67 to 7 per cent and total sugar was around 10 per cent.

2.6.4. Antioxidant activity

All parts of Annona are used as natural medicine in the tropics. It is considered as good source of natural antioxidants against various diseases.

Therefore, the isolation, characterization and utilization of these natural antioxidants are giving prime importance (Baskar *et al*., 2007).

2.6.4.1. A. muricata

Akomolafe and Ajayi (2015) reported that both the peel and the pulp of soursop scavenged hydroxyl radicals in a concentration dependent manner. But the scavenging capacity of the peel was higher than that of the pulp. This revealed that the fruit, especially the peel can be used as an alternative solution to synthetic antioxidants in combating the oxidative activity of hydroxyl radicals. According to Manigandan (2014) the pulp extract was having a total antioxidant activity of 14.74 µg of ascorbic acid/mg of extract

In a study on *in vitro* antioxidant potential of fruit samples, conducted by Singh *et al*. (2014) reported that soursop in methanolic extract exhibited strong antioxidant potential in DPPH (2,2-diphenyl 1-1-picrylhydrazyl) method.

Materials and methods

3. MATERIALS AND METHODS

The study on "Assessment of variability of *Annona* spp." was conducted at the department of Pomology and Floriculture. College of Horticulture, Kerala Agricultural University, Vellanikkara during 2014-2016.

3.1. Field survey and experimental materials

Several homesteads were surveyed in three districts in central zone of Kerala *viz*., Ernakulam, Thrissur and Palakkad from March 2015 to June 2016 for identifying *Annona* spp. which are of seedling origin (Fig.1). About 71 trees were tagged, of which 30 trees belonged to *Annona reticulata*, 25 trees to *Annona muricata* and 16 trees to Annona *squamosa.*

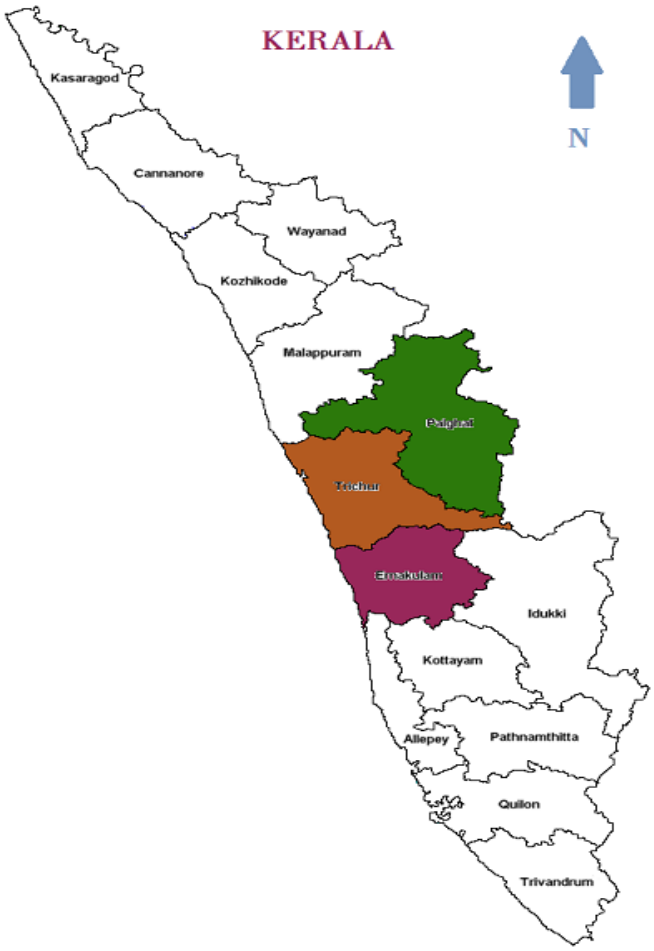


Plate 1: Survey locations showing three districts in Central Zone of Kerala

3.2. Plant characters

3.2.1. Age of the tree

Age of the trees was recorded based on information provided by the farmer.

3.2.2. Height of the tree

Height of the tree was measured from ground level to the top of the tree using a graduated pole and expressed in metres.

3.2.3. Spread of the tree

Spread of the tree was measured in North-South and East-West directions using a measuring tape and the average spread was calculated using the formula and expressed in metres.

$$\text{Average spread} = (\text{N-S}) + (\text{E-W}) / 2$$

3.2.4. Growth habit

Growth habit of the tree was recorded as erect, semi spreading and spreading.

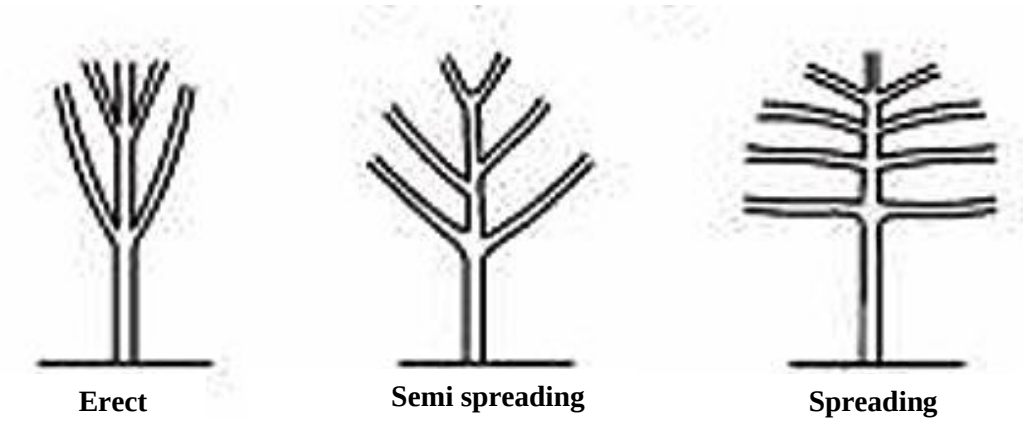
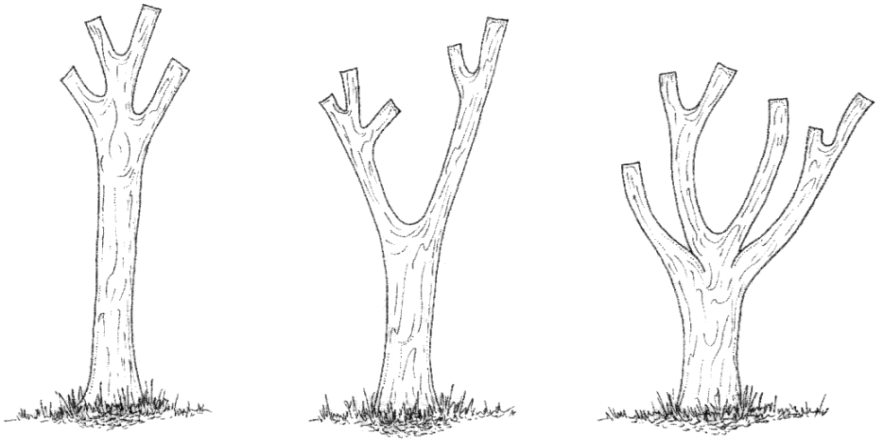


Fig. 1. Tree growth habit in *Annona* spp.

3.2.5. Branching pattern

Branching pattern of the trunk can start from ground level up to 50cm height by the descriptor given by IPGRI (2008). It is classified as one branch, two branches and three or more branches.



One branch **Two branches** **Three or more branches**

Fig. 2. Branching pattern in trees

3.2.6. Pubescence on shoot

Pubescence in young branches was recorded as absent or present. If present the colour was identified using colour chart of Royal Horticulture Society (RHS).

3.2.7. Orientation of leaf

Orientation of the leaf was noted as upright, semi-upright and horizontal.

3.3. Leaf characters

3.3.1. Shape of leaf lamina

Shape of the leaf blade was recorded by using the descriptor given by IPGRI (2008). The leaf blade shape was recorded as ovate, elliptic, obovate, lanceolate and other.

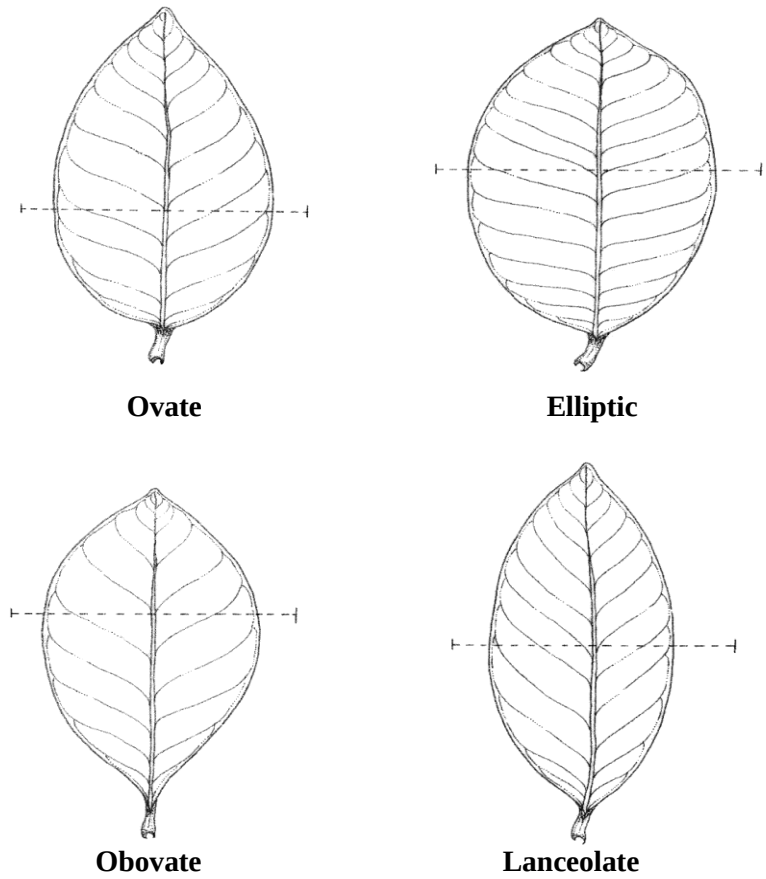


Fig. 3. Leaf lamina shape

3.3.2. Leaf apex

Leaf apex shape was recorded as per the descriptor given by IPGRI (2008). The apex shape was recorded as acute, rounded and acuminate.

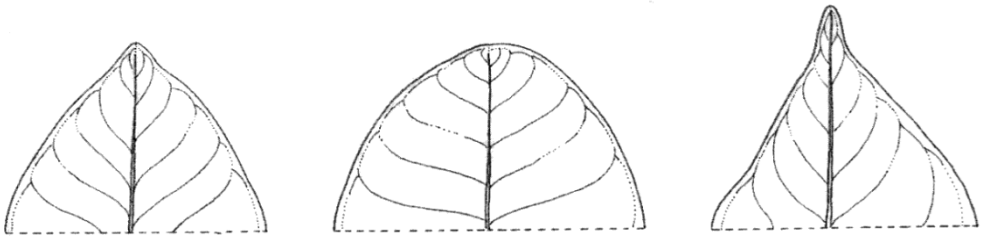


Fig. 4. Leaf apex shape

3.3.3. Leaf base

Leaf base was recorded as acute, rounded, obtuse and cordate based on the IPGRI (2008) descriptor.

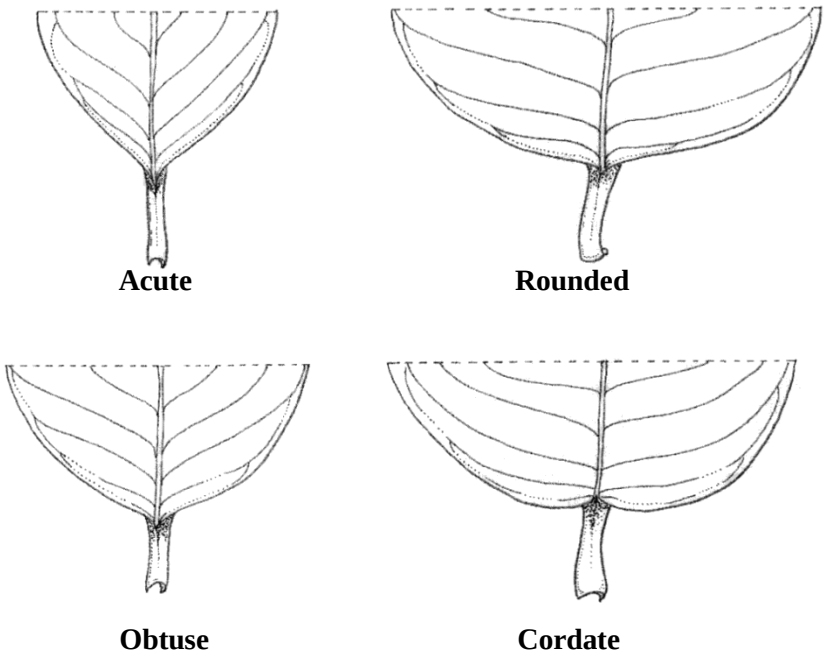
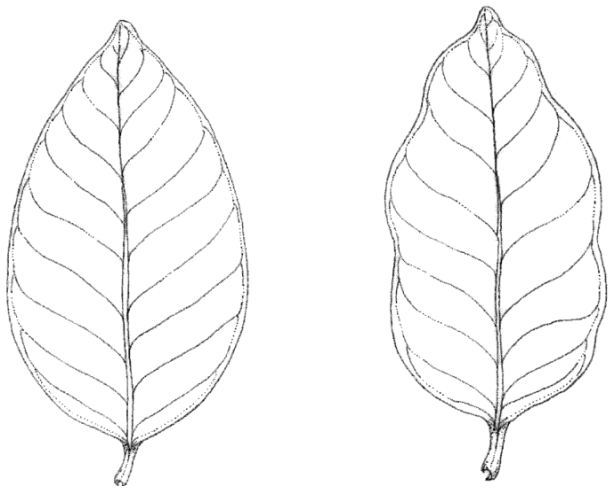


Fig. 5. Leaf base shape

3.3.4. Leaf margin

The shape of leaf margin was recorded as entire and wavy (IPGRI, 2008).



Entire **Wavy**

Fig. 6. Leaf margin

3.3.5. Nature of leaf lamina

The pubescence in leaf upper and lower surface was characterized as absent or present. If absent the leaf is recorded as glabrous.

3.3.6. Leaf length

The length of fully grown leaf at the centre place of leaf lamina was measured using a scale. The average values of 10 leaves were recorded for all the accessions studied. The leaf length was expressed in centimeters.

3.3.7. Leaf breadth

The width of fully grown leaf at the broadest place of leaf lamina was measured using a scale. The average values of 10 leaves were recorded for all the accessions studied. The leaf width was expressed in centimeters.

3.3.8. Petiole and vein colour

The colour of petiole and vein was characterized as light green, green, dark green and others. Colour Chart of Royal Horticulture society (RHS) was used to identify this parameter (IPGRI, 2008).

3.3.9. Colour of young leaf

The colour of young leaves was characterized as light green, green, dark green and others. Colour Chart of Royal Horticulture society (RHS) was used to identify the leaf colours (IPGRI, 2008).

3.3.10. Colour of mature leaf

The colour of mature leaves was characterized as light green, green, dark green and others. Colour Chart of Royal Horticulture society (RHS) was used to identify parameters (IPGRI, 2008).

3.3.11. Pubescence on leaf surface

The pubescences on leaf surface were characterized as absent and present (IPGRI, 2008).

3.4. Inflorescence characters

3.4.1. Flowering season

Time of flowering was noted, specifying the months.

3.4.2. Peak flowering season

Occurrence of peak flowering was recorded during flowering season

3.4.3. Flowering precocity

Number of times flowering occur in a year was noted.

3.4.4. Position of flower

Position of the flowers is recorded as either terminal or lateral.

3.4.5. Nature of flowering

Flowering was noted as it is solitary or as in a group.

3.4.6. Age of shoot at flowering

Age of shoot at flowering was noted as it occurs in current season growth or previous season growth.

3.5. Fruit characters

3.5.1. Fruiting season

Fruiting season was noted from the month of commencement of fruit development in the tree till the last month of fruit development in a tree.

3.5.2. Bearing habit

Bearing habit was noted as regular or alternate bearer.

3.5.3. Fruit shape

The fruit shape was characterized as round, oval, cordate, broadly ovate, oblate and other using IPGRI (2008) crop descriptor.

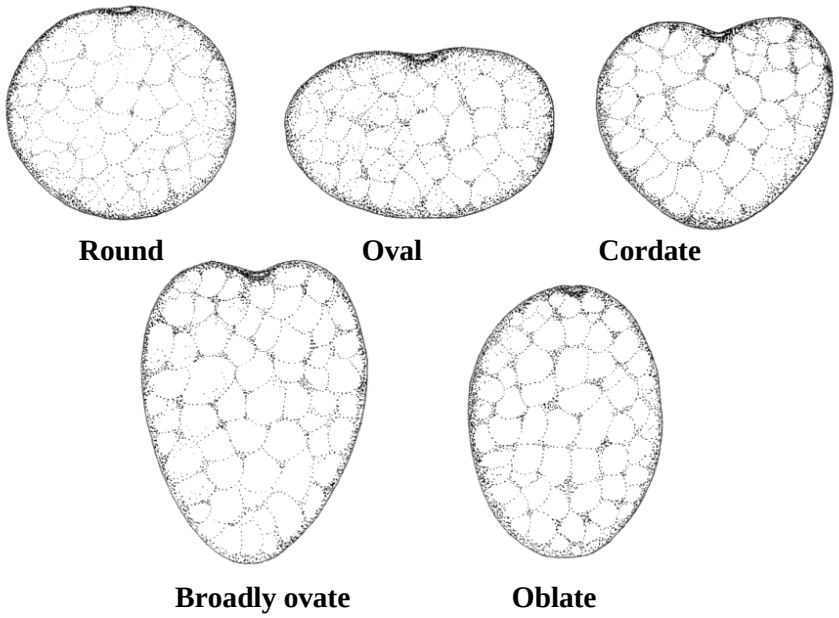


Fig. 7. Fruit shape

3.5.4. Fruit length

Length of individual fruit was measured from stalk end to stigmatic end using a scale and data was recorded. Average was drawn from readings recorded on five fruits and expressed in centimeters.

3.5.5. Fruit diameter

Diameter of individual fruit was measured at the widest plane using a scale. Average was drawn from readings recorded on five fruits and expressed in centimeters.

3.5.6. Fruit weight

Individual fruit weight was recorded using a weighing balance for five fruits collected from each accession and average was drawn and expressed in grams.

3.5.7. Fruit colour at maturity

The colour of mature fruits was characterized as light green, green, dark green, yellowish green, yellow, brownish green, brown and others IPGRI (2008).

3.5.8. Fruit colour at ripening

The colour of ripen fruits was characterized as light green, green, dark green, yellowish green, yellow, brownish green, brown and others (IPGRI, 2008).

3.5.9. Fruit surface

The fruit surface was characterized as Laevis (smooth), Impressa (slight depression), Umbonata (small protrusions), Tuberculata (medium protrusions), Mamillata (large protrusion) and other types (Schroeder, 1945).

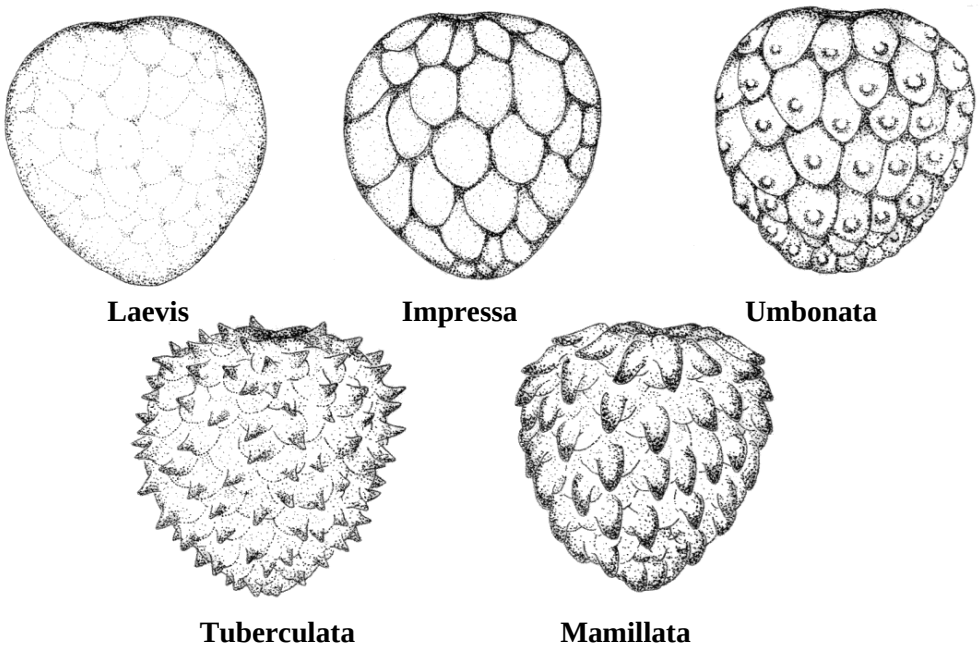


Fig. 8. Fruit surface

3.5.10. Number of fruits/tree

Number of fruits harvested in each harvest in each accession was counted and total number for the season was recorded.

3.5.11. Yield of fruits/tree

The fruits harvested in each harvest in each accession were weighed using a weighing balance and yield of fruits were recorded and computed the total yield per tree per season.

3.5.12. Number of flakes/fruit

Number of flakes per fruit was counted from five fruits in each accession and average was drawn.

3.5.13. Number of seed/fruit

Number of seed per fruit was counted from five fruits in each accession and average was drawn.

3.5.13. Seed length

Seed length and width of seeds were measured using a scale and data were recorded. Ten seeds were taken for observation and the average was calculated and expressed in millimeters.

3.5.14. Seed weight

Seeds were collected from extracted fruits. The fresh seeds per fruit were weighed in a digital weighing balance and weight recorded and expressed in grams.

3.5.15. Percentage edible portion

The edible portion is recorded by weighing the pulp extracted from fruits in a weighing balance and expressed in percentage.

3.5.16. Colour of seed

Seed coat colour was noticed by grey, dark brown, black and other (IPGRI, 2008).

3.5.17. Shelf life of fruit

Shelf life of fruits was recorded by counting the number days from ripening, that the fruit can be stored at room temperature without deteriorating its quality.

3.5.18. Sensory evaluation

A score chart was prepared based on nine point hedonic scale ranging from one to nine; one denotes poor and nine excellent qualities. The organoleptic evaluation was done by panel of 10 semi trained persons. The parameters considered were appearance, taste and aroma. The detail about score chart used in sensory evaluation is given in the Appendix I.

3.6. Quality parameters

3.6.1. Total Soluble Solids (TSS)

Total soluble solids of the fruit juice of ripe fruits was estimated directly by using 'ERMA' hand refractometer (range 0-32 ^{0} brix) and expressed in degree brix.

3.6.2. Acidity

Titratable acidity was estimated as per A.O.A.C method using 0.1 N NaOH. The solution (10 ml of fruit solution + 10 ml of distilled water) was titrated against 0.1 N NaOH using phenolphthalein as indicator and the acidity was expressed as percentage.

3.6.3. Reducing, non-reducing and total sugar of fruit pulp

Sugars were determined as per the procedure described by Ranganna (1986). To 10 grams of Annona fruit pulp 100 ml of distilled water was added and clarified with neutral lead acetate, excess lead was removed by adding potassium oxalate solution. The volume was then made up to 250ml and the solution was filtered by using Wattman no.1 filter paper. Aliquot of the solution was titrated against a mixture of Fehling's solution A and B using methylene blue as indicator. The reducing sugar was expressed as percentage on fresh weight basis.

The non-reducing sugars were estimated by subtracting the percent of reducing sugars from the total sugars. To 50ml of filtrate, 10 ml HCl was added and kept it for overnight, then neutralized with NaOH pellet solution and made up to 250 ml. An aliquot of this solution was titrated against a mixture of Fehling's solution A and B using methylene blue as indicator. The total sugar was expressed as percentage of fresh basis.

3.6.4. Antioxidant activity

Fruit pulp (2.5 g) extracted in 50 ml methanol solution was centrifuged at 7000rpm for 15 minutes then the supernatant was collected. This is termed as methanolic fruit extract.

The total antioxidant activity was determined by using Phosphomolybdenum method suggested by Prieto *et al*. (1999). The reagent mix was prepared at the ratio 1:1:1 using 0.6 M sulphuric acid, 28mM sodium phosphate and 4mM ammonium molybdate. To 1.25 ml methonolic fruit extract 11.25 ml reagent mix was added and it was incubated at 90^0C for 90 minutes in boiling water bath and then cooled to room temperature. Same way a blank and series of standard using ascorbic acid were also prepared.

Blank solution contained 1.25 ml methanol and 11.25 ml reagent mix where as the ascorbic acid standards were prepared at different concentration 0.5, 1, 1.5, 2, 2.5 ml along with reagent mix and then incubated. The solution attained a bluish green colour and the intensity was measured in terms of absorbance at 695 nm in Spectrophotometer. Total antioxidant capacity was expressed as number of equivalents of ascorbic acid in milligram per gram of sample.

3.7. Statistical analysis

Hierarchical cluster analysis was done to determine the extent of variability. For that the selected 71 accessions were scored as per the scores given in IPGRI (2008) descriptor and grouped each species into different clusters based on 18 qualitative characters *viz*., growth habit, branching pattern, pubescence on shoots, orientation of leaf, leaf blade, leaf base, leaf apex, leaf margin, nature of leaf lamina, petiole and vein colour, colour of young leaves and mature leaves, pubescence on leaves, fruit shape, fruit colour at maturity and ripening, fruit surface and colour of seed (Table 2).

Principal Component Analysis (PCA) and cluster analysis of quantitative characters for all the 71 accessions were done to determine variability of the three

species. Similarly PCA was done to determine promising types using eight quantitative characters *viz*., fruit weight, yield of fruits per tree, number of flakes per fruit, number of seeds per fruit, TSS, acidity, total sugar and antioxidant activity. Organoleptic evaluation of the fruits was done by applying Kendall's coefficient of concordance.

Table 2. Score as per IPGRI descriptor

Sl No.	Character	Descriptive state	Description
1	Growth habit	1	Erect
		2	Semi spreading
		3	Spreading
2	Branching pattern	1	One branch
		2	Two branches
		3	Three or more branches
3	Pubescence on shoot	0	Absent
		1	Present
4	Orientation of leaf	1	Upright
		2	Semi upright
		3	Horizontal
5	Leaf blade shape	1	Ovate
		2	Elliptic
		3	Obovate
		4	Lanceolate
6	Leaf apex	1	Acute
		2	Rounded
		3	Acuminate
7	Leaf base	1	Acute
		2	Rounded
		3	Obtuse
		4	Cordate
8	Leaf margin	1	Entire
		2	Wavy
9	Nature of leaf lamina	1	Pubescent
		2	Glabrous
10	Petiole and vein colour	1 2 3 99	Light green Green Dark green Others
11	Colour of young leaves		
12	Colour of mature leaves		
13	Pubescence on leaves	0	Absent
		1	Present
14	Fruit shape	1	Round
		2	Oblate
		3	Cordate
		4	Broadly cordate
15	Fruit colour at maturity	1 2 3 4 5 99	Light green Green Dark green Yellowish green Yellow Others
16	Fruit colour at ripening		
17	Fruit surface	1	Laevis (Smooth)
		2	Impressa(Slight depression)
		3	Umbonata (small Protrusion)
		4	Tuberculata (medium protrusions)
18	Colour of seed	1	Grey
		2	Dark brown
		3	Black

Results

4. RESULTS

The experiment on 'Assessment of variability in *Annona* spp.' was conducted in the Department of Pomology and Floriculture, College of Horticulture, Vellanikkara, Thrissur, Kerala, during 2014 to 2016.The objective of the study was to assess the natural variability of *Annona reticulata*, *A. squamosa* and *A. muricata* existing in central parts of Kerala and also to identify promising types for commercial cultivation. Results of the studies are presented in this chapter.

4.1 Assessment of variability

Detailed surveys were conducted to assess the variability of *Annona* spp. in the homesteads of Ernakulam, Thrissur and Palakkad districts of Kerala. A total of 71 plants were identified from all the three districts. Among *Annon*a spp., 30 numbers of *A. reticulata*, 16 numbers of *A. squamosa* and 25 numbers of *A. muricata* were selected for the study. These samples were subjected to quantitative and qualitative analysis to identify superior types. Details of the trees surveyed are furnished in Appendix II.

4.2. Plant characters

The observations on plant characters recorded are shown in tables 3, 5 and 7. All the trees studied were in the age of 4 to 8 years. The data on range, mean, standard error of mean and coefficient of variation for the tree characters is presented in tables 4, 6 and 8.

4.2.1. Age of the tree

The plants in the age group of 4 to 8 years were selected for the study in *A. reticulata* (Table 3). The maximum tree age was recorded in the accessions *viz*., AR 6 and AR 7 (8 years) followed by AR 10, AR 14, AR 15, AR 20, AR 27

and AR 30 (7 years). The minimum tree age was recorded in AR 4 (4 years). All other accessions were having an intermediate age.

But in *A. squamosa,* tree age recorded ranged from 4to 6 years (Table 5). The maximum tree age was recorded in the accession AS 2, AS 5, AS 11 and AS 12 (6 years) which was followed by AS 6 and AS 15 (5 years). All other accessions were in the age of 4 years.

Age of *A. muricata* trees varied from 4-7 years (Table 7). The maximum age was observed in the accessions AM 4, AM 12 and AM 25 (7 years) which was followed by AM 2, AM 9, AM 10, AM 13, AM 19, AM 21, AM 22 and AM 23 (6 years). The minimum age was recorded in accessions *viz*., AM 1, AM 7, AM 14 and AM 15 (4 years).

4.2.2. Height of the tree

Height of the trees in *Annona reticulata* ranged from 5.24 m to 8.75m (Table 3). The maximum tree height was recorded in AR 30 (8.75m) followed by AR 14, AR 24 and AR 26 (8.50 m). The minimum tree height was recorded in AR 22 (5.42 m). All other accessions had tree heights in between these accessions. The mean plant height was 7.08 m with a CV of 15.10 per cent (Table 4).

The tree height of *A. squamosa* ranged from 1.5 to 3 m (Table 5). In which, AS 6, AS 9, AS 15 were having maximum height (3 m) followed by AS 2, AS 8, AS 11, AS 12, AS 14 (2.5 m). The lowest tree height was recorded in AS 4, AS 7 and AS 16 (1.5 m). All other accessions were intermediate with respect to the height of tree. The mean tree height was 2.28 m with CV of 22.59 per cent (Table 6).

In *A. muricata,* height of the tree varied from 2 to 3.6 m (Table 7), with maximum tree height in AM 10 (3.6 m). The accessions AM 1, AM 4, AM 7,

Table 3. Plant characters of *Annona reticulata* accessions

Accession	Age of the tree (years)	Height of the tree (m)	Spread of the tree (m)	Growth habit	Branching pattern	Orientation of leaf
AR 1	5	5.3	5.60	Erect	one branch	Upright
AR 2	5	7.8	6.35	Erect	3 or more branches	Semi upright
AR 3	6	6.5	6.60	Erect	3 or more branches	Upright
AR 4	4	6.0	7.05	Semi spreading	2 branches	Upright
AR 5	5	8.3	7.30	Semi spreading	2 branches	Upright
AR 6	8	5.5	5.70	Erect	one branch	Semi upright
AR 7	5	6.3	7.10	Semi spreading	2 branches	Upright
AR 8	6	6.0	7.35	Semi spreading	2 branches	Upright
AR 9	5	6.5	6.50	Erect	2 branches	Semi upright
AR 10	7	7.8	6.45	Erect	2 branches	Semi upright
AR 11	6	7.5	7.25	Semi spreading	2 branches	Semi upright
AR12	5	8.0	7.35	Semi spreading	one branch	Semi upright
AR 13	6	8.3	7.70	Semi spreading	one branch	Semi upright
AR 14	7	8.5	6.75	Erect	2 branches	Semi upright
AR 15	7	6.5	6.55	Erect	2 branches	Upright
AR 16	5	6.3	6.95	Erect	2 branches	Upright
AR 17	6	7.0	6.75	Erect	One branch	Semi upright
AR 18	6	6.8	6.30	Erect	2 branches	Semi upright
AR 19	6	7.5	6.80	Erect	2 branches	Upright
AR 20	7	8.0	6.95	Erect	one branch	Upright
AR 21	5	5.5	5.95	Erect	one branch	Upright
AR 22	5	5.2	5.40	Erect	2 branches	Upright
AR 23	6	6.0	6.80	Erect	2 branches	Upright
AR 24	6	8.5	6.45	Erect	2 branches	Upright
AR 25	6	7.5	7.20	Semi spreading	3 or more branches	Upright
AR 26	6	8.5	6.80	Erect	one branch	Semi upright
AR 27	7	7.3	7.15	Semi spreading	one branch	Semi upright
AR 28	5	7.5	6.55	Erect	one branch	Upright
AR 29	6	7.8	6.40	Erect	one branch	Upright
AR 30	7	8.8	7.70	Semi spreading	one branch	Upright
Mean		**7.08**	**6.72**			
CV (%)		**15.10**	**8.48**			

Table 4. Variability in vegetative and fruit characters of *A. reticulata* accessions

Character	Range		Mean	SEM±	CV (%)
	Minimum	Maximum			
Tree height (m)	5.24	8.75	7.08	0.190	15.10
Spread of tree (m)	5.40	7.70	6.72	0.100	8.48
Leaf length (cm)	17.90	23.90	20.87	0.290	7.62
Leaf breadth (cm)	4.20	6.80	5.32	0.120	12.52
Fruit length (cm)	7.40	11.40	10.02	0.170	9.40
Fruit diameter (cm)	6.60	10.60	8.24	0.210	14.47
Fruit weight (g)	110.00	435.00	266.1	16.800	34.62
Number of fruits per tree	11.00	31.00	22.2	0.940	23.37
Yield per tree (kg)	1.92	13.17	5.97	0.500	46.55
Number of flakes per fruit	46.00	114.00	73.97	2.650	19.66
Number of seeds per fruit	43.00	93.00	65.03	2.330	19.59
Seed weight per fruit	13.34	19.53	17.21	0.270	8.61
Seed length (mm)	12.10	16.60	14.06	0.220	8.74
Seed breadth (mm)	4.10	8.40	6.14	0.180	16.18
Shelf life (days)	2.00	4.00	3.00	0.120	23.16
TSS (^{0}Brix)	13.40	16.60	14.86	0.150	5.77
Acidity (%)	0.16	0.29	0.24	0.009	21.86
Reducing sugar (%)	8.74	10.41	9.53	0.070	4.47
Non reducing sugar (%)	0.80	1.18	0.96	0.170	9.85
Total sugar (%)	9.73	11.36	10.50	0.070	3.82
Antioxidant activity (mg ascorbic acid/g of sample)	1.26	2.86	2.29	0.080	19.45

Table 5. Plant characters of *Annona squamosa* accessions

Accession	Age of the tree (years)	Height of the tree (m)	Spread of the tree (m)	Branching pattern	Orientation of leaf
AS 1	4	2.5	3.61	2 branches	Upright
AS 2	6	2.5	3.71	3 or more branches	Semi upright
AS 3	4	2.0	2.58	3 or more branches	Semi upright
AS 4	4	1.5	3.32	2 branches	Upright
AS 5	6	2.0	2.78	3 or more branches	Upright
AS 6	5	3.0	3.70	3 or more branches	Upright
AS 7	4	1.5	2.36	3 or more branches	Upright
AS 8	4	2.5	3.53	2 branches	Upright
AS 9	4	3.0	3.95	2 branches	Upright
AS 10	4	2.0	2.72	2 branches	Upright
AS 11	6	2.5	3.26	2 branches	Upright
AS 12	6	2.5	3.32	2 branches	Semi upright
AS 13	4	2.0	2.85	2 branches	Upright
AS 14	4	2.5	3.51	2 branches	Semi upright
AS 15	5	3.0	3.77	2 branches	Upright
AS 16	4	1.5	3.79	2 branches	Upright
Mean		**2.28**	**3.29**		
CV (%)		**22.59**	**14.89**		

Table 6. Variability in vegetative and fruit characters of *A. squamosa* accessions

Character	Range		Mean	SEM±	CV (%)
	Minimum	Maximum			
Tree height (m)	1.50	3.00	2.28	0.120	22.59
Spread of tree (m)	2.36	3.95	3.29	0.120	14.89
Leaf length (cm)	8.30	15.20	12.03	0.470	15.72
Leaf breadth (cm)	3.20	6.40	4.65	0.179	15.39
Fruit length (cm)	5.36	6.08	5.70	0.065	4.56
Fruit diameter (cm)	4.04	4.49	4.29	0.310	2.96
Fruit weight (g)	81.50	116.90	93.97	1.970	8.40
Number of fruits per tree	18.00	26.00	20.68	0.600	11.67
Yield per tree (kg)	1.54	2.29	1.94	0.060	12.37
Number of flakes per fruit	43.00	72.00	59.81	2.230	14.91
Number of seeds per fruit	21.00	39.00	26.69	1.120	16.80
Seed weight per fruit	6.44	8.97	7.40	0.160	8.99
Seed length (mm)	13.10	15.70	14.39	0.160	4.65
Seed breadth (mm)	4.10	5.90	4.85	0.150	12.69
Shelf life (days)	4.00	6.00	5.18	0.180	14.46
TSS (^{0}Brix)	18.23	19.90	18.92	0.120	2.61
Acidity (%)	0.16	0.22	0.19	0.004	9.95
Reducing sugar (%)	10.16	11.79	10.86	0.120	4.65
Non reducing sugar (%)	0.82	1.10	0.97	0.020	8.32
Total sugar (%)	11.26	12.78	11.83	0.110	3.99
Antioxidant activity (mg of ascorbic acid/g of sample)	1.64	3.23	2.54	0.100	16.54

Table 7. Plant characters of *Annona muricata* accessions

Accession	Age of the tree (years)	Height of the tree (m)	Spread of the tree (m)	Growth habit	Branching pattern	Orientation of leaf
AM 1	4	4.5	3.90	Erect	One branch	Horizontal
AM 2	6	3.5	3.42	Erect	One branch	Horizontal
AM 3	5	4	3.71	Erect	2 branches	Horizontal
AM 4	7	4.5	4.70	Semi spreading	One branch	Horizontal
AM 5	5	4	3.61	Erect	One branch	Horizontal
AM 6	5	3.5	3.76	Erect	One branch	Horizontal
AM 7	4	4.5	4.05	Erect	2 branches	Horizontal
AM 8	5	3.5	3.72	Erect	One branch	Horizontal
AM 9	6	3.0	4.19	Semi spreading	One branch	Horizontal
AM 10	6	4.6	4.60	Semi spreading	2 branches	Semi upright
AM 11	4	3.5	5.40	Spreading	One branch	Semi upright
AM 12	7	3.0	4.72	Spreading	One branch	Semi upright
AM 13	6	3.5	5.20	Spreading	One branch	Horizontal
AM 14	4	4.0	3.77	Erect	2 branches	Horizontal
AM 15	4	4.0	3.53	Erect	2 branches	Horizontal
AM 16	5	3.5	3.71	Erect	One branch	Horizontal
AM 17	5	4.0	4.45	Semi spreading	2 branches	Semi upright
AM 18	5	3.5	3.86	Erect	One branch	Horizontal
AM 19	6	4.5	4.16	Semi spreading	One branch	Semi upright
AM 20	5	3.5	3.73	Erect	One branch	Semi upright
AM 21	6	4.5	4.60	Semi spreading	One branch	Semi upright
AM 22	6	4.5	4.15	Semi spreading	One branch	Horizontal
AM 23	6	4.0	3.51	Erect	One branch	Horizontal
AM 24	5	4.0	3.79	Erect	One branch	Horizontal
AM 25	7	4.5	4.64	Erect	One branch	Horizontal
Mean		**2.92**	**4.11**			
CV (%)		**17.05**	**13.08**			

Table 8. Variability in vegetative and fruit characters of *A. muricata* accessions

Character	Range		Mean	SEM±	CV (%)
	Minimum	Maximum			
Tree height (m)	2.00	3.60	2.92	0.090	17.05
Spread of tree (m)	3.42	5.40	4.11	0.100	13.08
Leaf length (cm)	12.40	18.10	15.92	0.340	10.92
Leaf breadth (cm)	5.70	8.20	6.75	0.150	11.46
Fruit length (cm)	12.10	16.80	14.40	0.180	6.44
Fruit diameter (cm)	7.70	9.30	8.46	0.070	4.40
Fruit weight (g)	410.00	850.00	652.40	24.000	18.36
Number of fruits per tree	18.00	30.00	23.44	0.710	12.59
Yield per tree (kg)	8.82	22.68	15.20	0.660	21.77
Number of flakes per fruit	132.00	189.00	153.24	3.040	9.92
Number of seeds per fruit	42.00	59.00	52.16	0.860	8.24
Seed weight per fruit	13.95	18.29	16.02	0.240	7.49
Seed length (mm)	15.10	17.80	16.70	0.130	4.13
Seed breadth (mm)	5.90	7.80	6.73	0.100	7.51
Shelf life (days)	3.00	5.00	4.12	0.140	17.61
TSS (^{0}Brix)	12.20	14.90	13.30	0.110	4.25
Acidity (%)	0.36	0.37	0.36	0.001	1.69
Reducing sugar (%)	6.62	8.62	7.55	0.090	6.56
Non reducing sugar (%)	0.86	1.16	1.00	0.010	8.24
Total sugar (%)	7.72	9.57	8.56	0.090	5.56
Antioxidant activity (mg of ascorbic acid/g of sample)	3.52	4.52	4.06	0.050	6.95

AM 9, AM 21, AM 22, AM 25 were having a tree height of 3.5 m. The minimum height was recorded in accession AM 9 and AM 12 (2 m) with all other accession with height in between these accession. The mean value of tree height was 3.92 m with CV of 17.05 percent (Table 8).

4.2.3. Spread of the tree

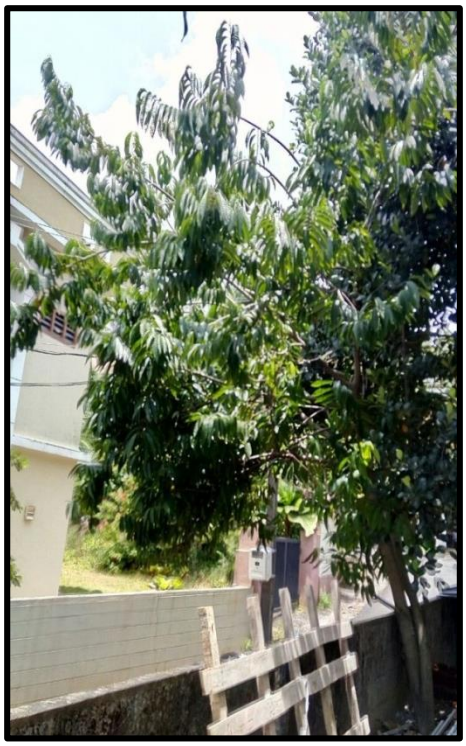
In *Annona reticulata,* spread of the trees varied from 5.4 to 7.7 m (Table 3). The accessions AR 13 and AR 30 was having maximum spread (7.7 m) followed by AR 8 and AR 12 (7.35 m). The minimum spread of the tree was observed in AR 22 (5.4 m). All other accessions were intermediate with respect to spread of the tree. The mean spread was 6.72 m with a CV of 8.48 per cent (Table 4).

The spread of the tree in *A. squamosa* was in the range of 2.36 to 3.95 m (Table 5). The maximum spread was recorded by AS 9 (3.95 m) followed by AS 16 (3.79 m), AS 15 (3.77 m) and AS 2 (3.71 m). The lowest spread was observed in AS 7 (2.36 m). The other accessions were in between these accessions. The mean value for spread of the tree was 3.29 m with CV of 14.89 per cent (Table 6).

In *A. muricata,* spread of the tree in the accessions varied from 3.42 to 5.4 m (Table 7) with highest in AM 11 (5.4 m). This was followed by AM 13 (5.2 m), AM 12 (4.72 m), AM 25 (4.64 m) and minimum was recorded in AM 2 (3.42 m). All other accessions were intermediate with respect to spread of the tree. However the mean was 4.11 m with a CV of 13.08 per cent (Table 8).

4.2.4. Growth habit

In *Annona reticulata,* both erect and semi spreading trees were observed (Table 3). Among the accessions, AR 4, AR 5, AR 7, AR 8, AR 11, AR 12, AR 13, AR 25, AR 27 and AR 30 were semi spreading types. All other accessions observed were erect types. In *A. squamosa,* all the accessions were erect in growth habit (Table 5) (Plate 2).

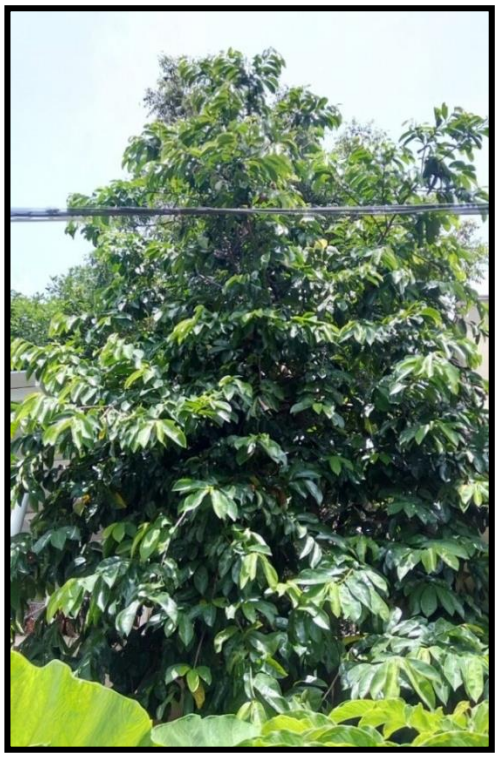


Erect ***A. reticulata*** **Semi spreading**

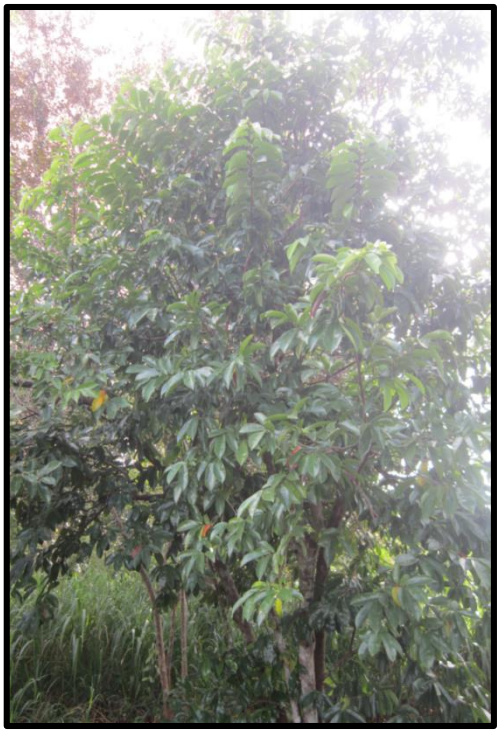
A. squamosa **- Erect**

Plate 2: Growth habit of Annona spp.

Erect (60 %)



Semi spreading (28 %)



Spreading (12 %)

Plate 3: Variability in growth habit of *Annona muricata*

The accessions of *A. muricata* belonged to erect, spreading and semi spreading growth habit (Table 7) (Plate 3). The accessions AM 11, AM 12 and AM 13 were observed to be spreading in nature. The accessions AM 4, AM 9, AM 10, AM 17, AM 19, AR 21 and AM 22 were of semi spreading nature.

4.2.5. Branching pattern

Different branching patterns were present in Annona trees *viz*., one branch, two branches and three or more branches (Plate 4 and 5). In *Annona reticulata,* two branches were more common among the accessions AR 4, AR 5, AR 7, AR 8, AR 9, AR 10, AR 11, AR 14, AR 15, AR 16, AR 18, AR 19, AR 22, AR 23 and AR 24. The accessions AR 1, AR 6, AR 12, AR 13, AR 17, AR 20, AR 21, AR 26, AR 27, AR 28, AR 29 and AR 30 were having one branch. Only three accessions *viz*., AR 2, AR 3 and AR 25 were having 3 or more branches (Table 3).

In *A. squamosa,* most of accessions *viz*., AS 1, AS 4, AS 8, AS 9, AS 10, AS 11, AS 12, AS 13, AS 14, AS 15 and AS 16 were having two branches. The accessions AS 2, AS 3, AS 5, AS 6 and AS 7 were with three or more branches (Table 5).

In *A. muricata,* accessions only one branch and two branches were noticed. The common branching pattern noticed was one branch in accessions *viz*., AM 1, AM 2, AM 4, AM 5, AM 6, AM 8, AM 9, AM 11, AM 12, AM 13, AM 16, AM 18, AM 19, AM 20, AM 21, AM 22, AM 23, AM 24 and AM 25. Other accessions *viz*., AM 3, AM 7, AM 10, AM 14, AM 15 and AM 17 were having two branches (Table 7).

4.2.6. Pubescence on shoot

In all seventy one accessions of the three species studied, there was no pubescence on the shoots.

Two branches

One branch

A. reticulata

Two branches

A. squamosa

Three or more branches

Plate 4: Variability in branching pattern of *Annona* spp.

One branch (76%)

Two branches (24%)

Plate 5: Branching pattern of *Annona muricata*

4.1.7. Orientation of leaf

Orientation of leaves in *Annona reticulata,* accessions was observed to be upright and semi upright (Table 3). The accession AR 2, AR 6, AR 9, AR 10, AR 11, AR 12, AR 13, AR 14, AR 17, AR 18, AR 26 and AR 27 were observed to be semi upright and all other accessions were of upright leaf orientation.

In *A. squamosa*, orientation of leaf was upright and semi upright (Table 5). In the accessions AS 2, AS 3, AS 12 and AS 14 the leaf orientation was semi upright and all others had upright orientation.

Both horizontal as well as semi upright orientation for the leaves was observed in *A. muricata* accessions (Table 7). In the accessions *viz*., AM 10, AM 11, AM 12, AM 17, AM 19, AM 20 and AM 21 a semi upright leaf orientation was noticed (Plate 6).

4.2. Leaf characters

The observations on leaf characters are presented in the tables 9 to 10.The data on range, mean, standard error of mean and coefficient of variation for the tree characters is presented in tables 4, 6 and 8.

4.3.1. Shape of leaf lamina

With regard to shape of leaf blade, lanceolate shape was noticed in all *Annona reticulata* accessions. In case of *A. squamosa,* all the accessions were having lanceolate shape except for AS 4, AS 6, AS 10, AS 11, AS 14 and AS 16 which had elliptic leaf blade (Table 10). In all *A. muricata* accessions, obovate leaf blade shape was observed (Plate7).

4.3.2. Leaf apex

In all the accessions of *Annona reticulata* acuminate leaf apex was noticed (Plate 8). In case of *A. squamosa,* it was observed that all the accessions

Upright (60%) **Semi upright (40%)**

A. reticulata

Upright (75%) **Semi upright (25%)**

A. squamosa

Horizontal (72%) **Semi upright (28%)**

A. muricata

Plate 6: Orientation of leaf in *Annona* spp.

***A. reticulata* – Lanceolate**

***A. muricata* - Obovate**

Lanceolate (62.5 %)

Elliptic (37.5 %)

A. squamosa

Plate 7: Shape of leaf lamina

***A. reticulata* – Acuminate** ***A. squamosa* – Acuminate**

Acuminate (92%) **Acute (8%)**

A. muricata

Plate 8: Shape of leaf apex

were having acute leaf apex. In the accessions of *A. muricata,* acuminate leaf apex was noticed except in AM 2 and AM 8 with acute leaf apex (Table 11).

4.3.3. Leaf base

In *Annona reticulata* and *A. muricata*, all the accessions were with acute leaf base. It was observed that in all the accessions of *A. squamosa* the leaf base was rounded (Plate 9).

4.3.4. Leaf margin

There was no variation with respect to leaf margin. In all the accessions of three species, entire leaf margin were noticed (Plate 10).

4.3.5. Nature of leaf lamina

In the three species of Annona, it was observed that leaf lamina were glaborus in nature in all the seventy one accessions (Plate 10).

4.3.6. Leaf length

Leaf length varied from 17.9 to 23.9 cm in *Annona reticulata* accessions. The maximum leaf length was observed in accession AR 2 (23.9 cm) followed by AR 7 (23.7 cm), AR 9 (22.9 cm) and AR 3 (22.8 cm). The minimum leaf length was noticed in the accession AR 4 (17.9 cm). All other accessions were intermediate with respect to leaf length. The mean leaf length was 20.87 cm with a CV value of 7.62 per cent (Table 9).

The accessions of *A. squamosa* recorded leaf length from 8.3 to 15.2 cm (Table 10). The maximum leaf length was observed in accession AS 3 (15.2 cm) which was followed by AS 15 (14.4 cm) and AS 8 (14.1 cm). The minimum leaf length was noticed in AS 4 (8.3 cm) with mean of 12.03 cm. The CV for leaf length was 15.72 per cent.

***A. reticulata* – Acute**

***A. squamosa* – Rounded**

***A. muricata* – Acute**

Plate 9: Shape of leaf base

A. reticulata

A. squamosa

A. muricata

Entire leaf margin and glabrous lamina

Plate 10: Shape of leaf margin

Table 9. Leaf characters of *Annona reticulata* accessions

Accession	Leaf length (cm)	Leaf breadth (cm)	Petiole and vein colour	Colour of young leaf	Colour of mature leaf
AR 1	22.5	5.4	Light green	Light green	Dark green
AR 2	23.9	5.2	Dark green	Light green	Green
AR 3	22.8	6.8	Dark green	Light green	Green
AR 4	17.9	4.6	Dark green	Light green	Green
AR 5	18.4	4.9	Dark green	Light green	Green
AR 6	21.2	4.4	Dark green	Light green	Green
AR 7	23.6	5.1	Dark green	Light green	Green
AR 8	190	6.0	Dark green	Light green	Green
AR 9	22.9	6.2	Dark green	Light green	Green
AR 10	21.6	4.9	Dark green	Light green	Green
AR 11	19.6	5.8	Dark green	Light green	Dark green
AR12	21.8	5.0	Dark green	Light green	Green
AR 13	19.2	5.4	Dark green	Light green	Green
AR 14	22.1	5.8	Light green	Green	Green
AR 15	20.8	4.6	Light green	Green	Green
AR 16	19.0	5.9	Light green	Green	Green
AR 17	20.2	4.7	Dark green	Light green	Green
AR 18	19.4	6.3	Dark green	Light green	Green
AR 19	21.2	5.1	Light green	Green	Dark green
AR 20	20.4	4.2	Light green	Green	Dark green
AR 21	19.6	5.2	Dark green	Light green	Green
AR 22	22.7	6.1	Light green	Green	Green
AR 23	21.3	4.6	Light green	Light green	Green
AR 24	19.3	5.8	Light green	Light green	Dark green
AR 25	19.8	5.4	Light green	Light green	Green
AR 26	20.6	4.4	Light green	Green	Dark green
AR 27	21.6	4.6	Light green	Light green	Green
AR 28	21.8	6.0	Light green	Light green	Green
AR 29	19.6	5.2	Light green	Light green	Green
AR 30	22.3	5.9	Light green	Light green	Green
Mean	**20.87**	**5.32**			
CV (%)	**7.62**	**12.52**			

Table 10. Leaf characters of *A. squamosa* accessions

Accession	Leaf blade	Leaf length (cm)	Leaf breadth (cm)	Petiole and vein colour	Colour of young leaf	Colour of mature leaf
AS 1	Lanceolate	12.5	3.6	Light green	Light green	Light green
AS 2	Lanceolate	10.1	3.1	Light green	Light green	Light green
AS 3	Lanceolate	15.2	5.4	Light green	Light green	Light green
AS 4	Elliptic	8.3	2.2	Light green	Light green	Dark green
AR 5	Lanceolate	9.6	2.9	Light green	Light green	Light green
AS 6	Elliptic	12.3	3.5	Light green	Light green	Light green
AS 7	Lanceolate	12.8	3.6	Light green	Light green	Light green
AS 8	Lanceolate	14.1	4.2	Dark green	Green	Light green
AS 9	Lanceolate	11.2	3.6	Light green	Light green	Light green
AS 10	Elliptic	10.3	3.4	Dark green	Light green	Dark green
AS 11	Elliptic	12.2	3.3	Light green	Light green	Dark green
AS 12	Lanceolate	12.5	3.8	Light green	Green	Dark green
AS 13	Lanceolate	13.2	4.1	Light green	Light green	Dark green
AS 14	Elliptic	10.5	3.3	Light green	Light green	Dark green
AS 15	Lanceolate	14.4	4.5	Dark green	Light green	Dark green
AS 16	Elliptic	13.3	3.9	Light green	Light green	Light green
Mean		**15.92**	**6.75**			
CV (%)		**10.92**	**11.46**			

Table 11. Leaf characters of *A. muricata* accessions

Accession	Leaf apex	Leaf length (cm)	Leaf breadth (cm)	Petiole and vein colour	Colour of mature leaf
AM 1	Acuminate	17.5	7.4	Light green	Dark green
AM 2	Acute	14.3	6.1	Light green	Dark green
AM 3	Acuminate	15.8	6.2	Dark green	Dark green
AM 4	Acuminate	15.2	5.8	Dark green	Dark green
AM 5	Acuminate	16.7	6.5	Dark green	Dark green
AM 6	Acuminate	18.1	8.2	Dark green	Dark green
AM 7	Acuminate	12.4	5.7	Dark green	Dark green
AM 8	Acute	12.8	6.7	Dark green	Dark green
AM 9	Acuminate	15.6	6.9	Light green	Green
AM 10	Acuminate	13.5	5.9	Light green	Dark green
AM 11	Acuminate	17.8	7.6	Dark green	Dark green
AM 12	Acuminate	17.1	7.3	Dark green	Dark green
AM 13	Acuminate	15.8	6.3	Dark green	Dark green
AM 14	Acuminate	13.1	6.0	Dark green	Dark green
AM 15	Acuminate	14.6	6.1	Dark green	Dark green
AM 16	Acuminate	15.6	5.9	Dark green	Dark green
AM 17	Acuminate	16.8	6.6	Dark green	Dark green
AM 18	Acuminate	17.4	7.6	Dark green	Dark green
AM 19	Acuminate	17.3	7.2	Dark green	Dark green
AM 20	Acuminate	18.0	7.9	Light green	Dark green
AM 21	Acuminate	17.7	7.5	Dark green	Dark green
AM 22	Acuminate	15.9	6.9	Dark green	Dark green
AM 23	Acuminate	16.3	6.6	Dark green	Green
AM 24	Acuminate	18.1	8.0	Dark green	Green
AM 25	Acuminate	14.7	5.8	Dark green	Dark green
Mean		**15.92**	**6.75**		
CV (%)		**10.92**	**11.46**		

Leaf length varied from 12.4 to 18.1 cm in *A. muricata* accessions (Table 11). The maximum leaf length was noticed in the accessions AM 6 and AM 24 followed by AM 20 (18.0 cm) and AM 11 (17.8 cm). The minimum leaf length was noticed in the accession AM 7 (12.4 cm). All other accessions were intermediate with respect to leaf length. The mean leaf length was 6.75 cm with a CV of 11.46 per cent.

4.3.7. Leaf breadth

In *Annona reticulata,* leaf breadth varied from 4.2 to 6.8 cm (Table 9). The maximum leaf breadth was observed in the accession AR 3 (6.8 cm) which was followed by AR 18 (6.3 cm), AR 9 (6.2 cm) and AR 22 (6.1 cm). The minimum leaf breadth was noticed in AR 20 (4.2 cm). The mean of leaf breadth and CV was 5.32 cm and 12.52 per cent respectively.

In accessions of *A. squamosa,* leaf breadth ranged from 2.2 to 5.4 cm (Table 10). The maximum leaf breadth was observed in the accession AS 3 (5.4 cm) which was followed by AS 15 (4.5 cm), AS 8 (4.2 cm) and AS 13 (4.1 cm). The minimum leaf breadth noticed in the accession AS 4 (2.2 cm). The mean value of leaf breadth was 4.65 cm with CV of 15.39 per cent.

Leaf breadth in *A. muricata* varied from 5.7 to 8.2 cm (Table 11). In accession AM 6 the maximum leaf breadth was noticed which was followed by AM 24 (8.0 cm), AM 20 (7.9 cm) and AM 11 (7.6 cm). The minimum leaf breadth was in the accession AM 7 (5.7 cm) with mean value of 6.75 cm and CV of 11.46 per cent.

4.3.8. Petiole and vein colour

In the accessions of *Annona reticulata viz.,* AR 1, AR 14, AR 15, AR 16, AR 19, AR 20, AR 22, AR 23, AR 24, AR 25, AR 26, AR 27, AR 28, AR 29 and AR 30 light green petiole and vein colour was observed (Table 9).

In *A. squamosa,* most common petiole and vein colour was light green in the accessions *viz.*, AS 1, AS 2, AS 3, AS 4, AS 5, AS 6, AS7, AS 9, AS 11, AS 12, AS 13, AS 14 and AS 16 (Table 10). All other accession in both species was with dark green colour as their petiole and vein colour.

The most common petiole and vein colour in *A. muricata* were dark green in the accessions *viz*., AM 4, AM 5, AM 6, AM 7, AM 8, AM 11, AM 12, AM 13, AM 14, AM 15, AM 16, AM 17, AM 18, AM 19, AM 21, AM 22, AM 23, AM 24 and AM 25 (Table 11). Whereas all other accessions exhibited light green petiole and vein colour.

4.3.9. Colour of young leaf

Young emerging leaves of *Annona* spp. showed varying colours such as light green, green and dark green (Plate 11). Most of the accessions had light green leaves. In *Annona reticulata,* green leaves were observed in accessions *viz.*, AR 14, AR 15, AR 16, AR 19, AR 20, AR 22 and AR 26 (Table 9) and light green in all other accessions.

In the accessions of *A. squamosa,* light green leaf colour was predominant but in AS 8 and AS 12 green leaves were observed (Table 10). But in *A. muricata,* colour of young leaves was light green in all the accessions.

4.3.10. Colour of mature leaf

Colour of mature leaves of the accessions varied from light green, green and dark green in all the accessions (Plate 11).The colour of mature leaves in *Annona reticulata* was green except in the accessions AR 1, AR 11, AR 19, AR 20, AR 24 and AR 26 which had dark green colour (Table 9).

In *A. squamosa* accessions AS 4, AS 10, AS 11, AS 12, AS 13, AS 14 and AS 15 dark green leaves were observed (Table 10). All other accessions were having light green mature leaves.

Green (23.33 %); Light green (87.66 %)

Dark green (20 %); Green (80 %)

A. reticulata

Light green (87.5 %); Green (12.5 %)

Light green (56.25 %); Dark green (43.75 %)

A. squamosa

Light green

Dark green (88 %); Green (12 %)

A. muricata

Plate 11: Colour of young and mature leaves in *Annona* spp.

The accessions AM 9, AM 23 and AM 24 of *A. muricata* had with green leaves and in majority of the accessions dark green leaves were observed (Table 11).

4.3.11. Pubescence on leaf surface

Pubescence were absent in both *Annona reticulata* and *A. muricata* on both upper and lower surfaces. In *A. squamosa,* all the accessions were having pubescence on its lower surface of young leaves.

4.4. Inflorescence characters

The observations on floral characters are presented in the tables 12 to 14.

4.4.1. Flowering season

The flowering season of all the three species varied between themselves as well as among the accessions. In *Annona reticulata,* flowering season was in between August-March (Table 12). The accession AR 1 recorded flowering from August. In the accessions AR 5, AR 6, AR 22, AR 25, AR 19 and AR 30 the flowering was observed till March. Only in the accession AR 12 two flowering seasons were observed.

In *A. squamosa* flowering was observed from, February to May (Table 13). The accession AS 1 and AS 4 recorded flowering from February to June. The flowering was observed from Feb to May in the accessions *viz*., AS 5, AS 6, AS 8, AS 13 and AS 14.

In *A. muricata* accessions the flowering season varied from August to March (Table14). Majority of the accessions were at flowering during October to January. The accessions AM 4 and AM 7 recorded flowering during August to December, AM 17 during January to March and accession AM 21 during December to March.

Table 12. Floral characters of *Annona reticulata* accessions

Accession	Flowering season	Month of peak flowering	Nature of flowering
AR 1	August - December	October	cluster
AR 2	September - December	November	cluster
AR 3	October -January	November	Solitary, cluster
AR 4	October - February	December	cluster
AR 5	November -March	January	cluster
AR 6	November -March	February	cluster
AR 7	September - January	November	cluster
AR 8	September - December	November	cluster
AR 9	September- January	October	cluster
AR 10	September - December	November	Solitary, cluster
AR 11	September - December	December	Cluster
AR12	Sept-Dec , Feb- May	October, March	cluster
AR 13	October -January	December	cluster
AR 14	October -January	December	cluster
AR 15	August -January	October	cluster
AR 16	October -January	December	cluster
AR 17	November -February	December	cluster
AR 18	October -January	December	cluster
AR 19	December -March	February	cluster
AR 20	September - December	November	cluster
AR 21	September - December	November	cluster
AR 22	November - March	January	Solitary, cluster
AR 23	October -January	December	cluster
AR 24	October -January	November	Cluster
AR 25	November -March	December	cluster
AR 26	October -January	December	cluster
AR 27	September - December	November	cluster
AR 28	September - December	November	cluster
AR 29	October -January	December	Solitary, cluster
AR 30	December - March	January	Cluster

Table 13.Floral characters of *Annona squamosa* accessions

Accession	Flowering season	Month of peak flowering	Nature of flowering
AS 1	February– June	March	Solitary, cluster
AS 2	January - April	March	Solitary, cluster
AS 3	January -April	March	Cluster
AS 4	February– June	April	Cluster
AS 5	February-May	March	Solitary, Cluster
AS 6	February -May	March	Solitary, Cluster
AS 7	January- May	April	Solitary, Cluster
AS 8	February-May	April	Cluster
AS 9	January - May	February	Cluster
AS 10	January -May	April	Solitary, Cluster
AS 11	January - April	March	Cluster
AS 12	January - April	February	Cluster
AS 13	February-May	April	Solitary, Cluster
AS 14	February-May	April	Solitary, cluster
AS 15	January - April	February	Cluster
AS 16	January - April	February	Solitary, Cluster

Table 14. Floral characters of *Annona muricata* accessions

Accession	Flowering season	Peak flowering season
AM 1	October –January	November
AM 2	November-January	December
AM 3	October –January	December
AM 4	August -December	November
AM 5	November-January	December
AM 6	October –January	December
AM 7	August- December	October
AM 8	August -January	October
AM 9	November-January	December
AM 10	August -January	November
AM 11	October –January	November
AM 12	October –January	December
AM 13	November-January	December
AM 14	October –January	November
AM 15	November-January	December
AM 16	October –January	November
AM 17	Jan-March	February
AM 18	August -January	October
AM 19	August -January	October
AM 20	October –January	December
AM 21	December- March	February
AM 22	October –January	February
AM 23	November-January	December
AM 24	August -January	October
AM 25	October –January	December

4.4.2. Peak flowering season

Peak flowering was observed during December for majority of the accessions in *Annona reticulata* and *A. muricata* accessions. The accessions AR 5, AR 22, AR 30 recorded peak flowering during January and in AR 6, AR 19 the peak flowering was observed during February (Table 12).

The accessions AM 7, AM 8, AM 18, AM 19 and AM 24 recorded peak flowering during October (Table14). In *A. squamosa,* peak flowering was observed during March and April (Table 13). The accessions AS 1, AS 2, AS 3, AS 5 and AS 6 recorded peak flowering during March. In the accessions AS 4, AS 7, AS 8, AS 10, AS 13 and AS 14 the peak flowering was observed in April.

4.4.3. Flowering precocity

Early bearing was not specifically observed among various accessions. The flowering was almost uniform in all the species.

4.4.4. Position of flower

In *Annona reticulata* and *A. squamosa* lateral flowering was observed in all the accessions. In *A. muricata,* laterals as well as on the trunk flowering were noticed.

4.4.5. Nature of flowering

In *Annona reticulata,* the accessions AR 3, AR 10, AR 22 and AR 29 recorded both solitary and cluster of flowers (Table 12). But in *A. muricata,* all the accessions were solitary in nature. The accessions of *A. squamosa viz*., AS 3, AS 4, AS 8, AS 9, AS 11, AS 12 and AS 15 flowers were observed to be in small clusters (Table 13) (Plate 12).

***A. reticulata* and *A. squamosa* - Lateral branches on current season growth as clusters**

***A. muricata* - Lateral branches, on trunk with solitary flowers**

Plate 12: Inflorescence of *Annona* spp.

4.4.6. Age of shoot at flowering

In both *Annona reticulata* and *A. squamosa* accessions flowering were observed in its current season shoots whereas in *A. muricata,* flower behaviour was cauliflorous as well as on older shoots.

4.5. Fruit characters

The observations on fruit characters are presented in the tables 15 to 20.The data on range, mean, standard error of mean and coefficient of variation for characters is presented in tables 4, 6 and 8.

4.5.1. Fruiting season

Fruiting season in *Annona reticulata* accessions were from September to May. In most of the accessions fruiting season was observed to be in November to February. This was followed by fruiting season in November-January in the accessions AR 2, AR 7, AR 8, AR 9, AR 10 and AR 11 (Table 15). Only the accession AR 12 recorded two fruiting season during November-January and March –June.

In *A. squamosa* accessions fruiting was observed to be from February to August. In which most of the accessions recorded fruiting during February to May. Only the accessions AS 1, AS 4 (March-August) and AS 5 (March-June) recorded distinct fruiting season (Table 16).

In *A. muricata,* fruiting was noticed to be from September to May. In which there was wide variability in the fruiting season was observed. The accessions AM 1, AM 6, AM 14, AM 16 and AM 25 recorded flowering during November to March. Distinct fruiting season was observed in the accessions *viz*., AM 17 (February- May), AM 7 (September- January) and AM 21 (January and April) (Table 17).

Table 15. Fruit characters of *Annona reticulata* accessions

Accession	Fruiting season	Fruit shape	Fruit length (cm)	Fruit diameter (cm)	Fruit weight (g)	Fruit colour at maturity	Fruit colour at ripening
AR 1	Sept -Jan	Cordate	10.2	9.0	186	Green	Reddish yellow
AR 2	Nov - Jan	Cordate	9.3	8.4	360	Light green	Reddish yellow
AR 3	Nov- Feb	Cordate	10.8	9.5	260	Light green	Yellowish green
AR 4	Nov- March	Cordate	8.2	7.4	200	Light green	Reddish yellow
AR 5	Dec- May	Cordate	10.6	9.1	160	Light green	Reddish yellow
AR 6	Dec - April	Broadly cordate	10.1	7.7	243	Green	Reddish yellow
AR 7	Nov - Jan	Cordate	9.8	6.8	165	Light green	Reddish yellow
AR 8	Nov - Jan	Cordate	10.3	9.4	270	Yellowish green	Yellowish green
AR 9	Nov - Jan	Cordate	10.9	10.4	435	Green	Yellow
AR 10	Nov - Jan	Broadly cordate	9.7	9.3	270	Yellowish green	Yellowish green
AR 11	Nov - Jan	Cordate	10.2	10.6	357	Light green	Reddish yellow
AR12	Nov-Jan, March- June	Cordate	8.7	9.9	345	Light green	Reddish yellow
AR 13	Nov- Feb	Cordate	11.0	8.9	229	Light green	Yellowish green
AR 14	Nov- Feb	Cordate	9.8	8.1	110	Light green	Yellowish green
AR 15	Sep- March	Cordate	7.4	8.3	180	Green	Reddish yellow
AR 16	Nov- Feb	Cordate	10.6	8.9	310	Light green	Reddish yellow
AR 17	Dec- March	Broadly cordate	10.4	9.1	400	Light green	Reddish yellow
AR 18	Nov- Feb	Cordate	11.1	8.9	425	Light green	Reddish yellow
AR 19	Jan- May	Cordate	10.8	7.2	376	Light green	Reddish yellow
AR 20	Oct- Jan	Cordate	9.9	6.6	280	Light green	Reddish yellow
AR 21	Oct- Jan	Cordate	10.0	6.8	325	Light green	Reddish yellow
AR 22	Dec- April	Cordate	10.8	9.0	225	Light green	Reddish yellow
AR 23	Nov- Feb	Cordate	11.4	8.3	352	Light green	Yellowish green
AR 24	Nov- Feb	Cordate	7.8	8.2	382	Light green	Yellowish green
AR 25	Dec- April	Broadly cordate	10.0	6.8	205	Light green	Reddish yellow
AR 26	Nov-Feb	Cordate	9.9	6.6	160	Light green	Reddish yellow
AR 27	Oct- Feb	Cordate	10.6	7.2	120	Light green	Reddish yellow
AR 28	Oct- Jan	Cordate	9.8	6.9	195	Yellowish green	Yellowish green
AR 29	Nov- Feb	Cordate	10.0	7.0	248	Yellowish green	Reddish yellow
AR 30	Jan- April	Cordate	10.4	6.8	210	Light green	Reddish yellow
Mean			**10.02**	**8.24**	**266.1**		
CV (%)			**9.40**	**14.47**	**34.62**		

Table 16. Fruit characters of *A. squamosa* accessions

Accession	Fruiting season	Fruit length (cm)	Fruit diameter (cm)	Fruit weight (g)	Fruit colour at maturity	Fruit colour at ripening
AS 1	March -Aug	5.94	5.68	96.60	Light green	Yellowish green
AS 2	Feb- May	5.61	5.51	89.20	Light green	Yellowish green
AS 3	Feb- May	5.85	5.63	94.30	Green	Light green
AS 4	March-Aug	5.43	5.57	88.90	Light green	Yellowish green
AS 5	March- June	5.98	5.69	92.70	Light green	Yellowish green
AS 6	March - July	5.40	5.46	81.50	Green	Yellowish green
AS 7	Feb- May	5.97	5.62	96.80	Light green	Yellowish green
AS 8	March- July	6.05	5.79	100.40	Light green	Yellowish green
AS 9	Feb- May	5.38	5.53	88.30	Light green	Yellowish green
AS 10	Feb- May	5.82	5.67	98.20	Light green	Yellowish green
AS 11	Feb- May	5.79	5.68	97.70	Green	Light green
AS 12	Feb- May	5.36	5.34	88.10	Light green	Yellowish green
AS 13	March- July	5.38	5.37	87.20	Green	Light green
AS 14	March- July	5.64	5.61	92.30	Green	Light green
AS 15	Feb- May	5.67	5.62	94.50	Green	Light green
AS 16	Feb - May	6.08	5.76	116.90	Light green	Yellowish green
Mean		**5.70**	**4.29**	**93.97**		
CV (%)		**4.56**	**2.96**	**8.40**		

Table 17. Fruit characters of *Annona muricata* accessions

Accession	Fruiting season	Fruit shape	Fruit length (cm)	Fruit diameter (cm)	Fruit weight (g)	Fruit colour at maturity	Fruit colour at ripening
AM 1	Nov-March	Broadly cordate	14.5	8.8	630	Green	Light green
AM 2	Dec- March	Broadly cordate	12.1	8.0	410	Green	Yellowish green
AM 3	Dec-March	Broadly cordate	13.4	8.3	670	Green	Yellowish green
AM 4	Sept- Feb	Cordate	14.6	8.9	660	Dark green	Green
AM 5	Dec-Feb	Cordate	13.8	8.4	730	Green	Yellowish green
AM 6	Nov-March	Broadly cordate	14.5	8.2	490	Green	Yellowish green
AM 7	Sept- Jan	Broadly cordate	15.0	8.6	620	Green	Yellowish green
AM 8	Sept- Feb	Broadly cordate	13.7	7.7	770	Green	Light green
AM 9	Dec- Feb	Broadly cordate	14.3	8.1	490	Green	Yellowish green
AM 10	Sept- March	Broadly cordate	13.6	8.9	430	Green	Yellowish green
AM 11	Nov-Feb	Cordate	13.9	8.6	650	Dark green	Green
AM 12	Nov-Feb	Broadly cordate	15.3	8.7	740	Green	Yellowish green
AM 13	Dec-March	Broadly cordate	14.9	8.3	680	Green	Yellowish green
AM 14	Nov-March	Broadly cordate	16.8	9.3	810	Green	Yellowish green
AM 15	Dec-Feb	Broadly cordate	14.7	8.6	710	Green	Light green
AM 16	Nov-March	Broadly cordate	14.4	8.7	830	Green	Yellowish green
AM 17	Feb-May	Broadly cordate	15.6	8.9	660	Green	Yellowish green
AM 18	Sept-March	Broadly cordate	15.2	8.6	850	Green	Yellowish green
AM 19	Sept- March	Broadly cordate	14.1	8.3	760	Dark green	Green
AM 20	Nov-Feb	Broadly cordate	13.9	7.8	590	Dark green	Green
AM 21	Jan -April	Cordate	14.8	8.5	610	Green	Yellowish green
AM 22	Nov-Feb	Cordate	15.3	8.2	780	Green	Yellowish green
AM 23	Dec-Feb	Broadly cordate	14.6	8.6	530	Green	Yellowish green
AM 24	Sept-March	Broadly cordate	14.0	8.4	630	Green	Light green
AM 25	Nov-March	Broadly cordate	13.1	8.1	580	Green	Yellowish green
Mean			**14.40**	**8.46**	**652.40**		
CV (%)			**6.44**	**4.40**	**18.36**		

4.5.2. Bearing habit

Flowering and fruiting were observed in all accessions and seems to be regular bearer. The farmers have also observed regular bearing for previous years.

4.5.3. Fruit shape

Fruit shapes noticed in three species were cordate and broadly cordate (Plate 13). The common fruit shape observed in *Annona reticulata* accessions was cordate. But in the accessions *viz*., AR 6, AR 10, AR 17 and AR 25 broadly cordate shaped fruits were noticed (Table 15).

In *A. squamosa* accessions only cordate shaped fruits were observed. The accessions of *A. muricata viz.*, AM 4, AM 5, AM 11, AM 21 and AM 22 were having cordate fruits and in all other accessions broadly cordate fruits were noticed (Table 17).

4.5.4. Fruit length

Fruit length in *Annona reticulata* accessions varied from 7.4 to 11.4 cm with mean of 10.02 cm (Table 15). The maximum fruit length was observed in the accession AR 23(11.4 cm) which was followed by AR 18 (11.1 cm), and AR 13 (11.0 cm). The minimum in fruit length was observed in AR 15 (7.4 cm). The CV of fruit length was 9.40 per cent.

Regarding the fruit length in *A. squamosa*, it varied from 5.36 to 6.08 cm (Table 16). Fruit length was maximum in AS 16 (6.08 cm) which was followed by AS 8 (6.05 cm), AS 5 (5.98 cm) and AS 7 (5.97 cm). The minimum was observed in AS 12 (5.36 cm). The mean and CV of fruit length was 5.70 cm and 4.56 per cent respectively.

In *A. muricata* accessions, fruit length was in the range of 12.1 to 16.8 cm (Table 17). It was in AM 14 the maximum fruit length was noticed followed by AM 17 (15.6 cm), AM 12 and AM 22 (15.3 cm). In the accession AM 2

Cordate (86.66 %) **Broadly cordate (13.33 %)**

A. reticulata

***A. squamosa* - cordate**

Broadly cordate (80 %) **Cordate (20 %)**

A. muricata

Plate 13: Fruit shape in *Annnona* spp.

(12.1 cm) minimum fruit length was noticed. The mean value for fruit length was 14.40 cm and CV was 6.44 per cent.

4.5.5. Fruit diameter

In *Annona reticulata,* the fruit diameter varied from 6.6 to 10.6 cm (Table 15). The maximum fruit diameter was noticed in AR 11 (10.6 cm) followed by AR 9 (10.4 cm), AR 12 (9.9 cm) and minimum was observed in AR 20 and AR 26 (6.6 cm). The mean and CV of fruit diameter was 8.24 cm and 14.47 per cent respectively.

Fruit diameter in *A. squamosa* accessions varied from 5.34 to 5.79 cm with a mean of 4.29 cm (Table 16). Fruit diameter was observed to be the maximum in the accession AS 8, followed by AS 16 (5.76 cm), AS 5 (5.69 cm), AS 1 and AS 11 (5.68 cm). The minimum fruit diameter was observed in the accession AS 12 (5.34 cm).The CV of fruit diameter was 2.96 per cent.

With regard to *A. muricata* accessions the fruit diameter varied from 7.7 to 9.3 cm (Table 17). It was maximum in the accession AM 14 (9.3 cm) which was followed by AM 11 and AM 4 (8.9 cm). The minimum fruit diameter was observed in the accession AM 8 (7.7 cm). All other accessions were intermediate with respect to fruit diameter. The mean value for fruit diameter was 8.46 cm with a CV of 4.40 per cent.

4.5.6. Fruit weight

Fruit weight varied widely among the three species. In *Annona reticulata,* it was in the range of 110 to 435 g with a mean of 266.1 g (Table 15). The maximum fruit weight was observed in the accession AR 9 (435 g) and that was followed by AR 18 (425 g), AR 17 (400 g) and AR 24 (382 g). The minimum was noticed in AR 14 (110 g). The CV was 34.62 per cent for fruit weight.

The fruit weight in *A. squamosa* accessions were in the range of 81.5 to 116.9 g and mean of 93.97 g (Table 16). In the accession AS 16 (116.9 g) maximum fruit weight was observed followed by AS 8 (100.4 g), AS 10 (98.2 g) and AS 11 (97.7 g). The minimum fruit weight was observed in the accession AS 6 (81.5 g). The CV of fruit weight was 8.40 per cent.

In *A. muricata* accessions fruit weight varied in the range of 410 to 850 g with a mean of 652.40 g (Table 17). In which the maximum was observed in AM 18 (850 g) followed by AM 16 (830 g), AM 14 (810 g) and AM 22 (780 g). The accession AM 2 (410 g) shown the lowest fruit weight. The CV with regard to fruit weight was 18.36 per cent.

4.5.7. Fruit colour at maturity

Fruit colour varied from light green, green, yellowish green and dark green in the accessions of *Annona* spp. at its maturity stage. In *Annona reticulata,* the observed predominant colour at maturity stage was light green. Only few accessions *viz*., AR 1, AR 6, AR 9 and AR 16 green coloured surface. The accessions AR 8, AR 10, AR 28, and AR 29 were having yellowish green surface (Table 15).

The *A. squamosa* accessions were with light green and green coloured fruits at maturity. Majority of the accessions were with light green fruits except the accessions *viz*., AS 3, AS 6, AS 11, AS 13, AS 14, and AS 15 which had green coloured surface (Table 16).

Dark green and green coloured fruits were observed in *A. muricata* accessions. The accessions AM 4, AM 11, AM 19 and AM 20 had dark green surface. In all other accessions fruit colour observed was green at its maturity (Table 17).

4.5.8. Fruit colour at ripening

A range of fruit colours at ripening was observed such as light green, yellowish green, green, yellow and light pink (Plate 14). In *Annona reticulata,* all the accessions were with reddish yellow surface except in the accessions AR 3, AR 8, AR 10, AR 13, AR 14, AR 23, AR 24 and AR 28 with yellowish green colour. Yellow colour at ripening was only observed in the accession AR 9 (Table 15).

Fruit colour at ripening was yellowish green in almost all accessions of *A. squamosa,* except light green in AS 3, AS 11, AS 13, AS 14 and AS 15 (Table16). In *A. muricata* accessions the most common colour at ripening was yellowish green. But in accessions AM 1, AM 8, AM 15 and AM 24 light green colour was observed at ripening stage. In some accessions *viz*., AM 4, AM 11, AM 19 and AM 20 green colour was also noticed (Table 17).

4.5.9. Fruit surface

Fruit surface varied widely among all the three species *of Annona.* The fruit surface was laevis (smooth) in *Annona reticulata* but in few accessions *viz*., AR 8,AR 9, AR 19, AR 20, AR 22 and AR 23 the surface was impressa (slight depression) (Table 18). It was observed that, all the accessions of *A. squamosa* were with umbonata (small protrusion) surface and *A. muricata* were with tuberculata surface (medium protrusion) (Plate 15).

4.5.10. Number of fruits per tree

Number of fruits per tree was varying in all the three species. The accessions of *Annona reticulata* recorded number of fruits per tree in the range of 31 to 51 (Table 18). The maximum number of fruits was observed in the accession AR 18 (51) which was followed by AR 2 (50), AR 13 and AR 17 (49).

Reddish yellow (73.33 %) **Yellowish green (26.66 %)**

A. reticulata

Yellowish green (68.75 %) **Light green (31.25 %)**

A. squamosa

Green **Yellowish green**

A. muricata

Plate 14: Variability of fruit Colour at ripening in *Annnona* spp.

Impressa (20 %)

Laevis (80 %)

A. reticulata

***A. squamosa* - Umbonata**

***A. muricata* - Tuberculata**

Plate 15: Fruit Surface in *Annnona* spp.

The accession AR 9 recorded minimum number of fruits per tree (31). The mean number of fruits per tree was 22.20 and CV was 23.37 per cent.

Regarding the number of fruits per tree in *A. squamosa,* It was observed to be in the range of 18 to 26 (Table 19). In which maximum was observed in AS 9 (26) followed by AS 14 (24), AS 7and AS 12 (23). The accessions *viz*., AS 2, AS 4, AS 10 and AS16 (18) recorded minimum number of fruits among all the accessions. The mean number of fruits per tree and CV was 20.68 and 11.67 per cent respectively.

The accessions of *A. muricata* recorded 18 to 30 fruits per tree with mean of 23.44 (Table 20). The maximum number of fruits was observed in AM 10 (30 fruits) followed by AM 17 (29), AM 9, AM 14 and AM 23 (28). The minimum number of fruits per tree was noticed in the accession AM 6 (18). The CV was 12.59 per cent.

4.5.11. Yield of fruits per tree

Yield of fruits per tree was highly variable in all the accessions of the three species. It varied from 3.92 to 15.18 kg in *Annona reticulata* accessions with a mean of 5.97 kg (Table 18). The accessions AR 18 (15.18 kg) recorded maximum yield of fruits per tree which was followed by AR 17 (13.6 kg), AR 2 (12.8 kg) and AR 19 (12.15 kg). The accession AR 27 (3.92 kg) recorded minimum yield of fruits per tree. The CV of yield per tree was 46.55 per cent.

In *A. Squamosa,* the accessions were having its fruit yield in the range of 1.54 to 2.29 kg with a mean of 1.94 kg (Table 19).The accession AS 9 (2.29 kg) recorded maximum yield of fruits per tree which was followed by AS 7 (2.22 kg), AS 14 (2.21 kg) and AS 16 (2.10 kg). The CV was 12.37 per cent for yield.

Yield of fruits in *A. muricata was* higher than in other two species. It varied from 8.82 to 22.68 kg with a mean value of 15.20 kg (Table 20). The maximum yield of fruit was recorded in the accession AM 14 (22.68 kg) which

was followed by AM 16 (22.41 kg), AM 8 (19.25 kg) and AM 17 (19.14 kg). In the accession AM 6 (8.82 kg), the minimum yield of fruits was observed. All other accessions were intermediate with respect to yield of fruits per tree. The CV of yield of fruits per tree was 21.77 per cent.

4.5.12. Number of flakes per fruit

Number of flakes also varied in all the three species. In *A. reticulata,* number of flakes per fruit was in the range of 46 to 114 and mean of 73.97 (Table 18), where the maximum number was recorded in AR 18 followed by AR 17 (98), AR 2 (94) and AR 9 (89). The minimum number of flakes was recorded in the accession AR 14 (46). The CV was 19.66 per cent.

With regard to *A. squamosa,* number of flakes varied from 33 to 62 with mean of 59.81(Table 19). The maximum number of flakes was recorded in accession AS 16 (62) followed by AS 8 (61), AS 1 (58) and AS 10 (57). The minimum number of flakes was recorded in the accession AS 6 (33). The CV was14.91 per cent for number of flakes per fruit.

Among all other species the highest number of flakes per fruit was recorded in *A. muricata,* which varied from 132 to 189 (Table 20). The maximum number of flakes was recorded in AM 18 (189) which was followed by AM 14 (184), AM 16 (178) and AM 5 (167) and minimum in AM 10 (132). The mean number of flakes and CV was 153.24 and 9.92 per cent respectively.

4.5.13. Number of seeds per fruit

The number of seeds per fruit in *A. reticulata* accessions, varied from 43 to 93 with a mean of 65.03 (Table 18). The maximum number of seed was recorded in the accession AR 18 (93) which was followed by AR 2 (87), AR 17 (84) and AR 16 (78). The minimum number was recorded in the accession AR 14 (43). The CV of number of seeds was 19.59 per cent.

In *A. squamosa,* number of seeds per fruit ranged from 11 to 29 with a mean of 26.69 (Table 19). The accession AS 8 (29) recorded maximum number of seed followed by AS 16 (22), AS 11 (20), AS 4 and AS 10 (19). The minimum number of seeds per fruit was observed in the accession AS 1(11). The CV value was 16.80 per cent.

In *A. muricata* accessions, number of seed per fruit varied from 42 to 59 (Table 20). It was maximum in the accession AM 16 (59) which were followed by AM 4 (58), AM 1, AM 5, AM 9 and AM 22 (57) and the lowest number was seen in accession AM 17 (42). The mean and CV of number of seeds was52.16 and 8.24 per cent.

4.5.14. Seed size

4.5.14.1. Seed length

Seed length in *A. reticulata* varied from 12.1 to 16.6 mm with a mean of 14.06 mm (Table 18).The accession AR 19 recorded maximum seed length followed by AR 17 and AR 22 (15.9 mm). Seed length was minimum in the accession AR 28 (12.1 mm). The seed length was with a CV of 8.74 per cent.

Considering seed length of *A. squamosa,* it was observed that it varied from 13.1 to 15.7 mm (Table 19). The maximum was noticed in the accession AS 4 (15.7 mm) which was followed by AS 8 (15.2 mm), AS 12 and AS 15 (14.9 mm). The minimum seed length was recorded in the accession AS 12 (13.1 mm). The mean seed length was 14.39 mm with CV of 4.65 per cent.

Seed length in *A. muricata* accessions ranged from 15.1 to 17.8 mm (Table 20). The maximum seed length was recorded in the accessions AM 10 and AM 20 (17.8 mm) followed by AM 15 (17.7 mm) and AM 16 (17.5 mm) and minimum in AM 6 (15.1mm). The mean seed length and CV was 16.70 mm and 4.13 per cent.

4.5.14.2. Seed breadth

Seed breadth varied from 4.1 to 8.4 mm in *Annona reticulata* accessions (Table 18). In accession AR 4 (8.4 mm) it was recorded maximum followed by AR 22 (7.8 mm), AR 2 and AR 26 (7.5 mm). The minimum seed breadth was noticed in AR 6 (4.1mm). The mean seed breadth was 6.14 mm with CV of 16.18 per cent.

In A. *squamosa* accessions the seed breadth varied from 4.1 to 5.9 mm. It was in AS 9 the maximum seed breadth was observed followed by AS 8 (5.8 mm), AS 2 (5.7 mm) and AS 15 (5.6 mm). In the accession AS 12 (4.1 mm) the minimum seed breadth was recorded (Table 19). The mean seed breadth and CV was 4.85 mm and 12.69 per cent respectively.

Seed breadth in *A. muricata* accessions varied from 5.9 to 7.8 mm with maximum in AM 10 (Table 20).It was followed by AM 23 (7.5 mm), AM 16 (7.4 mm) and AM 15 (7.3mm). The minimum seed breadth was noticed in the accession AM 31 (5.9 mm). The mean seed breadth was 6.73 mm with CV of 7.51 per cent.

4.5.15. Seed weight per fruit

Seed weight varied from 13.34 to 19.53 g in *A. reticulata* accessions (Table 18). The maximum seed weight was recorded in AR 18 (19.53 g) which was followed by AR 2 (19.14 g), AR15 (19.04 g) and AR 9 (18.63 g). The minimum seed weight was observed in the accession AR 29 (13.34 g). The mean seed weight per fruit was 17.21 g with CV of 8.61 per cent.

The accessions of *A. squamosa* had a varying seed weight in the range of 6.44 to 8.97 g (Table 19).In which the maximum seed weight was recorded in AS 8 (8.97 g) followed by AS 4 (8.12 g), AS 15 (8.06 g) and AS 11 (7.8 g).

Table 18. Fruit and seed characters of *Annona reticulata* accessions

Acc. No	Fruit surface	Number of fruits/ tree	Yield /tree (kg)	Number of flakes/ fruit	Number of seed/ fruit	Seed length (mm)	Seed breadth (mm)	Seed weight/ fruit (g)	Colour of seed	Shelf life (days)
AR 1	Laevis	44	6.46	82	63	14.3	6.0	18.24	Black	3
AR 2	Laevis	50	12.80	94	87	13.6	7.5	19.14	Black	4
AR 3	Laevis	48	9.30	78	71	15.0	5.2	18.72	Dark brown	3
AR 4	Laevis	36	5.20	48	44	13.8	8.4	14.48	Dark brown	4
AR 5	Laevis	44	5.84	62	56	12.1	6.7	16.68	Black	3
AR 6	Laevis	46	8.32	76	66	15.7	4.1	17.82	Black	3
AR 7	Laevis	46	6.29	68	62	13.6	6.4	16.12	Black	3
AR 8	Impressa	38	6.86	80	76	13.3	5.3	18.27	Black	3
AR 9	Impressa	31	6.79	89	81	13.2	6.0	18.63	Black	3
AR 10	Laevis	45	8.75	74	65	14.4	6.2	17.60	Black	4
AR 11	Laevis	43	10.21	80	71	15.8	6.6	18.33	Black	3
AR12	Laevis	40	8.90	76	66	12.6	4.3	17.40	Black	3
AR 13	Laevis	49	8.64	66	60	15.7	5.9	17.16	Black	2
AR 14	Laevis	41	4.31	46	43	13.0	6.2	14.92	Black	3
AR15	Laevis	42	5.96	83	71	12.3	5.1	19.04	Black	2
AR 16	Laevis	46	10.06	86	78	14.5	6.5	17.94	Black	2
AR 17	Laevis	49	13.60	98	84	15.9	4.8	18.48	Black	2
AR 18	Laevis	51	15.18	114	93	13.1	5.7	19.53	Black	2
AR 19	Impressa	47	12.15	76	68	16.6	7.3	16.64	Black	3
AR 20	Impressa	39	7.32	69	60	14.2	5.4	16.80	Black	4
AR 21	Laevis	45	10.13	77	72	13.3	6.1	17.28	Dark brown	4
AR 22	Impressa	42	6.95	53	49	15.9	7.8	15.72	Black	2
AR 23	Impressa	38	8.34	72	61	15.1	7.3	16.64	Black	3
AR 24	Laevis	33	6.97	79	74	13.0	6.1	17.76	Black	2
AR 25	Laevis	35	5.08	73	68	14.2	5.6	17.35	Black	3
AR 26	Laevis	40	5.20	68	58	13.7	7.5	15.92	Black	4
AR 27	Laevis	36	3.92	54	46	13.4	6.2	14.80	Black	4
AR 28	Laevis	41	6.10	72	57	12.1	5.7	17.82	Black	3
AR 29	Laevis	44	7.95	58	46	14.8	6.6	13.34	Dark brown	3
AR 30	Laevis	37	5.57	68	55	13.6	5.8	17.95	Black	3
Mean		**22.2**	**5.97**	**73.97**	**65.03**	**14.06**	**6.14**	**17.21**		**3**
CV (%)		**23.37**	**46.55**	**19.66**	**19.59**	**8.74**	**16.18**	**8.61**		**23.16**

Table19. Fruit and seed characters of *Annona squamosa* accessions

Acc. No	Number of fruits/ tree	Yield of fruits/ tree (kg)	Number of flakes/ fruit	Number of seed/ fruit	Seed length (mm)	Seed breadth (mm)	Seed weight /fruit (g)	Colour of seed	Shelf life (days)
AS 1	20	1.93	58	11	13.8	4.2	6.93	Black	5
AS 2	18	1.60	42	14	14.3	5.7	7.68	Black	6
AS 3	21	1.98	45	16	13.4	4.4	6.50	Black	4
AS 4	18	1.60	38	19	15.7	5.9	8.12	Dark brown	4
AS 5	22	2.03	54	13	14.4	4.6	7.13	Dark brown	6
AS 6	19	1.54	33	17	14.8	4.3	7.56	Dark brown	6
AS 7	23	2.22	56	15	14.6	4.7	7.50	Dark brown	5
AS 8	21	2.10	61	29	15.2	5.8	8.97	Dark brown	5
AS 9	26	2.29	40	12	14.1	4.5	7.26	Black	5
AS 10	18	1.76	57	19	14.6	4.9	7.20	Dark brown	6
AS 11	21	2.05	54	20	14.9	5.0	7.80	Dark brown	6
AS 12	23	2.02	46	14	13.1	4.1	6.48	Dark brown	6
AS 13	19	1.65	42	17	14.3	4.5	7.56	Dark brown	4
AS 14	24	2.21	53	13	13.7	4.2	6.44	Dark brown	5
AS 15	20	1.89	56	16	14.9	5.6	8.06	Dark brown	5
AS 16	18	2.10	62	22	14.5	5.2	7.36	Dark brown	5
Mean	**20.68**	**1.94**	**59.81**	**26.69**	**14.39**	**4.85**	**7.40**		**5.18**
CV (%)	**11.67**	**12.37**	**14.91**	**16.80**	**4.65**	**12.69**	**8.99**		**14.46**

Table 20. Fruit and seed characters of *Annona muricata* accessions

Acc. No	Number of fruits/ tree	Yield of fruits per tree (kg)	Number of flakes/ fruit	Number of seed/ fruit	Seed length (mm)	Seed breadth (mm)	Seed weight /fruit (g)	Colour of seed	Shelf life (days)
AM 1	20	12.60	159	53	16.4	6.3	14.31	Black	4
AM 2	26	10.66	133	47	17.2	7.0	14.10	Black	5
AM 3	24	16.08	166	54	16.7	6.1	16.74	Black	3
AM 4	22	14.52	154	58	16.3	6.7	16.24	Black	4
AM 5	20	14.60	167	51	17.2	7.2	17.34	Black	4
AM 6	18	8.82	138	45	15.1	6.1	13.95	Dark brown	5
AM 7	21	13.02	151	53	16.9	6.4	16.43	Black	4
AM 8	25	19.25	165	49	16.4	6.7	17.64	Black	4
AM 9	28	13.72	138	57	17.3	7.2	16.53	Black	5
AM 10	30	12.90	132	49	17.8	7.8	14.70	Dark brown	4
AM 11	25	16.25	148	53	17.0	7.0	15.37	Black	4
AM 12	19	14.06	157	48	15.6	6.6	15.84	Black	4
AM 13	24	16.32	143	50	16.2	6.9	14.50	Black	3
AM 14	28	22.68	184	52	15.9	6.0	16.12	Black	3
AM 15	21	14.91	151	57	17.7	7.3	16.53	Black	5
AM 16	27	22.41	178	59	17.5	7.4	18.29	Black	5
AM 17	29	19.14	146	42	16.4	6.7	14.28	Black	5
AM 18	20	17.00	189	54	16.1	6.2	16.74	Dark brown	4
AM 19	24	18.24	152	58	16.6	6.4	15.66	Black	3
AM 20	22	12.98	148	49	17.8	7.1	16.66	Black	3
AM 21	25	15.25	141	53	16.0	5.9	16.96	Black	4
AM 22	20	15.60	162	57	16.9	6.6	17.10	Black	4
AM 23	28	14.84	145	54	17.3	7.5	15.12	Black	4
AM 24	19	11.97	148	53	16.6	6.9	16.43	Black	5
AM 25	21	12.18	136	49	16.8	6.4	17.15	Black	5
Mean	**23.44**	**15.20**	**153.24**	**52.16**	**16.70**	**6.73**	**16.02**		**4.12**
CV (%)	**12.59**	**21.77**	**9.92**	**8.24**	**4.13**	**7.51**	**7.49**		**17.61**

Table 21. Percentage edible portion of *Annona* spp.

Accession	Percentage edible portion	Accession	Percentage edible portion	Accession	Percentage edible portion
AR 1	76.19	**AS 1**	54.82	**AM 1**	74.72
AR 2	80.68	**AS 2**	53.39	**AM 2**	73.56
AR 3	78.80	**AS 3**	55.10	**AM 3**	74.50
AR 4	78.76	**AS 4**	52.86	**AM 4**	74.53
AR 5	75.57	**AS 5**	54.30	**AM 5**	74.62
AR 6	78.66	**AS 6**	52.72	**AM 6**	74.15
AR 7	76.20	**AS 7**	54.25	**AM 7**	74.35
AR 8	79.23	**AS 8**	53.06	**AM 8**	74.70
AR 9	81.71	**AS 9**	53.77	**AM 9**	73.62
AR 10	79.48	**AS 10**	54.66	**AM 10**	73.58
AR 11	80.86	**AS 11**	54.01	**AM 11**	74.63
AR12	80.95	**AS 12**	54.64	**AM 12**	74.85
AR 13	78.50	**AS 13**	53.33	**AM 13**	74.86
AR 14	72.43	**AS 14**	55.02	**AM 14**	75.00
AR15	75.42	**AS 15**	53.47	**AM 15**	74.67
AR 16	80.21	**AS 16**	55.70	**AM 16**	74.79
AR 17	81.38			**AM 17**	74.83
AR 18	81.40			**AM 18**	75.03
AR 19	81.57			**AM 19**	74.93
AR 20	80.00			**AM 20**	74.17
AR 21	80.68			**AM 21**	74.21
AR 22	79.01			**AM 22**	74.80
AR 23	81.27			**AM 23**	74.14
AR 24	81.35			**AM 24**	74.39
AR 25	77.53			**AM 25**	74.04
AR 26	76.05				
AR 27	73.66				
AR 28	76.86				
AR 29	80.62				
AR 30	77.45				

The minimum seed weight was observed in AS 14 (6.4 g). The mean seed weight per fruit was 7.40 g with CV of 8.99 per cent.

In *A. muricata,* the accessions recorded seed weight varying from 13.95 to 18.29 g (Table 20). The accession, AM 16 (18.29g) recorded the maximum seed weight which was followed by AM 8 (17.64 g), AM 5 (17.34 g) and AM 25 (17.15 g). It was observed that the accession AM 6 (13.95 g) was with the minimum seed weight. The mean seed weight and CV was 16.02 g and 7.49 per cent respectively.

4.5.16. Percentage edible portion

Percentage edible portion of all the accessions are presented in table 21. In *A. reticulata, the* percentage edible portion varied from 72.43 to81.71 per cent. The highest percentage of edible portion was recorded by the accession AR 9 (81.71 %) followed by AR 19 (81.57 %) and AR 18 (81.40 %). The lowest percentage of edible portion was recorded in AR 14 (72.43 %).

The *A. squamosa* accessions recorded percentage edible portion in the range of 52.72 to 55.70 per cent. The highest edible portion was observed in AS 16 (55.70 %) followed by AS 3 (55.10 %) and AS 1 (54.82 %). The accession AS 6 (52.72 %) recorded the lowest edible portion percentage.

With regard to percentage edible portion in *A. muricata*, ranged from 73.56 to 75.03 per cent. The highest was recorded in AM 18 (75.03 %) followed by AM 14 (75.00 %) and AM 19 (74.93 %). It was the lowest in AM 2 (63.56 %).

4.5.17. Colour of seed

The colour of seed in all the accessions of the three species was dark brown and black (Plate 16). In *Annona reticulata,* it was observed that all the accessions had black seeds except AR 3, AR 4, AR 21 and AR 29, which had dark brown seeds (Table 18). The *A. squamosa* accessions were with dark brown seeds

Dark brown (75%) **Black (25%)**

A. reticulata

Dark brown (75%) **Black (25%)**

A. squamosa

Black (88 %) **Golden brown (12 %)**

A. muricata

Plate 16: Variability in colour of seeds in *Annnona* spp.

except in AS 1, AS 2, AS 3 and AS 9 with black seeds (Table 19). Black seed were observed in all of the *A. muricata* accessions except in AM 6, AM 10 and AM 18 with dark brown seeds (Table 20).

4.5.18. Shelf life of fruit

In *Annona reticulata,* accessions the shelf life varied from 2-4 days (Table 18) (Plate 17). The maximum shelf life was recorded in the accessions AR 4, AR 2, AR 10, 20, AR 21, AR 26 and AR 27 (4 days). The minimum shelf life was recorded in the accessions AR 13, AR 15, AR 16, AR 17, AR 18, AR 22 and AR 24 (2 days). The mean shelf life was 3 days with CV of 23.16 per cent.

The accessions of *A. squamosa* recorded shelf life in the range of 4-6 days (Table 19). The maximum days were noticed in the accessions AS 2, AS 5, AS 6, AS 10, AS 11 and AS 12 (6 days). The minimum days were recorded in the accessions AS 3, AS 4 and AS 13. The mean and CV was 5.18 days and 14.46 per cent respectively.

In *A. muricata* accessions the shelf life varied from 3-5 days (Table 20). In which the maximum shelf life was recorded in the accessions *viz*., AM 2, AM 6, AM 9, AM 15, AM 16, AM 17, AM 24 and AM 25 (5 days). The minimum number of days was observed in the accessions AM 3, AM 13, AM 14, AM 19 and AM 20 (3 days). The mean shelf life was 4.12 days with CV of 17.61 per cent.

4.5.19. Sensory evaluation

The data of sensory evaluation on organoleptic characters *viz*., appearance, texture, taste, aroma and sweetness of different accessions are presented in the tables 22 to 24. In *A. reticulata* accessions (Table 22), the mean rank ranged from 2.80 to 28.40 for appearance. In which highest mean rank was in AR 23 (28.40) followed by AR 11 (27.70) and AR 9 (26.40). The lowest rank was for the accession AR 7 (2.80).

A. reticulata after 4 daysof storage

A. squamosa after 6 days of storage

A. muricata after 5 daysof storage

Plate 17: Spoilage of fruits at storage in *Annnona* spp.

Table 22. Mean rank score of sensory parameters of *A. reticulata* accessions

Accession	Appearance	Texture	Taste	Aroma	Sweetness	Total score
AR 1	17.60	10.90	18.40	13.90	19.40	80.2
AR 2	9.60	6.90	14.80	11.60	9.00	51.9
AR 3	19.60	23.20	28.00	26.70	27.10	124.6
AR 4	4.00	13.00	19.60	20.50	20.80	77.9
AR 5	17.30	18.10	18.10	18.10	19.10	90.7
AR 6	17.30	17.40	14.80	9.50	12.20	71.2
AR 7	2.80	8.80	14.50	11.90	12.60	50.6
AR 8	19.10	20.50	22.60	22.40	22.80	107.4
AR 9	26.40	22.60	9.10	7.70	9.10	74.9
AR 10	9.40	9.00	6.00	9.80	5.90	40.1
AR 11	27.70	28.00	17.80	14.20	19.20	106.9
AR 12	3.90	6.90	10.80	16.00	12.80	50.4
AR 13	21.10	19.80	25.60	22.40	24.50	113.4
AR 14	13.40	18.10	10.80	11.80	14.20	68.3
AR 15	4.60	5.00	6.00	3.80	5.80	25.2
AR 16	17.60	20.80	27.30	26.90	28.50	121.1
AR 17	21.40	20.60	4.20	7.70	4.50	58.4
AR 18	19.60	18.40	1.30	1.10	2.40	42.8
AR 19	17.30	22.10	9.00	10.00	14.20	72.6
AR 20	11.40	6.90	28.20	26.80	26.50	99.8
AR 21	21.40	22.20	28.00	27.50	28.20	127.3
AR 22	19.90	13.00	6.00	13.70	4.30	56.9
AR 23	28.40	20.50	22.60	22.10	21.10	114.7
AR 24	4.40	9.00	10.80	13.90	12.20	50.3
AR 25	19.10	20.80	19.60	17.90	21.10	98.5
AR 26	9.60	10.90	18.40	20.00	15.80	74.7
AR 27	19.60	18.10	6.30	5.60	4.10	53.7
AR 28	13.30	9.00	14.80	13.90	13.80	64.8
AR 29	11.10	7.10	20.80	23.70	21.20	83.9
AR 30	17.10	17.40	10.80	13.90	12.60	71.8
Sig. value of Kendall's W test	0.032	0.064	0.015	0.026	0.019	

The mean rank for texture ranged from 5.00 to 28.00. The highest mean rank was observed in AR 7 (28.00) followed by AR 3 (23.20) and AR 9 (22.60). It was lowest in the accession AR 15 (5.00). With regard to taste the mean rank varied from 1.30 to 28.20. The mean rank observed in the accession AR 20 (28.20) was highest followed by AR 3and AR 21 (28.00). The accession AR 18 (1.30) was with lowest mean rank. The mean rank for aroma ranged from 1.10 to 27.50. In which it was highest in the accession AR 21 (27.50) followed by AR 16 (26.90) and AR 20 (26.80). The lowest rank was recorded in AR 18 (1.10). With respect to Sweetness, the mean rank varied from 2.40 to 28.50 with highest in AR 16 followed by AR 21 (28.20) and AR 3 (27.10). The lowest mean rank was recorded in AR 18 (2.40). The accession AR 21 recorded highest total score of 127.3 followed by AR 3 with 124.6 and AR 16 with 121.1. Based on total score the accessions AR 21 (127.3) and AR 3 (124.6) were superior and they were highly preferred by panellist.

In *A.squamosa* accessions (Table 23), mean rank for appearance ranged from 2.10 to 15.00. In which, the highest was observed in the accession AS 16 (15.00) followed by AS 8 (12.50) and AS 1 (12.10). The lowest mean rank was observed in AS 12 (2.10). Considering the texture of the fruits, it varied from 1.80 to 13.50. The highest mean rank was noticed in the accession AS 15 (13.50) followed by AS 16 (13.40) and AS 7 (12.40). The lowest mean rank was recorded in the accession AS 6 (4.80).The mean rank for taste ranged from 3.00 to 14.70. It was highest in the accession AS 8 (14.70) followed by AS 16 (13.80), AS 3 and AS 6 (12.00). It was lowest in the accession AS 14 (3.00). With regard to aroma the mean rank varied from 3.40 to 12.50. The highest was recorded by AS 8 and AS 13 (12.50) followed by AS 3 (11.60). Whereas the lowest mean rank was observed in AS 5 (3.40). While considering sweetness, it varied from 3.10 to 15.10. The highest mean rank was noticed in the accession AS 8 (15.10) followed by AS 16 (13.30) and AS 11 (11.40). The lowest mean rank was in AS 5 (1.50). The total score of AS 8 was highest with 65.8 followed by AS 16 (65.5) and AS 7 (52.2). These two accessions are more preferred by panellist.

Table 23. Mean rank score of sensory parameters of *A. squamosa* accessions

Accession	Appearance	Texture	Taste	Aroma	Sweetness	Total score
AS 1	12.10	7.60	5.70	10.40	6.60	42.4
AS 2	7.10	8.60	9.70	7.20	10.10	42.7
AS 3	10.80	6.30	12.00	11.60	11.30	52.0
AS 4	7.20	11.00	7.00	7.20	10.30	42.7
AS5	7.30	6.10	3.80	3.40	1.50	22.1
AS 6	2.70	4.80	12.00	10.00	11.30	40.8
AS 7	11.60	12.40	10.70	8.50	9.00	52.2
AS 8	12.50	11.00	14.70	12.50	15.10	65.8
AS 9	6.00	1.80	9.70	10.10	7.80	35.4
AS 10	7.20	7.30	3.60	3.60	4.20	25.9
AS 11	9.60	10.90	8.00	8.40	11.40	48.3
AS 12	2.10	5.10	8.40	6.90	7.80	30.3
AS 13	4.70	7.50	9.50	12.50	9.00	43.2
AS 14	8.50	8.70	3.00	6.50	4.20	30.9
AS 15	11.60	13.50	4.40	7.20	3.10	39.8
AS 16	15.00	13.40	13.80	10.00	13.30	65.5
Sig. Value of Kendall's W test	0.099	0.040	0.107	0.033	0.047	

Table 24. Mean rank score of sensory parameters of *A. muricata* accessions

Accession	Appearance	Texture	Taste	Aroma	Sweetness	Total score
AM 1	10.20	12.80	7.40	12.70	5.30	48.4
AM 2	3.50	6.00	16.70	10.60	16.80	53.6
AM 3	12.20	9.10	7.40	4.00	9.30	42.0
AM 4	15.20	15.30	19.60	14.50	18.20	82.8
AM 5	18.00	17.30	3.20	5.60	5.90	50.0
AM 6	7.20	6.50	7.40	7.30	10.80	39.2
AM 7	13.80	15.00	16.70	16.90	15.60	78.0
AM 8	20.30	19.40	11.40	8.90	11.30	71.3
AM 9	5.90	7.50	16.50	14.90	15.60	60.4
AM 10	3.50	2.50	9.10	8.90	4.50	28.5
AM 11	13.50	12.80	17.50	18.90	20.10	82.8
AM 12	20.60	19.20	21.40	16.90	21.50	99.6
AM 13	9.10	9.60	5.40	5.60	11.20	40.9
AM 14	22.10	22.40	11.10	16.80	9.20	81.6
AM 15	16.90	17.30	16.50	19.00	17.20	86.9
AM 16	23.10	17.50	5.70	8.90	4.30	59.5
AM 17	13.50	12.80	19.60	16.60	22.40	84.9
AM 18	22.70	21.90	12.60	14.50	13.90	85.6
AM 19	16.90	15.40	25.00	24.20	23.40	104.9
AM 20	6.70	9.50	18.50	17.00	20.20	71.9
AM 21	13.50	15.30	5.10	7.30	5.30	46.5
AM 22	18.30	17.10	14.60	12.70	15.80	78.5
AM 23	3.60	7.50	10.80	10.80	6.70	39.4
AM 24	10.50	9.50	16.70	18.80	11.30	66.8
AM 25	4.20	5.80	9.10	12.70	9.20	41.0
Sig. Value of Kendall's W test	0.009	0.032	0.113	0.016	0.029	

The accessions of *A. muricata* (Table 24) recorded a varying mean rank for appearance. It ranged from 3.50 to 23.10. In which highest was observed in the accession AM 16 (23.10) followed by AM 18 (22.70) and AM 14 (22.10). The lowest mean rank was recorded in AM 10 (3.50). The mean rank for texture ranged from 2.50 to 22.40. It was highest in the accession AM 14 (22.40) followed by AM 18 (21.90) and AM 8 (19.40). The lowest mean rank was recorded in AM 10.The mean rank for taste ranged from 3.20 to 25.00. The highest mean rank was observed in the accession AM 19 (25.00) followed by AM 12 (21.40) and AM 4 and AM 17 (19.60). The lowest mean rank was observed in the accession AM 5 (3.20). With regard to aroma, the mean rank varied from 4.00 to 24.20. In which the highest mean rank was observed in AM 19 (24.20) followed by AM 15 (19.00) and AM 11 (18.90). The lowest mean rank was noticed in AM 3 (4.00). The mean rank for sweetness ranged from 4.30 to 23.40. It was highest in the accession AM 19 (23.40) followed by AM 17 (22.40) and AM 12 (21.50). The lowest mean rank was observed in AM 16 (4.30). The total score was highest in AM 19 (104.9) followed by AM 12 (99.6) and AM 15 (86.9). These were having more preference among the panellist. The accession AM 19 was the only one sweet type identified from the accession.

4.6. Quality parameters

The quality parameters of the fruit samples are presented in the tables 24 to 25.The data on range, mean, standard error of mean and coefficient of variation for the tree characters is presented in tables 4, 6 and 8.

4.6.1. Total Soluble Solids

TSS of the fruit samples in *Annona reticulata* varied from 13.4 to 16.6 ^{0}Brix (Table 25). AR 6 (16.6 ^{0}Brix) recorded the maximum TSS and AR 8 (13.4 ^{0}Brix) recorded minimum TSS. The mean TSS was 14.86 ^{0}Brix with CV of 5.77 per cent.

Table 25. Quality parameters of *Annona reticulata* accessions

Accession	TSS (^{0}Brix)	Acidity (%)	Reducing sugar (%)	Non reducing sugar (%)	Total sugar (%)	Antioxidant activity (mg of ascorbic acid/g of sample)
AR 1	15.4	0.28	9.46	0.84	10.3	2.66
AR 2	16.5	0.28	10.16	0.95	11.11	2.39
AR 3	15.7	0.16	9.61	1.07	10.68	2.08
AR 4	15.9	0.28	9.32	1.11	10.43	2.79
AR 5	15.3	0.28	9.19	1.05	10.24	1.99
AR 6	16.6	0.28	10.08	0.93	11.01	2.86
AR 7	15.8	0.29	9.54	1.03	10.57	1.26
AR 8	13.4	0.16	8.86	1.18	10.04	2.39
AR 9	14.5	0.28	9.39	0.98	10.37	2.13
AR 10	14.0	0.28	9.12	1.12	10.24	2.73
AR 11	15.5	0.28	10.24	0.92	11.16	1.64
AR12	14.3	0.28	9.25	1.03	10.28	2.83
AR 13	13.7	0.16	8.74	0.99	9.73	2.69
AR 14	14.4	0.28	9.12	0.92	10.04	2.43
AR 15	14.8	0.29	9.46	1.02	10.48	2.77
AR 16	14.7	0.16	9.54	0.82	10.36	2.32
AR 17	14.8	0.28	9.76	0.83	10.59	2.64
AR 18	13.6	0.28	9.05	0.91	9.96	2.43
AR 19	14.5	0.28	9.61	0.80	10.41	2.08
AR 20	14.8	0.16	9.68	0.91	10.59	1.64
AR 21	15.9	0.16	10.41	0.87	11.28	2.17
AR 22	15.0	0.29	9.46	1.02	10.48	1.45
AR 23	14.3	0.16	9.39	0.91	10.30	2.27
AR 24	14.9	0.29	9.76	0.83	10.59	1.91
AR 25	15.3	0.28	10.16	0.97	11.13	2.26
AR 26	15.7	0.27	10.33	1.03	11.36	2.81
AR 27	14.8	0.28	9.39	0.98	10.37	2.52
AR 28	14.7	0.27	9.54	0.89	10.43	2.79
AR 29	13.9	0.16	9.32	0.96	10.28	1.61
AR 30	13.4	0.29	9.19	1.01	10.20	2.41
Mean	**14.86**	**0.24**	**9.53**	**0.96**	**10.50**	**2.29**
CV (%)	**5.77**	**21.86**	**4.47**	**9.85**	**3.82**	**19.45**

In *A. squamosa* TSS of the samples varied from 18.23 to 19.9 ^{0}Brix (Table 26). The accession with highest TSS was AS7 (19.9 ^{0}Brix) and lowest was AS 3 (18.23 ^{0}Brix). The mean TSS and CV was 18.92 ^{0}Brix and 2.61 per cent respectively.

The accessions of *A. muricata* recorded their TSS in the range of 12.2 to 14.9 ^{0}Brix (Table 27). The accession AM 19 (14.9^{0}Brix) recorded highest TSS and AM 16 (12.2 ^{0}Brix) recorded lowest TSS. The mean TSS was 13.30 ^{0}Brix with CV of 4.25 per cent.

4.6.2. Acidity

Acidity of *Annona reticulata* accessions was in the range of 0.16 to 0.29 per cent (Table 25). It was maximum in the accessions AR 7, AR 15, AR 24 and AR 30. It was minimum in the accessions *viz*., AR 3, AR 8 AR 13, AR 16, AR 20, AR 21, AR 23 and AR 29. The mean acidity was 0.24 per cent with CV of 21.86 per cent.

In *A. squamosa* acidity varied from 0.16 to 0.22 per cent (Table 26). The acidity was maximum in the accessions *viz*., AS 4 and AS 14 (0.22 %) and was minimum in the accessions AS 8 and AS 16 (0.16 %). The mean acidity and CV was 0.19 per cent and 9.95 per cent respectively.

The accessions of *A. muricata* recorded acidity in the range of 0.364 to 0.38 per cent (Table 27). The maximum acidity was recorded in the accession AM 3 (0.38 %). All other accessions recorded minimum acidity of 0.364 per cent except in AM 1, AM 5, AM 9, AM 14, AM 16, AM 18, AM19, AM 24 and AM 25 which was 0.376 per cent.

4.6.3. Reducing, non-reducing and total sugar of fruit pulp

Reducing sugar in the fruit samples varied from 8.74 to 10.41 per cent in *Annona reticulata* accessions (Table 25). The accession AR 21 (10.41 %)

Table 26. Quality parameters of *A. squamosa* accessions

Accession	TSS (^{0}Brix)	Acidity (%)	Reducing sugar (%)	Non reducing sugar (%)	Total sugar (%)	Antioxidant activity (mg of ascorbic acid/g of sample)
AS 1	18.65	0.21	10.68	0.92	11.60	2.39
AS 2	19.50	0.20	11.46	0.82	12.28	2.86
AS 3	18.23	0.18	10.16	1.10	11.26	2.43
AS 4	18.80	0.22	10.68	0.89	11.57	2.13
AS 5	18.30	0.21	10.24	1.07	11.31	2.69
AS 6	19.45	0.18	11.36	0.89	12.25	1.99
AS 7	19.90	0.19	11.79	0.99	12.78	2.86
AS 8	18.70	0.16	10.59	1.01	11.60	2.32
AS 9	18.88	0.19	10.77	0.91	11.68	2.79
AS 10	19.25	0.21	11.26	0.93	12.19	2.52
AS 11	19.60	0.18	11.57	1.05	12.62	3.13
AS 12	19.00	0.19	11.06	0.95	12.01	2.26
AS 13	18.40	0.18	10.33	1.05	11.38	2.81
AS 14	18.67	0.22	10.50	0.94	11.44	1.64
AS 15	18.90	0.21	10.96	1.00	11.96	3.23
AS 16	18.50	0.16	10.41	1.08	11.49	2.73
Mean	**18.92**	**0.19**	**10.86**	**0.97**	**11.83**	**2.54**
CV (%)	**2.61**	**9.95**	**4.65**	**8.32**	**3.99**	**16.54**

Table 27. Quality parameters of *A. muricata* accessions

Accession	TSS (^{0}Brix)	Acidity (%)	Reducing sugar (%)	Non reducing sugar (%)	Total sugar (%)	Antioxidant activity (mg of ascorbic acid/g of sample)
AM 1	12.5	0.376	6.75	1.02	7.77	4.01
AM 2	13.7	0.364	7.06	0.91	7.97	3.52
AM 3	13.1	0.380	7.76	0.96	8.72	3.91
AM 4	13.9	0.364	8.01	0.91	8.92	3.65
AM 5	12.4	0.376	6.86	1.06	7.92	4.17
AM 6	12.6	0.364	6.98	1.03	8.01	4.26
AM 7	13.2	0.364	7.44	0.89	8.33	3.91
AM 8	13.3	0.364	7.48	0.99	8.47	4.43
AM 9	13.6	0.376	7.96	0.86	8.82	3.73
AM 10	13.0	0.364	7.96	0.96	8.92	3.99
AM 11	13.7	0.364	8.06	0.91	8.97	4.06
AM 12	13.5	0.364	7.91	1.03	8.94	3.82
AM 13	12.9	0.364	7.02	0.99	8.01	4.46
AM 14	13.7	0.376	7.86	1.16	9.02	3.86
AM 15	13.4	0.364	7.57	1.10	8.67	3.73
AM 16	12.2	0.376	6.90	1.07	7.97	4.48
AM 17	13.8	0.364	7.96	0.90	8.86	4.26
AM 18	13.5	0.376	7.71	1.08	8.79	4.17
AM 19	14.9	0.376	8.62	0.95	9.57	4.23
AM 20	13.2	0.364	7.81	1.11	8.92	4.15
AM 21	13.1	0.364	7.53	1.06	8.59	4.19
AM 22	13.4	0.364	7.62	0.96	8.58	4.01
AM 23	12.9	0.364	6.62	1.10	7.72	4.43
AM 24	13.7	0.376	7.91	1.05	8.96	3.73
AM 25	13.3	0.376	7.48	1.11	8.59	4.52
Mean	**13.30**	**0.360**	**7.55**	**1.00**	**8.56**	**4.06**
CV (%)	**4.25**	**1.69**	**6.56**	**8.24**	**5.56**	**6.95**

recorded the maximum value and minimum value was recorded by AR 13 (8.74 %). The mean reducing sugar was 9.53 per cent with CV of 4.47 per cent.

In *A. squamosa,* reducing sugar varied from 10.16 to 11.79 per cent (Table 26). The maximum value of 11.79 per cent was recorded in the accession AS 7 and minimum value of 10.16 per cent was recorded in the accession AS 3. The mean value of reducing sugar was 10.86 per cent with CV of 4.65 per cent.

Reducing sugar in *A. muricata* ranged from 6.62 to 8.62 per cent (Table 27). In which the maximum was recorded in the accession AM 19 (8.62 %) and minimum was recorded in AM 23 (6.62 %). The mean and CV was 7.55 per cent and 6.56 per cent respectively.

Non reducing sugar of fruit samples ranged from 0.82 to 1.18 per cent in *A. reticulata* accessions with a mean of 0.96 per cent (Table 25). The maximum value was in AR 8 (1.1.8 %) and minimum in the accessions AR 16 (0.82 %). The CV of non reducing sugar was 9.85 per cent.

Whereas in *A. squamosa* accessions non reducing sugar varied from 0.82 to 1.1 per cent (Table 26). The maximum value of 1.1 per cent was recorded in AS 3 and minimum value of 0.82 per cent was recorded in AS 2. The mean value of non reducing sugar was 0.97 per cent with CV of 8.32 per cent.

In *A. muricata,* the accessions recorded non reducing sugar in the range of 0.86 to 1.16per cent with a mean of 1 per cent (Table 27). In which maximum value of 1.16 per cent was recorded in AM 14 and minimum value of 0.86 per cent was in AM 9.The CV of non reducing sugar was 8.24 per cent.

Total sugar of the fruit samples in *Annona reticulata* varied from 9.73 to 11.36 per cent (Table 25). The maximum value was recorded by AR 26 (11.36 %) and minimum value was in AR 13 (9.73 %). The mean total sugar was 10.5 per cent with CV of 3.82 per cent.

In *A. squamosa* total sugar was in the range of 11.26 to 12.78 per cent (Table 26). The maximum value of 12.78 per cent was recorded by AS 7 and minimum value of 11.26 per cent was recorded in AS 3. The mean and CV was 11.83 per cent and 3.99 per cent respectively.

Total sugar varied from 7.72 to 9.57 per cent in *A. muricata* accessions (Table 27). In which the maximum value of 9.57 per cent was recorded in the accession AM 19 and minimum value of 7.72 per cent was in the accession AM 23. The mean total sugar was 8.56 per cent with CV of 5.56 per cent.

4.6.4. Antioxidant activity

The antioxidant activity in *Annona reticulata* varied from 1.26 to 2.86 mg of ascorbic acid/g of sample (Table 25). The maximum value of 2.86 mg was recorded in the accession AR 6 and minimum value of 1.26 mg of ascorbic acid/g of sample recorded in AR 7. The mean antioxidant activity was 2.29 mg of ascorbic acid/ g of sample with CV of 19.45 per cent.

In *A. squamosa,* antioxidant activity varied from 1.64 to 2.86 mg of ascorbic acid/g of sample with a mean of 2.54 mg of ascorbic acid/g of sample (Table 26). The maximum value was recorded in AS 2 and AS 7 (2.86 mg/g). The minimum value of antioxidant activity was recorded in AS 14 (1.64 mg/g). The CV was 16.54 per cent.

The accessions of *A. muricata* exhibited antioxidant activity in the range of 3.52 to 4.52 mg of ascorbic acid/g of sample (Table 27). The accession AM 25 recorded maximum value of 4.5 mg and minimum value of 3.52 mg was recorded in the accession AM 2. The mean and CV was 4.06 mg of ascorbic acid/g of sample and 6.95 per cent respectively.

4.7. Qualitative characters

Qualitative characters of about 18 were observed for cluster analysis and wide variability was observed in these characters. Besides, floral characters were also evaluated to determine its variability among accessions of each species. In *Annona reticulata* only 11 characters are considered, in *A. squamosa* nine characters and in *A. muricata* only 10 characters are further considered for analysis. All other characters were non variable. The percentage frequency of accessions distributed into each character was calculated and presented in table 28.

4.7.1. Plant characters

Plant characters *viz*., growth habit, branching pattern and orientation of leaf were considered in *A. reticulata*. Two types of growth habit such as erect and semi spreading types were observed in this species. Erect types (66.66 %) were common followed by semi spreading types (33.33 %). In case of branching pattern, one branch, two branches and three branches were noticed. Among them, two branches (50 %) were common followed by one branch (40 %) and three branches (10 %). Orientation of leaf commonly observed was upright and semi upright. In most of the accession orientation of leaf was found to be upright (60 %) and in some it was semi upright (40 %).

In *A. squamosa*, plant characters *viz*., branching pattern and orientation of leaf were only considered. The common branching pattern observed was two branches (68.75 %) followed by three or more branches (31.25 %). Regarding the orientation of leaf, most common was upright (75 %) which was followed by semi upright (25 %).Plant characters that are considered in *A. muricata* accessions were growth habit, branching pattern and orientation of leaf. Erect, semi spreading and spreading type of trees are observed in this species. In which 60 per cent trees are erect types, 28 per cent were semi spreading and 12 per cent were spreading with respect to growth habit. The common branching pattern noticed in soursop

accessions were one branched (76 %) followed by two branched trees (24 %). Orientation of leaf was horizontal (72 %) in most of the accessions followed by semi upright ones (28 %).

4.7.2. Leaf characters

In *A reticulata* accessions, leaf characters that are variable are Petiole and vein colour, colour of young leaves and colour of mature leaves. The percentage frequency of petiole and vein colour was observed to be equal *i.e*., 50 per cent each for light green and dark green colour. In most of the accessions, colour of young leaves was light green (76.66 %) followed by green (23.33 %). About 80 per cent of the mature leaves observed were green in colour and 20 per cent were of dark green colour.

Annona squamosa accessions exhibited variability in the characters *viz*., leaf blade shape, petiole and vein colour, colour of young and mature leaves. Leaf blade shape was lanceolate (62.5 %) among most of the accessions and elliptic (37.5 %) in shape in other accessions. Petiole and vein colour was light green (81.25 %) and dark green (18.75 %) in the accessions. The colour of young leaves was light green (87.5 %) in almost all the accession and a few was with green colour (12.5 %). Regarding the colour of mature leaves most of the accessions were light green (56.25 %) coloured followed by dark green (43.75 %) coloured ones.

Leaf characters *viz*., leaf apex, petiole and vein colour, colour of mature leaves were some of the varying parameters in *A. muricata.* Leaf apex was observed to be acuminate (92 %) in majority of the accessions which was followed by acute leaf types (8 %). Petiole and vein colour observed was predominant with dark green (80 %) colour followed by green (20 %) coloured types. Colour of mature leaves was observed to be dark green (88 %) followed by green (12 %).

Table 28. Percentage frequency of accessions in each qualitative character

Characters	***Annona reticulata***	***A. squamosa***	***A. muricata***
Growth habit	Erect (33.33) Semi spreading (66.66)	Erect (100)	Erect (60) Semi spreading (28) Spreading (12)
Branching pattern	Two branches (50) One branch (40) Three or more branches (10)	Two branches (68.75) Three or more branches (31.25)	One branch (76) Two branches(24)
Orientation of leaf	Upright (60) Semi upright (40)	upright (75) Semi upright (25)	Horizontal (72) Semi upright (28)
Leaf blade	Lanceolate (100)	Lanceolate (62.5) Elliptic (37.5)	Obovate (100)
Leaf apex	Accuminate (100)	Acute (100)	Acuminate (92) Acute (8)
Petiole and vein colour	Light green (50) Dark green (50)	Light green (81.25) Dark green (18.75)	Dark green (80) Green (20)
Colour of young leaves	Light green (876.66) Green (23.33)	Light green (87.5) Green (12.5)	Light green (100)
Colour of mature leaves	Green (80) Dark green (20)	Light green (56.25) Dark green (43.75)	Dark green (88) Green (12)
Peak flowering	December (36.66) November (33.33) October (13.33) January (10) February (6.66)	March (37.5) April (37.5) February (25)	December (44) November (24) October (20) February (12)
Solitary or cluster flowers	Cluster (86.66) Solitary and cluster (13.33)	Solitary and cluster (56.25) Cluster (43.75)	Solitary (100)
Fruit shape	Cordate (86.66) Broadly cordate (13.33)	Cordate (100)	Broadly cordate (80) Cordate (20)
Colour of fruit at maturity	Yellowish green (73.33) Light green (13.33) Green colour (13.33)	Light green (62.5) Green (37.5)	Green (84) Dark green (16)
Colour of fruit at ripening	Reddish yellow (73.33) Yellowish green (26.66)	Yellowish green (68.75) Light green (31.25)	Yellowish green (28) Green (16)
Fruit surface	Laevis (80) Impressa (20)	Umbonata (100)	Tuberculata (100)
Colour of seed	Dark brown (75) Black (25)	Dark brown (75) Black (25)	Black (88) Golden brown (12)

4.7.5. Floral characters

Floral characters *viz*., peak flowering season and solitary or cluster flowers was observed to be variable in the accessions.

In *A. reticulata,* peak flowering was observed during December (36.66 %) in most of the accessions. About 33.33 per cent trees peak flowering was observed during November, in 13.33 per cent trees it was during October, in 10 per cent trees it was during January and 6.66 per cent peak flowering was observed during February. With respect to flowering as solitary or cluster, majority of the accessions were observed to be in cluster (86.66 %) and others were with both solitary and cluster flowers (13.33 %).

Peak flowering in *A. squamosa,* accessions was observed to be in March (37.5 %), April (37.5 %) and February (25 %). The flowers were observed to be as solitary and clusters (56.25 %) in most of the accessions and in few it was in clusters (43.75 %).

In *A. muricata* accessions, only peak flowering season exhibited variability. In most of the accessions, it was observed during December (44 %). In other accessions it was during November (24 %), October (20 %), and February (12 %).

4.7.4. Fruit characters

In *A. reticulata*, fruit shape, fruit colour at maturity and ripening, fruit surface and colour of seed were variable parameters. Most of the fruits were with cordate shape (86.66 %) and others were broadly cordate (13.33 %) in shape. The predominant colour of fruits at maturity was yellowish green (73.33 %), followed by light green (13.33 %) and green colour (13.33 %). But during ripening stage the predominant colour observed was reddish yellow (73.33 %) followed by yellowish green (26.66 %). With regard to fruit surface 80 per cent of the accessions observed were with laevis surface and only 20 per cent were with

impressa surface. The predominant colour of seed was black (86.66%) and in few accessions it was dark brown in colour (13.33 %).

The fruit characters *viz.*, fruit colour at maturity and ripening, colour of seed was variable parameters among the accessions of *A. squamosa*. In the accessions, major fruit colour observed during its maturity was light green (62.5 %) and others were with green (37.5 %) surface. Fruit colour at ripening was yellowish green (68.75 %) followed by light green (31.25 %) colour. Variability in seeds was also noticed. Most of the seeds were dark brown (75 %) and black coloured (25 %) in the accessions.

In *A. muricata* accessions, fruit shape, fruit colour at maturity and ripening and colour of the seeds exhibited variability. Regarding fruit shape, about 80 per cent of them were with broadly cordate shape and 20 per cent were with cordate shape. Fruit colour at maturity was green (84 %) followed by dark green (16 %) in the accessions. With respect to fruit colour at ripening, yellowish green (28 %) were predominant followed by green (16 %) coloured and light green (12 %) coloured fruits. Seed colour is variable among the other species same away, soursop accessions also exhibited variability in their seed colour. The predominant colour of seeds was black (88 %) followed by dark brown (12 %) types.

4.7.5. Clustering based on Qualitative characters

Agglomerative hierarchical clustering was performed based on the Jaccard's similarity coefficient using UPGMA method in NTSYS 2.2. The observations on various qualitative parameters of *Annona* spp. such as growth habit, branching pattern, pubescence on shoot, orientation of leaf, leaf blade, leaf base, leaf apex, leaf margin, nature of leaf lamina, petiole and vein colour, colour of young leaves, colour of mature leaves, pubescence on leaves, fruit shape, fruit colour at maturity, fruit colour at ripening, fruit surface and colour of seed were

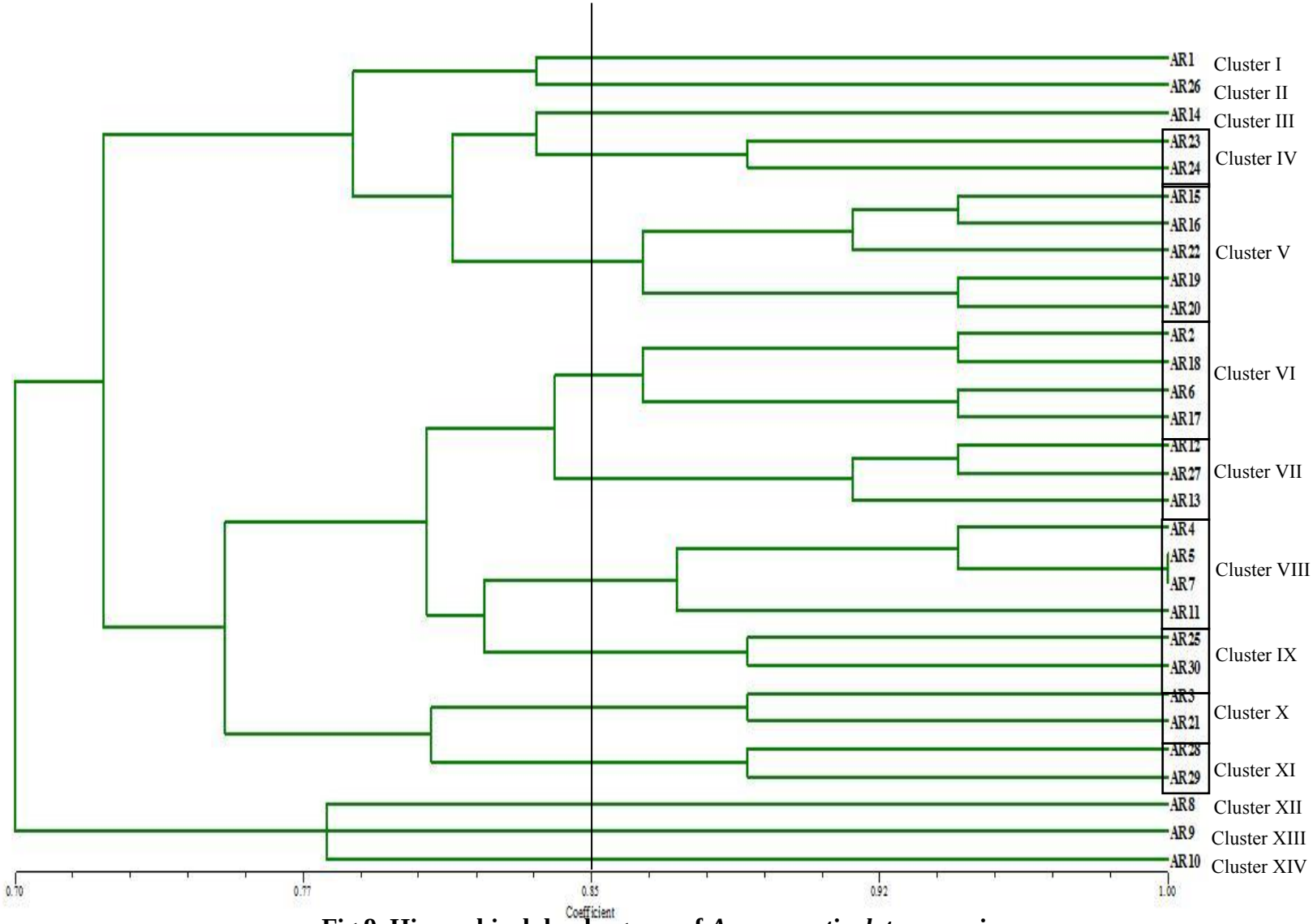


Fig 9. Hierarchical dendrogram of *Annona reticulata* accessions

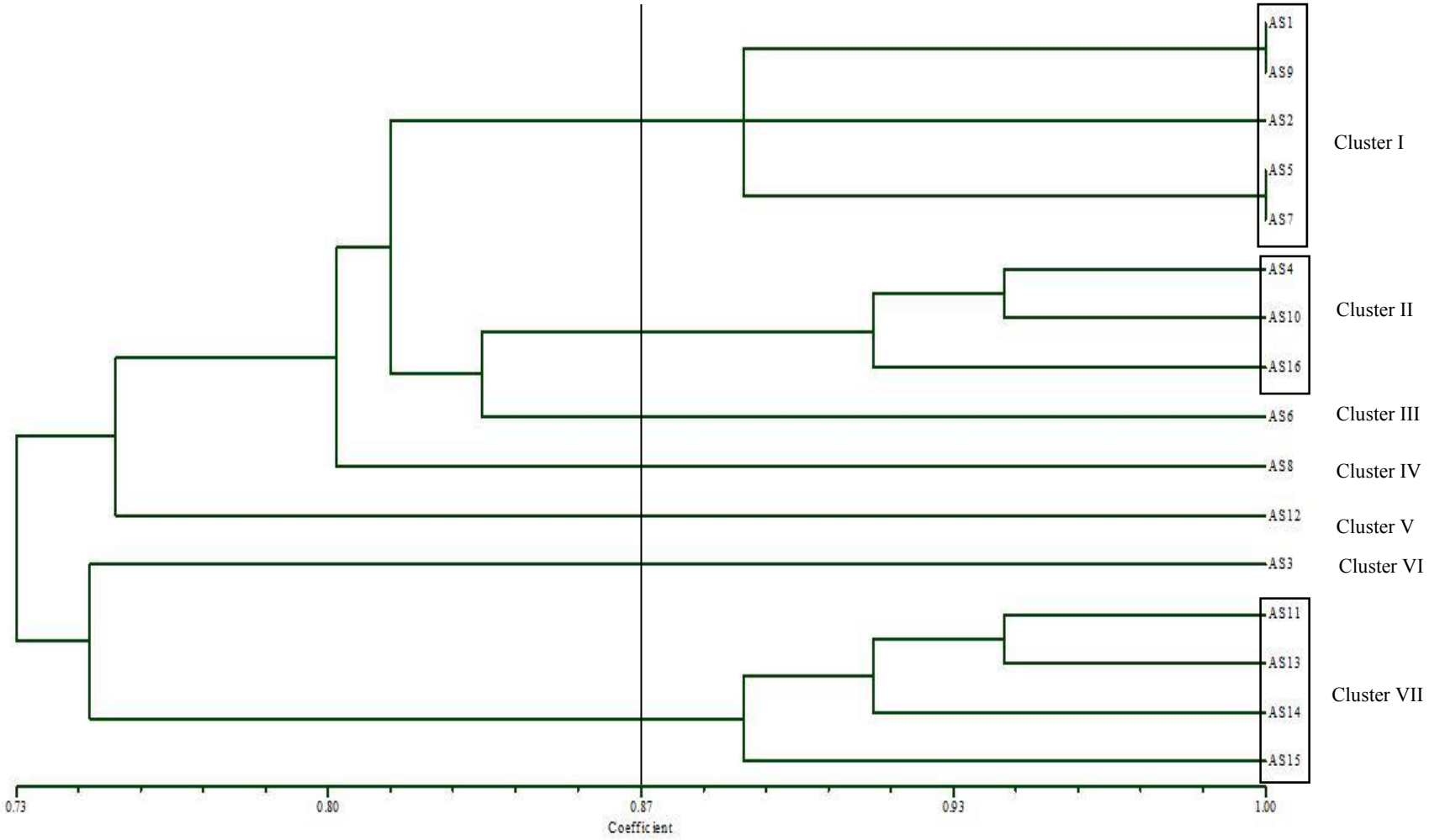


Fig 10. Hierarchical dendrogram of *Annona squamosa* accessions

Table 29. Accessions involved in the qualitative clustering of *A. reticulata*

Cluster I	AR 1
Cluster II	AR 26
Cluster III	AR 14
Cluster IV	AR 23, AR 24
Cluster V	AR 15, AR 16, AR 22, AR 19, AR 20
Cluster VI	AR 2, AR 18, AR 6, AR 17
Cluster VII	AR 12, AR 27, AR 13
Cluster VIII	AR 4, AR 5, AR 7, AR 11
Cluster IX	AR 25, AR 30
Cluster X	AR 3, AR 21
Cluster XI	AR 28, AR 29
Cluster XII	AR 8
Cluster XIII	AR 9
Cluster XIV	AR 10

Table 30. Accessions involved in the qualitative clustering of *A. squamosa*

Cluster I	**Cluster II**	**Cluster III**	**Cluster IV**	**Cluster V**	**Cluster VI**	**Cluster VII**
AS 1	AS 4	AS 6	AS 8	AS 12	AS 3	AS 11
AS 9	AS 10					AS 13
AS 2	AS 16					AS 14
AS 5						AS 15
AS 7						

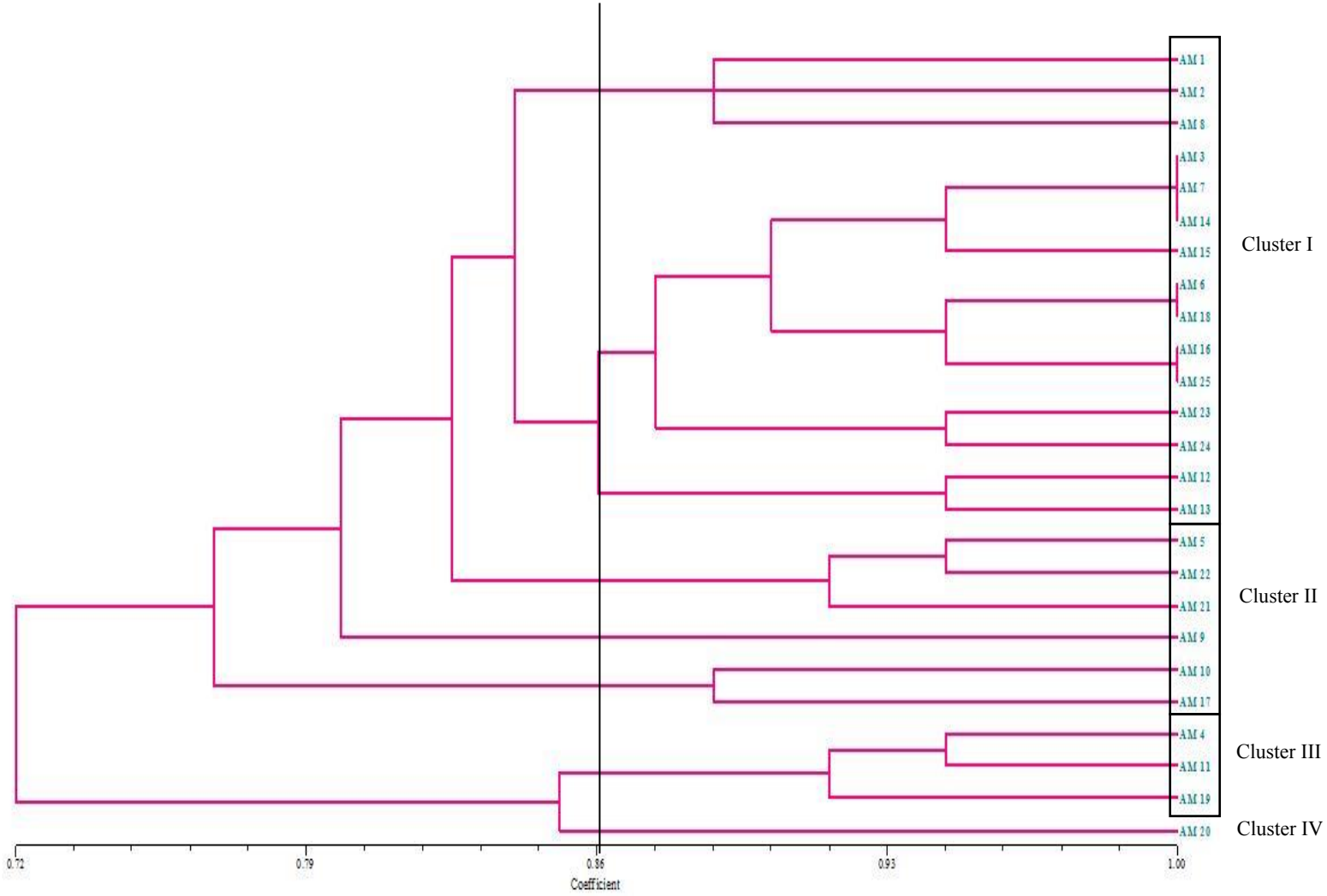


Fig 11. Hierarchical dendrogram of *Annona muricata* accessions

Table 31. Accessions involved in the qualitative clustering of *A. muricata*

Cluster I	Cluster II	Cluster III	Cluster IV
AM 1	AM 5	AM 4	AM 20
AM 2	AM 22	AM 11	
AM 8	AM 21	AM 19	
AM 3	AM 9		
AM 7	AM 10		
AM 14	AM 17		
AM 15			
AM 6			
AM 18			
AM 16			
AM 25			
AM 23			
AM 24			
AM 12			
AM 13			

recorded in all the accessions of three distinct species such as *Annona reticulata*, *A. squamosa* and *A. muricata.* The accessions of three different species where considered separately because the species were totally distinct and independent of each other with respect to each and every character.

The clustering of individual species with a total collection size, 30 of *Annona reticulata,* 16 of *A. squamosa,* 25 of *A. muricata* resulted in 14 clusters in *A. reticulata,* seven for *A. squamosa* and four clusters in *A. muricata.* The dendrogram for the three species are presented in Fig. 9 to 11. All the clustering was done at a default similarity coefficient of 88 per cent. The first inference read from clustering exercise was *A. muricata* has accessions more similar than that of *A. reticulata and A. squamosa. A. reticulata* contributed more variability among the three species studied. The cluster and the accession falling in each and every cluster for three species are given in the tables 29 to 31.

In *Annona reticulata,* cluster V is having maximum number of accessions (5). The cluster VI and VIII had 4 accessions each. Cluster VII had 3 accessions each and cluster IV, IX, X, XI, had 2 accessions each. All the other clusters had only one accession in the cluster (Table 29). In *A. squamosa,* cluster I is having 5 accessions followed by cluster VII with 4 accessions and cluster II with 3 accessions. All other clusters such as III, IV, V, and VI were having only one accession in the cluster (Table 30). In *A. muricata,* cluster I is the largest one with 15 accessions followed by cluster II with 6 accessions. Cluster III was having 3 members and cluster IV was having only one accession (Table 31).

4.8. Principal Component Analysis (PCA)

The PCA of accessions based on set of observations were carried out separately for the three species and the distinct characters were concluded to determine the variability existing in three species (Fig. 12). Thus by analysing the score plot (Fig.13) it was observed that there was no clusters in which the

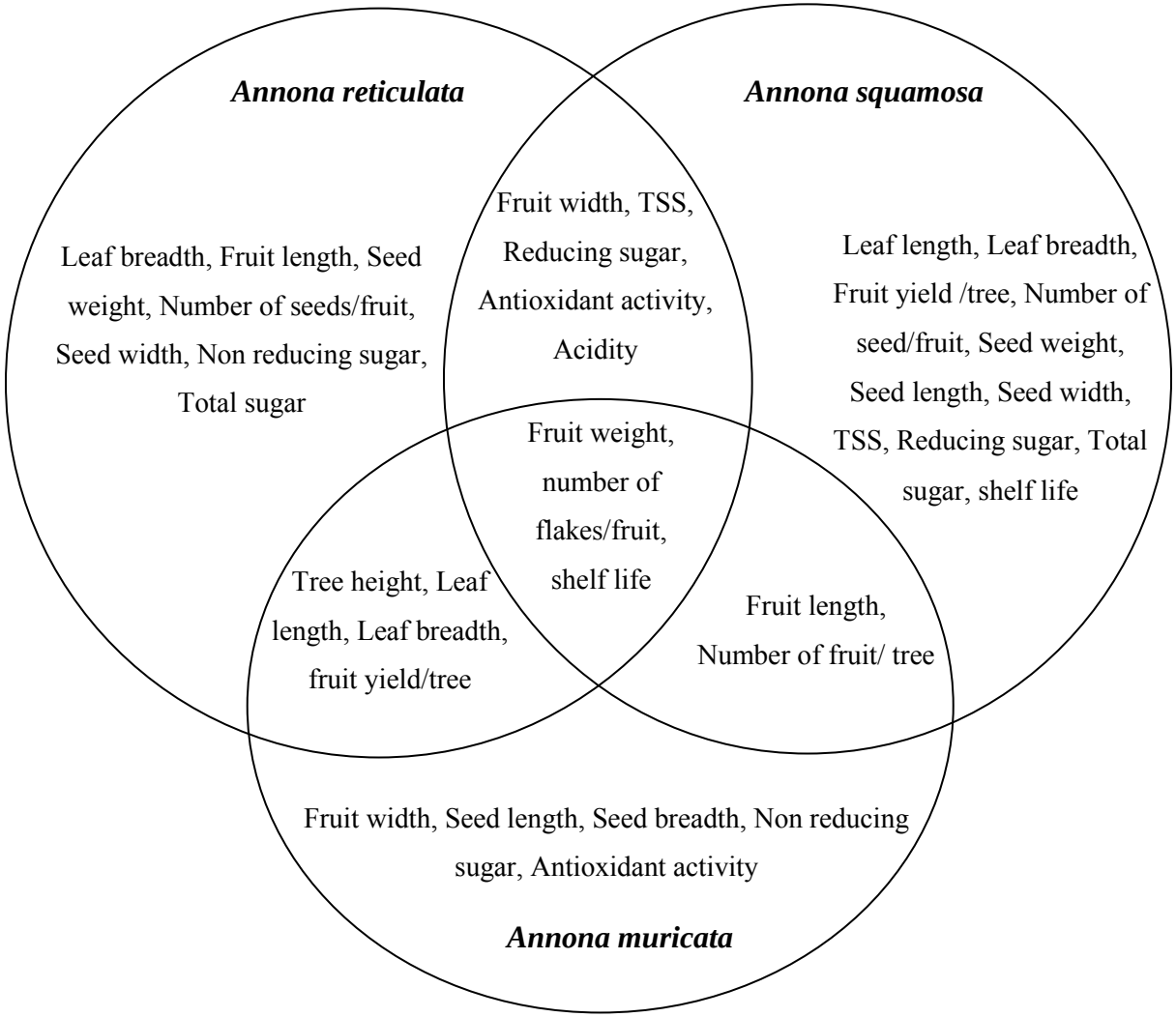


Fig. 12. Common and distinct characters of *Annona* spp.

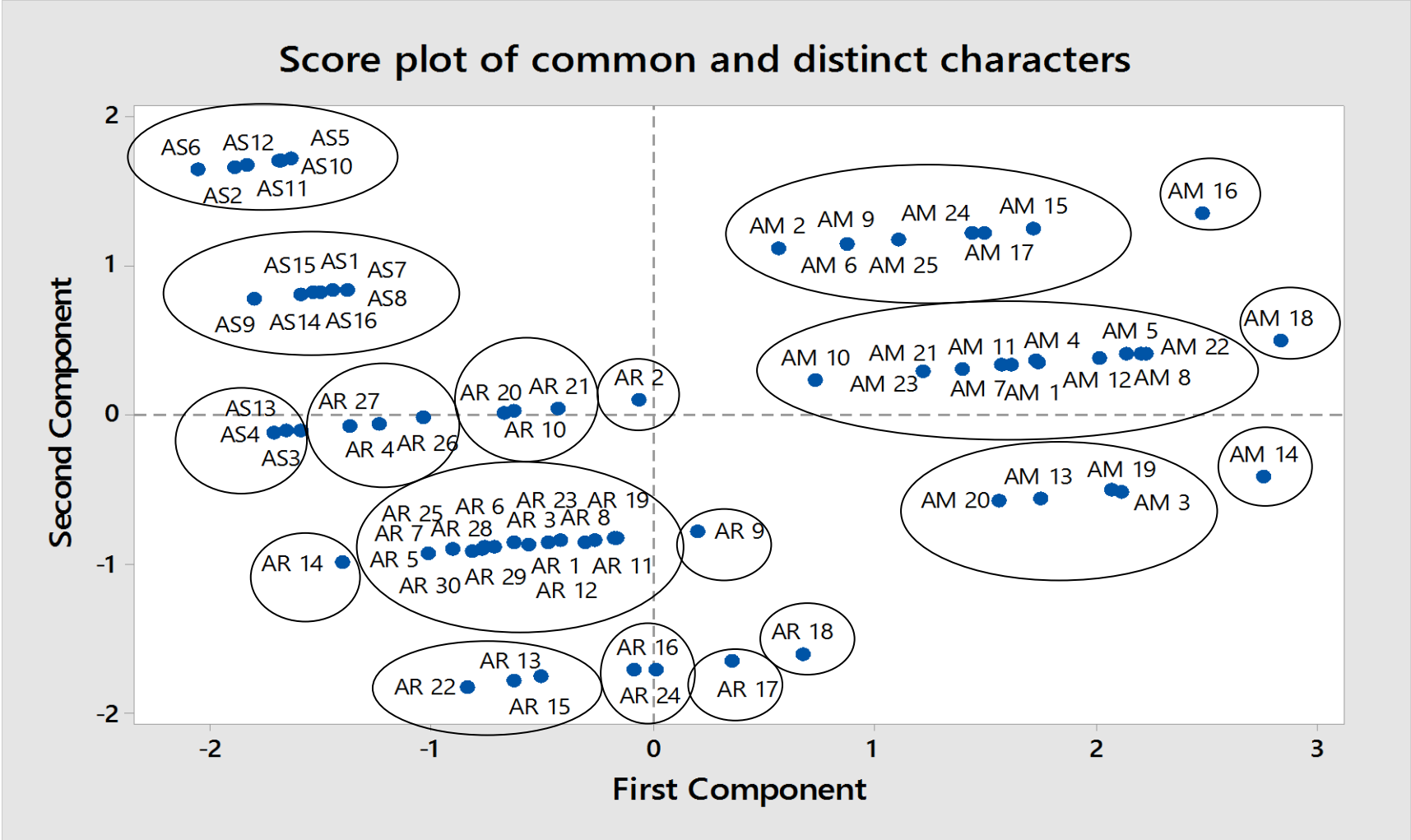


Fig. 13. Score plot of common and distinct characters of *Annona* spp.

Table 32. Cluster listing based on common and distinct characters of *Annona* spp.

Cluster Name	Accessions	Number of accessions
Cluster I	AS 6, AS 12, AS 2, AS 11, AS 10, AS 5	6
Cluster II	AS 9, AS 15, AS 1, AS 14, AS 16, AS 7, AS 8	7
Cluster III	AS 13, AS 4, AS 3	3
Cluster IV	AR 27, AR 4, AR 26	3
Cluster V	AR 20, AR 10, AR 21	3
Cluster VI	AR 2	1
Cluster VII	AR 14	1
Cluster VIII	AR 5, AR 7, AR 30, AR 25, AR 28, AR 29, AR 1, AR 11, AR 19, AR 8, AR 12, AR 6, AR 23, AR 3	14
Cluster IX	AR 9	1
Cluster X	AR 22, AR 15, AR 13	3
Cluster XI	AR 16, AR 24	2
Cluster XII	AR 17	1
Cluster XIII	AR 18	1
Cluster XIV	AM 2, AM 9, AM 6, AM 25, AM 24, AM 17, AM 15	7
Cluster XV	AM 16	1
Cluster XVI	AM 10, AM 21, AM 23, AM 11, AM 7, AM 1, AM 4, AM 12, AM 8, AM 22, AM 5	11
Cluster XVII	AM 18	1
Cluster XVIII	AM 20, AM 13, AM 19, AM 3	4
Cluster XIX	AM 14	1

accessions of three species overlap. Each species had separate clusters which denote they are distinct within these characters (Table 32).

4.8.1. Principal component analysis for elite accessions

A total of eight quantitative characters *viz*., fruit weight, yield of fruits per tree, number of flakes per fruit, number of seed per fruit, TSS, acidity, total sugar and antioxidant activity were considered for the analysis. Other characters were deleted in order to determine the best accessions by considering fruit characters and quality parameters. The Eigen values and the contribution to total variation all the three species are presented in tables 33 to 35. The number of components that has to be retained for grouping is determined by considering eigen value one or greater. Thus there were three principal components that hold value more than one.

4.8.1.1. Principal component analysis of *Annona reticulata* accessions

The scree plot of PCA (Fig. 13) shows that the first three eigen values correspond to the total percentage of variation in the data. The first three component extracted, the total cumulative variance of these three factors accounted 79.2 per cent and components had eigen values >1.

The PC 1 was composed of the characters *viz*., fruit weight, yield of fruits per tree, number of flakes per fruit and number of seed per fruit with PC loadings of 0.482, 0.481, 0.512 and 0.516. All these characters contributed positively to PC 1. In PC 2, the characters TSS and total sugar with PC loadings -0.703 and -0.683 were negatively contributed by PC 2. The component PC 3 is positively contributed by acidity and antioxidant activity with PC loading of 0.631 and 0.724 respectively (Table 33).

To observe the relationship between these characters an attempt was done to plot the first three components that contributed variance. The PC loading plot (Fig 14) shows that there is strong association between fruit weight, number

Table 33. Loadings of principal components showing contribution of quantitative characters of *A. reticulata* accessions

Sl No	Characters	PC 1	PC 2	PC 3
1	Fruit weight (g)	**0.482**	0.076	-0.154
2	Yield of fruits per tree (kg)	**0.481**	0.042	-0.092
3	Number of flakes per fruit	**0.512**	0.019	0.160
4	Number of seed per fruit	**0.516**	-0.040	0.082
5	TSS (^{0}Brix)	-0.012	**-0.703**	0.067
6	Acidity (%)	-0.009	-0.130	**0.631**
7	Total sugar (%)	0.084	**-0.683**	-0.087
8	Antioxidant activity (mg of ascorbic acid/g of sample)	0.014	0.118	**0.724**
	Eigen values	3.364	1.812	1.159
	Variability (%)	42.1	22.7	14.5
	Cumulative (%)	42.1	64.7	79.2

Table 34. Loadings of principal components showing contribution of quantitative characters of *A. squamosa* accessions

Sl No	Characters	PC 1	PC 2	PC 3
1	Fruit weight (g)	0.559	-0.005	0.083
2	Yield of fruits per tree (kg)	0.348	-0.056	0.470
3	Number of flakes per fruit	0.506	0.018	0.334
4	Number of seed per fruit	0.367	0.076	-0.594
5	TSS (^{0}Brix)	-0.120	0.644	0.039
6	Acidity (%)	-0.348	-0.106	0.527
7	Total sugar (%)	-0.060	0.668	0.063
8	Antioxidant activity (mg of ascorbic acid/g of sample)	0.192	0.344	0.158
	Eigen values	2.69	2.13	1.33
	Variability (%)	33.6	26.7	16.6
	Cumulative (%)	33.6	60.3	76.9

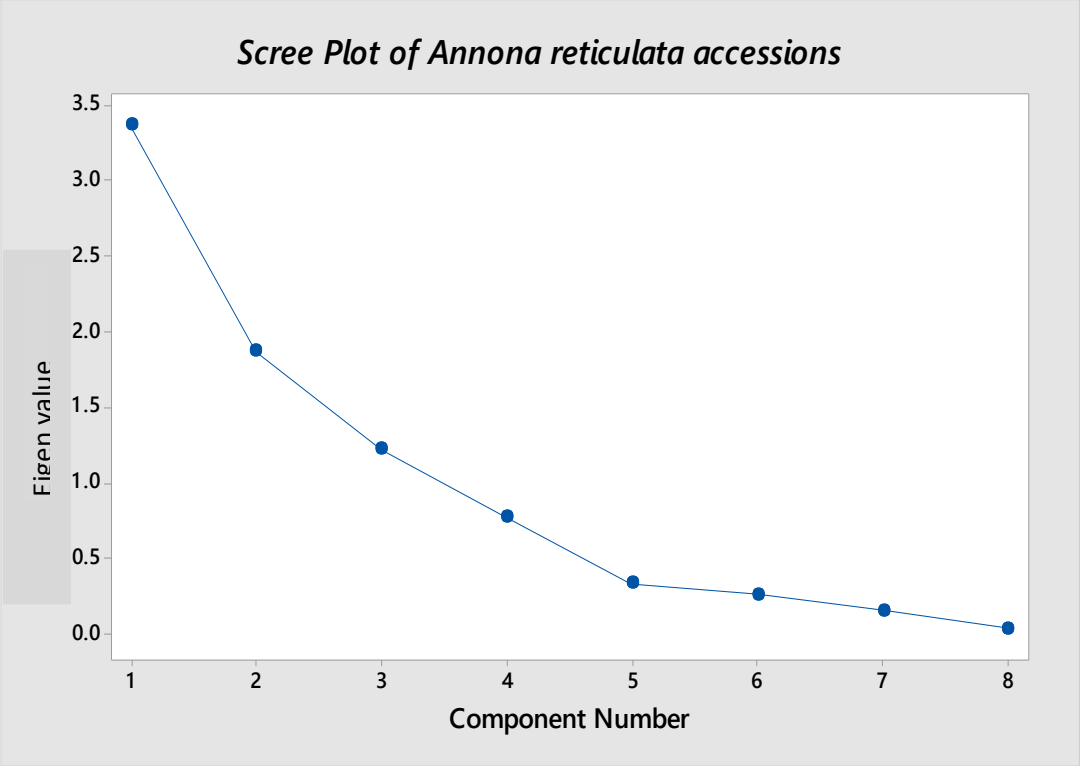


Fig. 14. Scree plot of *Annona reticulata* accessions

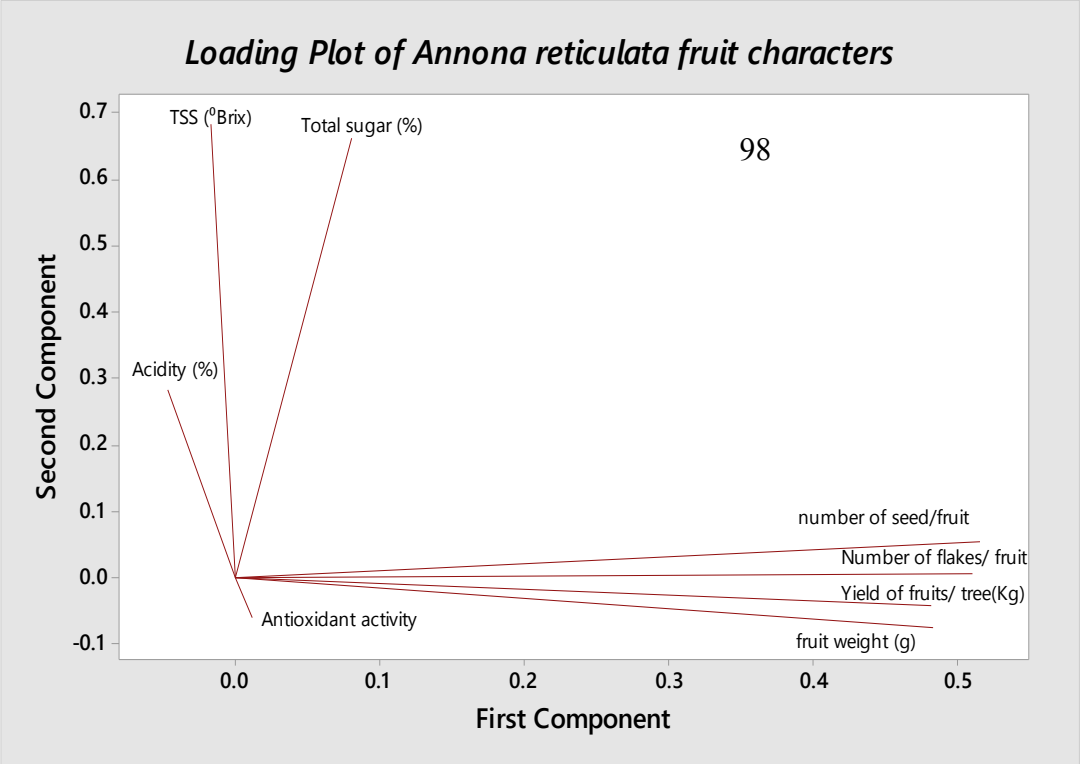


Fig. 15. Loading plot of *Annona reticulata* accessions

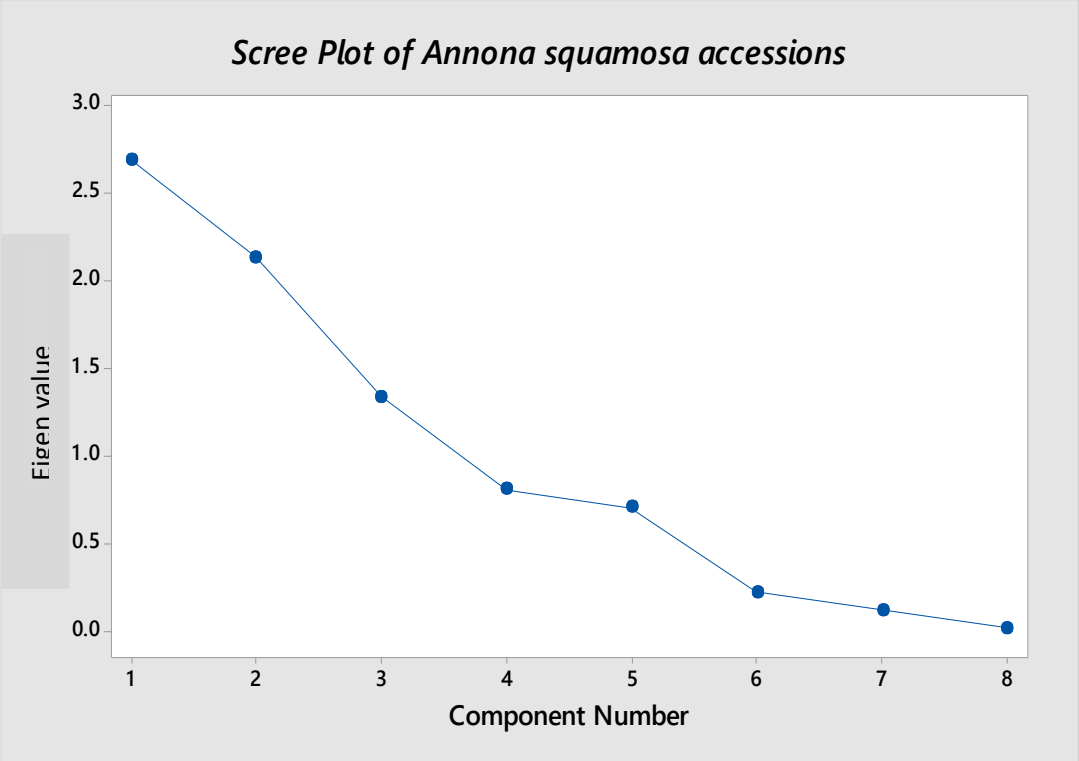


Fig. 16. Scree plot of *Annona squamosa* accessions

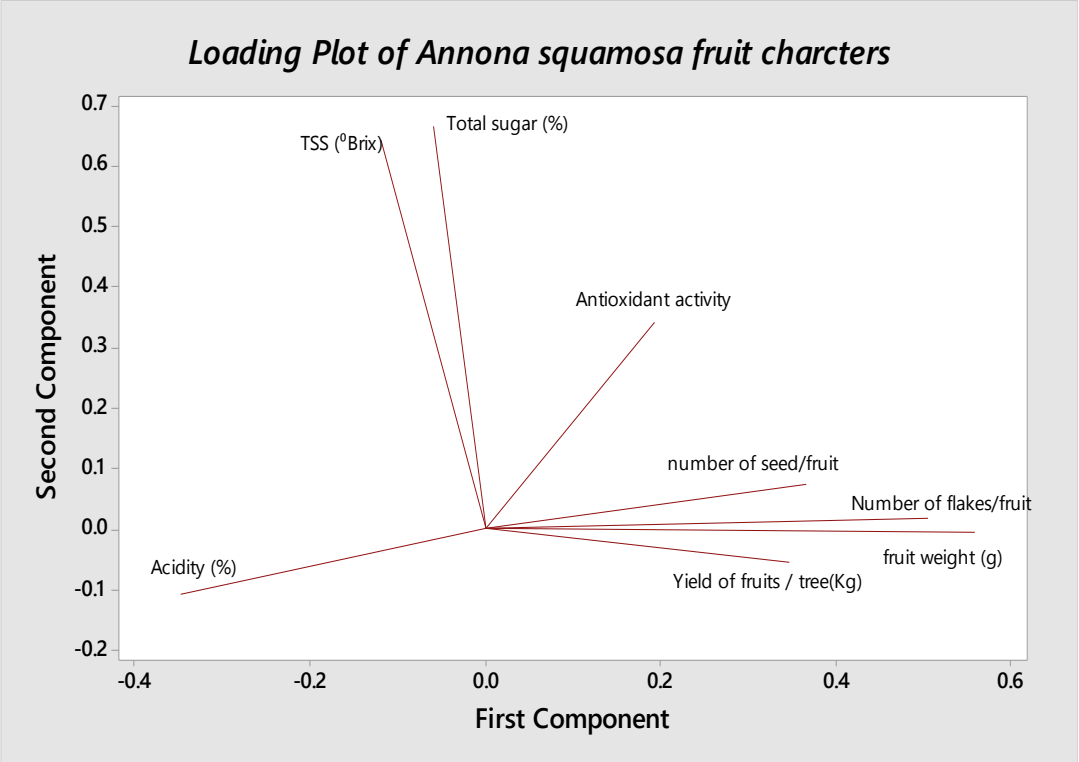


Fig. 17. Loading plot of *Annona squamosa* accessions

of flakes, yield of fruits per tree and number of seeds per fruit as indicated by acute angle between the vectors. The parameters TSS and total sugar are at right angle to other characters indicating negative correlation.

4.8.1.2. Principal component analysis of *Annona squamosa* accessions

The scree plot of PCA (Fig.15) shows that the first three eigen values corresponds to variation in the data, The first three PCA's extracted the total cumulative variance of 76.9 per cent and components had eigen values >1.

The PCA grouped eight characters into three different components. The PC loadings *viz*., 0.559 and 0.506 of fruit weight and number of flakes per fruit contributed positively to the first component (PC 1). In PC 2, TSS, total sugar and antioxidant activity with PC loadings of 0.644, 0.668 and 0.344 contributed positively to this component. PC 3 was positively contributed by character yield of fruits per tree, acidity and negatively contributed by number of seed per fruit with PC loadings of 0.470 and -0.594 respectively (Table 34).

The PC loading plot (Fig. 16) indicates that fruit weight; number of flakes per fruit, yield of fruits per tree, TSS, total sugar, and antioxidant activity are in positive correlation with an acute angle between the vectors.

4.8.1.2. Principal component analysis of *Annona muricata* accessions

The scree plot of PCA (Fig. 17) shows that the first three eigen values correspond to the total percentage of variation in this dat. The first three main PCA's extracted, the total cumulative variance of these three factors amounted 77.5 per cent and components had eigen values >1.

The characters that were more positively contributed to PC 1 are fruit weight, yield of fruits per tree, and number of flakes per fruit with PC loadings of 0.522, 0.475 and 0.504. In PC 2 the PC loadings were -0.629 and -0.586 for the characters *viz*., TSS and total sugar. These two characters are negatively.

Table 35. Loadings of principal components showing contribution of quantitative characters of *A. muricata* accessions

Sl No	Characters	PC 1	PC 2	PC 3
1	Fruit weight (g)	0.522	0.079	-0.165
2	Yield of fruits per tree (kg)	0.475	0.066	-0.340
3	Number of flakes per fruit	0.504	0.163	0.086
4	Number of seed per fruit	0.314	-0.112	0.518
5	TSS (^{0}Brix)	0.102	-0.629	-0.229
6	Acidity (%)	0.312	0.044	0.483
7	Total sugar (%)	0.185	-0.586	-0.237
8	Antioxidant activity (mg of ascorbic acid/g of sample)	0.085	0.459	-0.490
	Eigen values	3.04	2.02	1.12
	Variability (%)	38.1	25.3	14.1
	Cumulative (%)	38.1	63.4	77.5

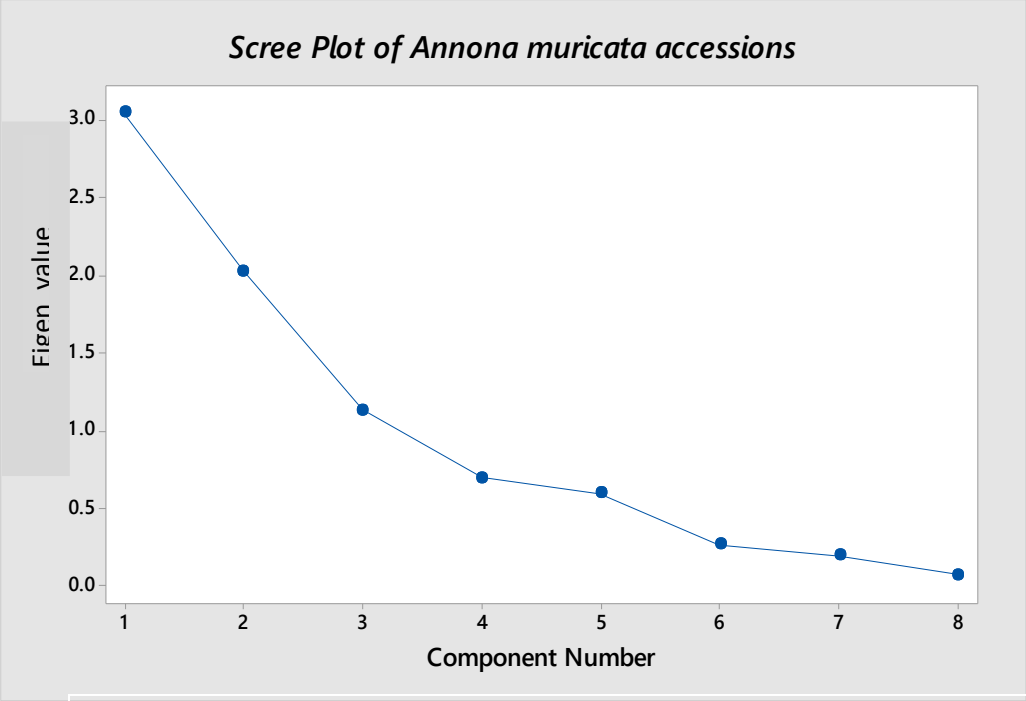


Fig. 18. Scree plot of *Annona muricata* accessions

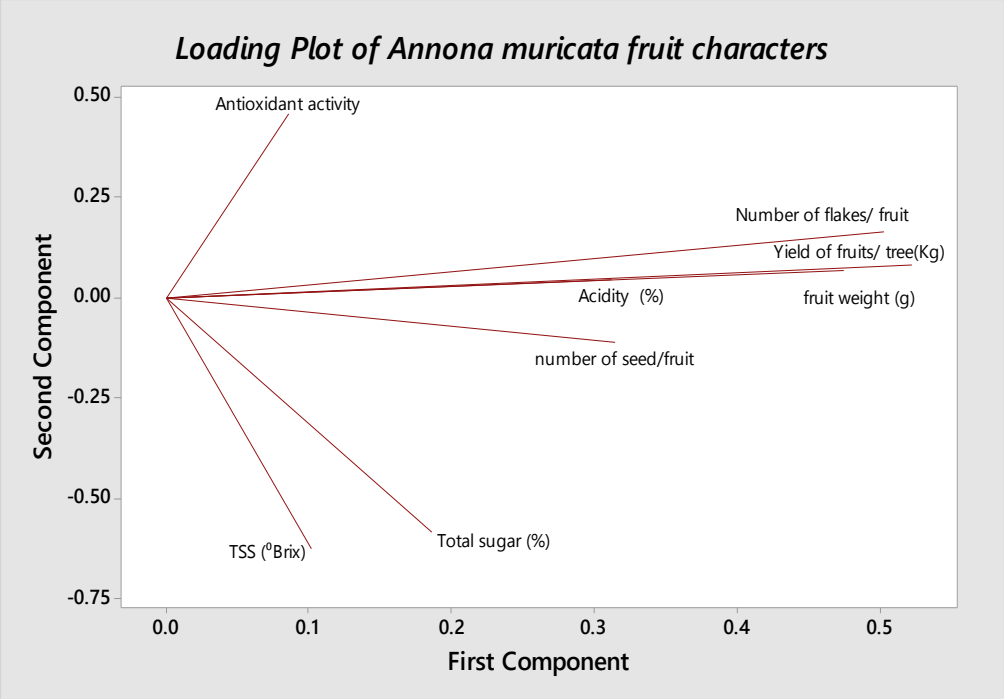


Fig. 19. Loading plot of *Annona muricata* accessions

contributed to PC 2. PC 3 was positively contributed by number of seed per fruit and acidity with PC loadings of 0.518 and 0.483 respectively. But it was negatively contributed by antioxidant activity with -0.490 as PC loading (Table 35).

An attempt to plot PC loading plot (Fig.18) was done on the characters and it represents that fruit weight, yield of fruits per tree and number of flakes are in positive correlation since the vectors are in acute angle. The characters TSS and total sugar are at right angle to the characters indicating that they are negatively correlated.

4.8.2. Cluster analysis from PCA

Clustering was carried out by considering certain characters *viz*., fruit weight, yield of fruits per tree, number of flakes per fruit, number of seed per fruit, TSS, acidity, total sugar and antioxidant activity. The three species were subjected to PCA analysis separately by using the selected characters and clustering is done from score plot. The cluster wise listing is presented in the table 36, 38, 40 and cluster wise summary is presented in the tables 37, 39 and 41.

4.8.2.1. Cluster analysis of *Annona reticulata* accessions

From the score plot (Fig 19), 18 clusters were obtained (Table 36). The cluster VI, IX, XIII and XV were with maximum number of accessions followed by cluster IV, XII, XIV and XVII. The clusters I, II, III, V, VII, VIII, X, XI, XVI and XVIII were with only one accession in them. The data representing the cluster mean of the characters is presented in table 37.

With regard to fruit weight, the maximum was observed in cluster III (425 g) followed by cluster X (400 g) and cluster IX (373.7 g). The minimum fruit weight was noticed in the cluster V (110 g).

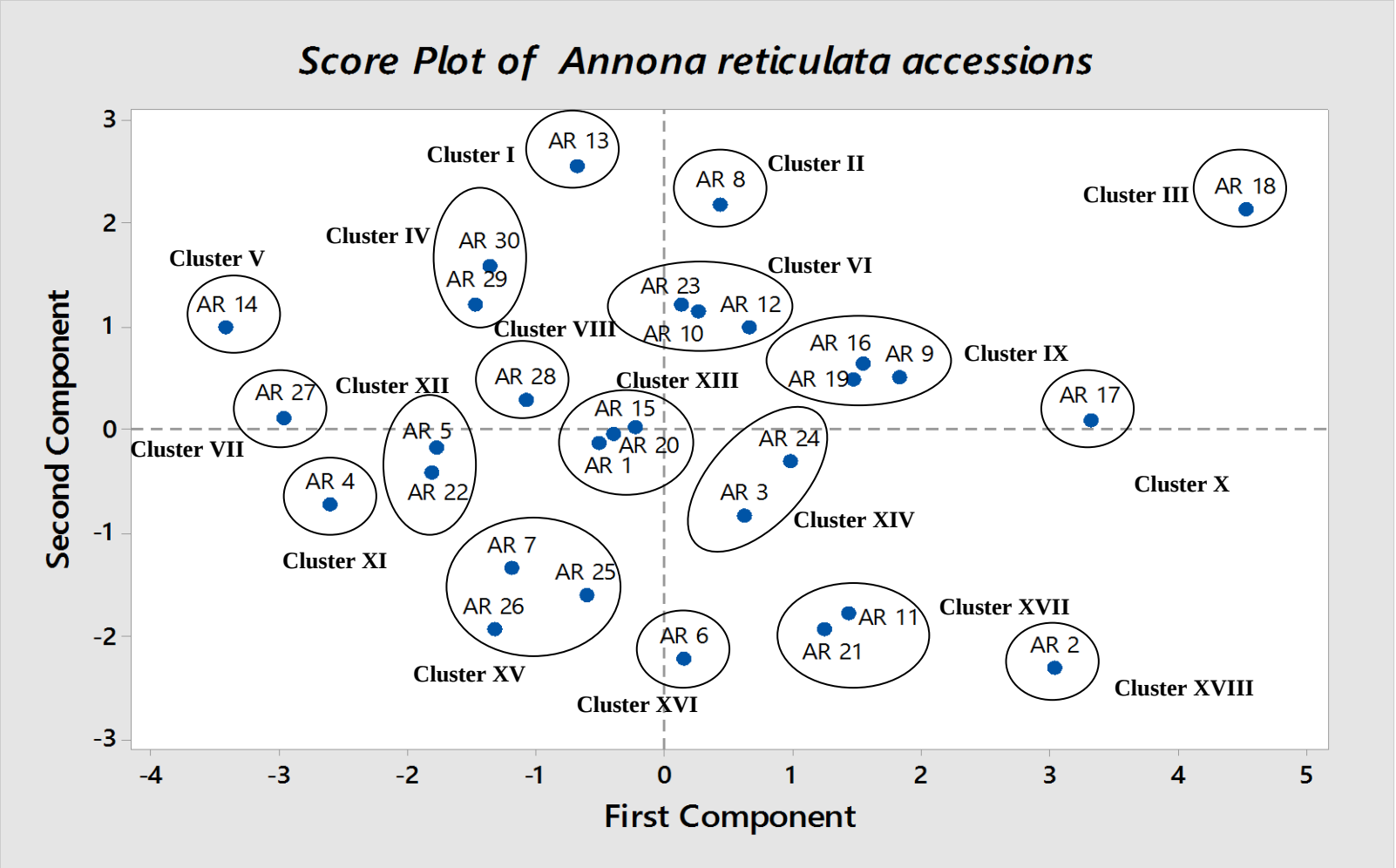


Fig. 20. Score plot of *Annona reticulata* accessions

Table 36. Cluster listing based on principal component analysis of *A. reticulata* accessions

Cluster I	AR 13
Cluster II	AR 8
Cluster III	AR 18
Cluster IV	AR 30, AR 29
Cluster V	AR 14
Cluster VI	AR 10, AR 23, AR 12
Cluster VII	AR 27
Cluster VIII	AR 28
Cluster IX	AR 16, AR 19, AR 9
Cluster X	AR 17
Cluster XI	AR 4
Cluster XII	AR 5, AR 22
Cluster XIII	AR 1, AR 20, AR 15
Cluster XIV	AR 24, AR 3
Cluster XV	AR 7, AR 26, AR 25
Cluster XVI	AR 6
Cluster XVII	AR 21, AR 11
Cluster XVIII	AR 2

Table 37. Cluster mean based on quantitative data of fruits of *Annona reticulata* accessions

Cluster	Fruit weight (g)	Yield/tree (kg)	Number of flakes/ fruit	Number of seed/fruit	TSS (^{0}B)	Acidity (%)	Total sugar (%)	Antioxidant activity
Cluster I	229.0	6.64	66.00	60.0	13.70	0.16	9.73	2.69
Cluster II	270.0	4.86	80.00	76.0	13.40	0.16	10.04	2.39
Cluster III	425.0	13.18	114.00	93.0	13.60	0.28	9.96	2.43
Cluster IV	229.0	4.76	63.00	50.5	13.65	0.22	10.24	2.01
Cluster V	110.0	2.31	46.00	43.0	14.40	0.28	10.04	2.43
Cluster VI	322.3	6.66	74.00	64.0	14.18	0.24	10.27	2.61
Cluster VII	120.0	1.92	54.00	46.0	14.80	0.28	10.37	2.52
Cluster VIII	195.0	4.09	72.00	57.0	14.70	0.27	10.43	2.79
Cluster IX	373.7	7.67	83.67	75.8	14.56	0.24	10.38	2.17
Cluster X	400.0	11.60	98.00	84.0	14.80	0.28	10.59	2.64
Cluster XI	200.0	3.20	48.00	44.0	15.90	0.28	10.43	2.79
Cluster XII	192.5	4.39	57.50	52.5	15.15	0.28	10.36	1.72
Cluster XIII	215.3	4.58	78.00	64.8	15.00	0.24	10.45	2.35
Cluster XIV	321.0	6.13	78.50	72.5	15.30	0.22	10.63	1.99
Cluster XV	176.7	3.52	69.67	62.8	15.60	0.25	11.02	2.11
Cluster XVI	243.0	6.32	76.00	66.0	16.60	0.28	11.01	2.86
Cluster XVII	341.0	8.16	78.50	71.5	15.70	0.22	11.22	1.90
Cluster XVIII	360.0	10.80	94.00	87.0	16.50	0.28	11.11	2.39

Yield of fruits per tree was observed to be higher in cluster III (13.18 kg). It was followed by 11.6 kg in cluster X and 10.80 kg in cluster XVIII. The lowest yield was noticed in the accessions included in cluster V II (1.92 kg).

Number of flakes is an important character with respect to the fruit. It was observed to be higher in the cluster III (114 flakes) which was followed by cluster X (98 flakes) and XVIII (94 flakes). The cluster V (46 flakes) recorded the lowest number of flakes per fruit.

The fruits with less number of seeds are mostly preferred. But in the cluster III (93 seeds), mean number of seeds per fruit was observed as maximum followed by cluster XVIII (87 seeds) and X (84 seeds). Cluster V was with minimum seed (43).

TSS of a fruit determines its quality, it was maximum in the cluster XVI (16.6 ^{0}B). This was followed by cluster XVIII (16.5 ^{0}Brix) and XI (15.9 ^{0}Brix). TSS was minimum in the accessions included in cluster II (13.4 ^{0}Brix).

With regard to acidity it varied from 0.16 to 0.28 per cent in the clusters. The maximum acidity of 0.28 per cent was recorded in the clusters III, V, VII, X, XI, XII, XVI and XVIII. It was minimum in the cluster I and II (0.16%).

Total sugar is also an important quality parameter as TSS. It was maximum in the cluster XVII (11.22 %) followed by cluster XVIII (11.11 %) and XV (11.02 %). The cluster I (9.73 %) recorded minimum total sugar among all others.

Antioxidant activity of fruits was observed as maximum in the cluster XVI (2.86 mg of ascorbic acid/g of sample) that was followed by cluster VIII and XI (2.79 mg of ascorbic /g of sample). It was minimum in the cluster XII (1.72 mg of ascorbic acid/g of sample).

4.8.2.2. Cluster analysis of *Annona squamosa* accessions

The 16 accessions that are studied for cluster analysis using PCA score plot (Fig. 20) was categorised into 13 clusters (Table 38) with cluster VIII with three accessions. The clusters I, IV and V were with two accessions in them and all other clusters were with single accession in them. The data on cluster mean of the characters is presented in table 39.

Fruit weight was found to be less in this species when compared to other two species. The cluster X (116.9 g) recorded maximum fruit weight followed by cluster IX (100.4 g) and cluster I (97.25 g). The minimum weight was noticed in the cluster III (81.5 g).

While considering the yield of fruits per tree, accessions in cluster XI was noticed to be high yielder. That was followed by cluster V (2.15 kg) and cluster I (2.13 kg). But the accessions in cluster III recorded lowest yield.

Number of flakes per fruit varied among all the clusters. In cluster X (72 flakes) was observed followed by cluster IX (71 flakes) and cluster IV (66.5 flakes). The minimum number of flakes was noticed in the cluster III (43 flakes).

Number of seeds in fruits was variable among the clusters. It was maximum in cluster IX (39 seeds) followed by cluster X (32 seeds) and cluster VI (29 seeds). The minimum number of seeds was noticed in the clusters V and XI (23 seeds).

With respect to TSS cluster I recorded highest TSS of 19.75 ^{0}Brix followed by 19.50 ^{0}Brix in cluster II and 19.45 ^{0}Brix in cluster III. TSS was noticed to be lowest in the cluster VIII (18.39 ^{0}B).

Acidity in the fruit varied from 0.16 per cent to 0.22 per cent. The maximum acidity was observed in the clusters VI and XI (0.22 %). The minimum acidity was noticed in the cluster IX and X (0.16 %).

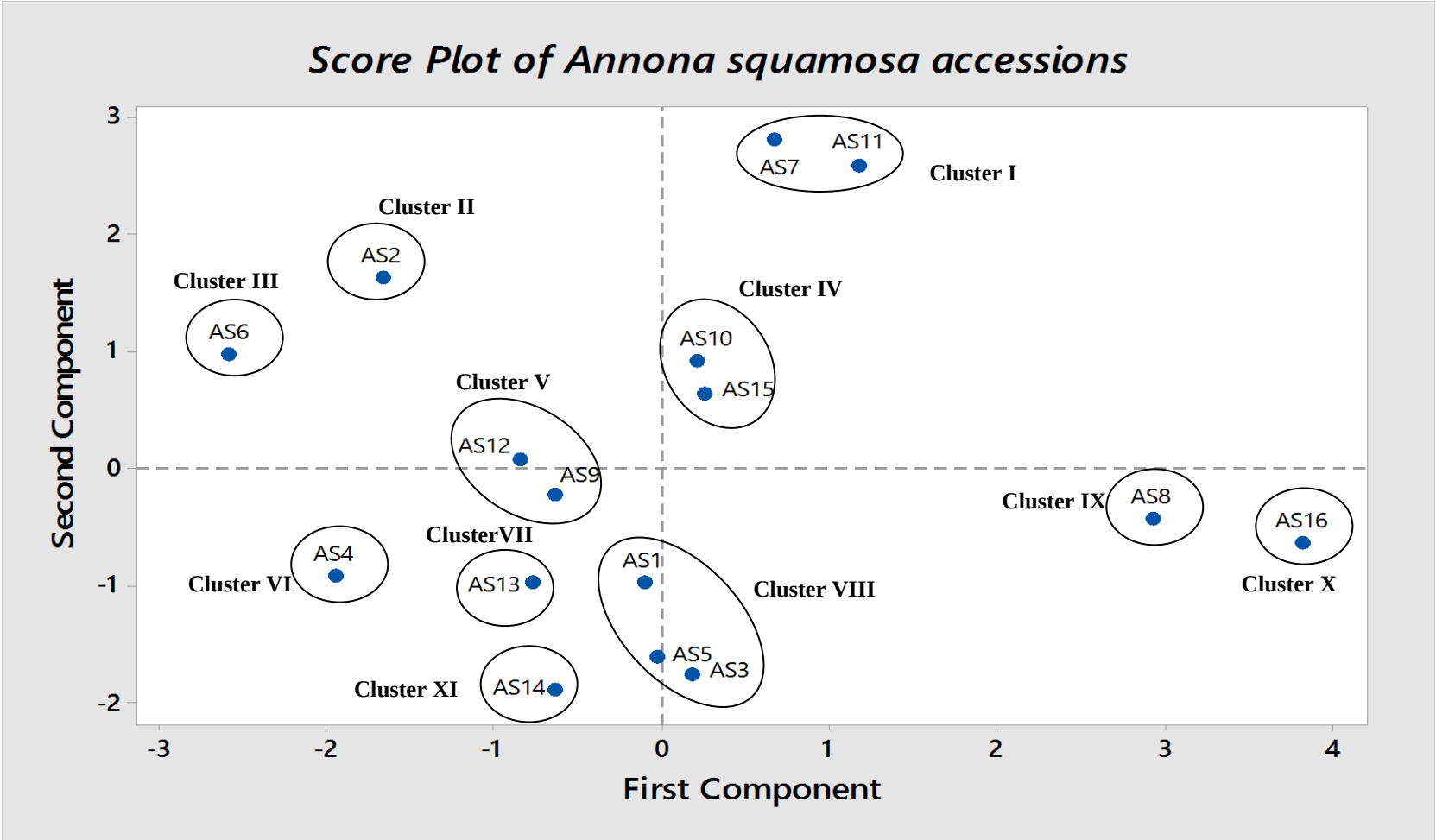


Fig. 21. Score plot of *Annona squamosa* accessions

Table 38. Cluster listing based on principal component analysis of *Annona squamosa* accessions

Cluster I	AS 7, AS 11
Cluster II	AS 2
Cluster III	AS 6
Cluster IV	AS 10, AS 15
Cluster V	AS 12, AS 9
Cluster VI	AS 4
Cluster VII	AS 13
Cluster VIII	AS 1, AS 5, AS 3
Cluster IX	AS 8
Cluster X	AS 16
Cluster XI	AS 14

Table 39. Cluster mean based on quantitative data of fruits of *Annona squamosa* accessions

Cluster	Fruit weight (g)	Yield/tree (kg)	Number of flakes/ fruit	Number of seed/fruit	TSS (^{0}B)	Acidity (%)	Total sugar (%)	Antioxidant activity
Cluster I	97.25	2.13	65.0	27.5	19.75	0.19	12.70	2.995
Cluster II	89.20	1.60	52.0	24.0	19.50	0.20	12.28	2.86
Cluster III	81.50	1.54	43.0	27.0	19.45	0.18	12.25	1.99
Cluster IV	96.35	1.82	66.5	27.5	19.07	0.21	12.07	2.87
Cluster V	88.20	2.15	53.0	23.0	18.94	0.19	11.85	2.52
Cluster VI	88.90	1.60	48.0	29.0	18.80	0.22	11.57	2.13
Cluster VII	87.20	1.65	52.0	27.0	18.40	0.18	11.38	2.81
Cluster VIII	94.50	1.98	62.3	23.3	18.39	0.20	11.39	2.50
Cluster IX	100.40	2.11	71.0	39.0	18.70	0.16	11.60	2.32
Cluster X	116.90	2.10	72.0	32.0	18.50	0.16	11.49	2.73
Cluster XI	92.30	2.21	63.0	23.0	18.67	0.22	11.44	1.64

With regard to total sugar, cluster I recorded maximum of 12.7 per cent followed by 12.28 per cent in cluster II and 12.25 per cent in cluster III. The minimum was observed in cluster VII (11.38 %).

The antioxidant activity in the fruits was maximum in cluster I (2.99 mg of ascorbic acid/g of sample) followed by cluster II (2.86 mg of ascorbic acid/g of sample) and cluster VIII (2.81 mg of ascorbic acid/g of sample). The cluster XI recorded minimum antioxidant activity of 1.64 mg of ascorbic acid /g of sample.

4.8.2.3. Cluster analysis of *Annona muricata* accessions

The 25 accession studied were distributed among 14 clusters (Table 40) after PCA analysis and clustering using score plot (Fig. 21). The cluster VI was with maximum number of accessions i.e., five followed by cluster III, XII and XIII with three accessions in them. All other clusters were with one accession except cluster VII with two accessions. The data on cluster mean of the characters is shown in table 41.

Fruit weight in this species was higher compared to other two species. The cluster VIII was with maximum fruit weight of 850 g. Followed by 830 g in cluster I and 810 g in cluster IX. The cluster X was with minimum fruit weight of 410 g.

Fruit yield per tree is an important character for all the accessions. About 22.68 kg yield was recorded in the cluster IX followed by cluster I with 22.41 kg and cluster V with 19.25 kg. The cluster IV (8.82 kg) was noticed to be a poor yielder.

While considering the number of flakes per fruit, cluster VIII recorded maximum with 189 flakes followed by cluster IX with 184 flakes and cluster I with 178 flakes. The minimum number of flakes was noticed in the cluster XI (132 flakes).

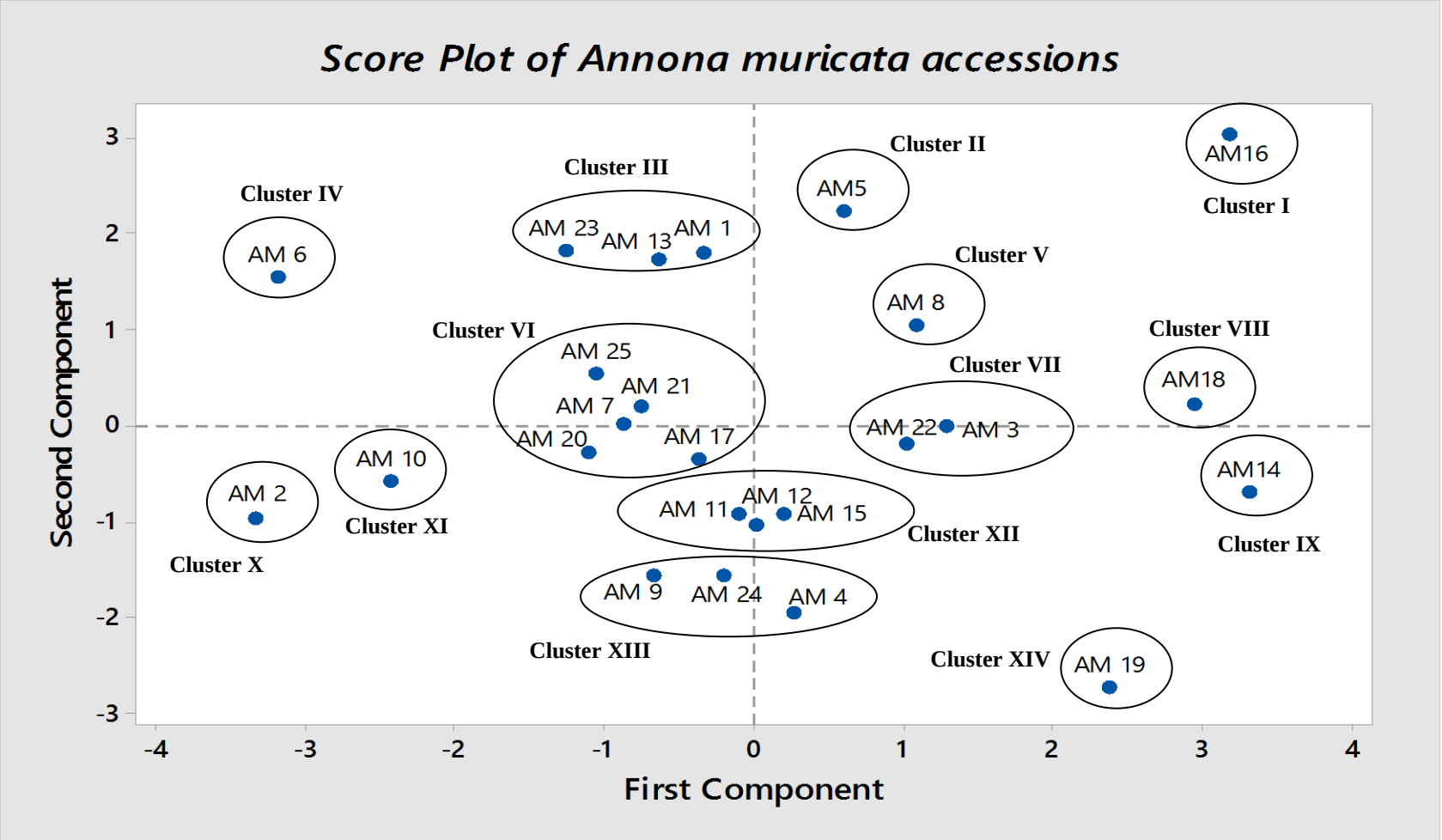


Fig. 22. Score plot of *Annona muricata* accessions

Table 40. Cluster listing based on principal component analysis of *Annona muricata* accessions

Cluster I	AM 16
Cluster II	AM 5
Cluster III	AM 23, AM 13, AM 1
Cluster IV	AM 6
Cluster V	AM 8
Cluster VI	AM 25, AM 21, AM 7, AM 20, AM 17
Cluster VII	AM 22, AM 3
Cluster VIII	AM 18
Cluster IX	AM 14
Cluster X	AM 2
Cluster XI	AM 10
Cluster XII	AM 12, AM 15, AM 11
Cluster XIII	AM 9, AM 24, AM 4
Cluster XIV	AM 19

Table 41. Cluster mean based on quantitative data of fruits of *Annona muricata* accessions

Cluster	Fruit weight (g)	Yield/tree (kg)	Number of flakes/ fruit	Number of seed/fruit	TSS (^{0}B)	Acidity (%)	Total sugar (%)	Antioxidant activity
Cluster I	830.0	22.41	178.0	59.0	12.20	0.376	7.97	4.48
Cluster II	730.0	14.60	167.0	51.0	12.40	0.376	7.92	4.17
Cluster III	613.3	14.59	149.0	52.3	12.76	0.368	7.83	4.30
Cluster IV	490.0	8.82	138.0	45.0	12.60	0.364	8.01	4.26
Cluster V	770.0	19.25	165.0	49.0	13.30	0.364	8.47	4.43
Cluster VI	612.0	14.51	144.4	49.2	13.32	0.366	8.65	4.20
Cluster VII	725.0	15.84	164.0	55.5	13.25	0.372	8.65	3.96
Cluster VIII	850.0	17.00	189.0	54.0	13.50	0.376	8.79	4.17
Cluster IX	810.0	22.68	184.0	52.0	13.70	0.376	9.07	3.86
Cluster X	410.0	10.66	133.0	47.0	13.70	0.364	7.97	3.52
Cluster XI	430.0	12.90	132.0	49.0	13.00	0.364	8.92	3.99
Cluster XII	700.0	15.07	152.0	52.8	13.53	0.364	8.86	3.87
Cluster XIII	593.3	13.40	146.8	56.0	13.73	0.372	8.90	3.70
Cluster XIV	760.0	18.24	152.0	58.0	14.90	0.376	9.57	4.23

Number of seed per fruit was maximum in the cluster I (59 seeds) followed by cluster XIV (58 seeds) and XIII (56 seeds). The cluster IV recorded minimum number of seeds (45 seeds).

In cluster XIV, TSS recorded maximum of 14.90 ^{0}Brix followed by cluster XIII with 13.73 ^{0}Brix. The minimum TSS was noticed in the cluster I (12.20 ^{0}Brix).

Acidity in fruits ranged from 0.364 per cent to 0.376 per cent. The maximum acidity was observed in the cluster I, II, VIII, IX and XIV (0.376 %). The clusters IV, V, X, XI and XII recorded minimum acidity (0.364 %).

Total sugar varied from 9.57 per cent and 7.83 per cent. The cluster XIV recorded highest total sugar of 9.57 per cent followed by cluster IX with 9.02 per cent and cluster XI with 8.92 per cent. The minimum total sugar was noticed in the cluster III (7.83 %).

With regard to antioxidant activity, cluster I (4.48 mg of ascorbic acid/g of sample) recorded maximum antioxidant activity followed by cluster V (4.43 mg of ascorbic acid/g of sample) and cluster III (4.3 mg of ascorbic acid/g of sample). The lowest antioxidant activity was observed in cluster X (3.52 mg of ascorbic acid/g of sample).

Discussion

5. Discussion

Annona spp. is considered as an underutilized fruit crop in Kerala. It is having great potential as a source of nutrients as well as medicinal values. The study on 'Assessment of variability in *Annona* spp.' was conducted with the objectives of assessment of variability in the species *viz*., *Annona reticulata, A. squamosa* and *A. muricata* and to identify promising types for cultivation. The results of the study are discussed in this chapter.

5.1. Assessment of variability

Variation in *Annona* spp. was due to heterozygosity and cross pollination nature of these crops. Hence there exist a large variation in almost all the characters like leaf, inflorescence and fruit (Cheema, 1928).

In the present study, a survey was conducted in the homesteads of Thrissur, Palakkad and Ernakulam districts of Kerala to assess the variability of *A. reticulata*, *A. squamosa* and *A. muricata*. The description of ecotypes with special reference to vegetative and fruiting characters was recorded. All the characters observed were variable among the accessions in three species of Annona. Folorunso and Olorode (2006) also reported variability in qualitative and quantitative characters in four species of Annona in Nigeria.

Clustering based on qualitative characters conducted separately for three species also revealed the existence of variation among the accessions. The Principal component analysis followed by clustering based on quantitative fruit characters *viz*., fruit weight, yield per tree, number of flakes per fruit, number of seed per fruit, TSS, total sugar and antioxidant activity were also studied.

5.2. Plant characters

In *A.reticulata* most of the trees studied were in the age of 4 to 8 years. The height of these trees varied from 5.2 to 8.8 m with a mean of 7.08 m. The

Table 42. Comparison of quantitative characters in *Annona* spp.

Character	*Annona reticulata*		*A. squamosa*		*A. muricata*	
	Mean	**CV (%)**	**Mean**	**CV (%)**	**Mean**	**CV (%)**
Tree height (m)	7.08	15.10	2.28	22.59	2.92	17.05
Spread of tree (m)	6.72	8.48	3.29	14.89	4.11	13.08
Leaf length (cm)	20.87	7.62	12.03	15.72	15.92	10.92
Leaf breadth (cm)	5.32	12.52	4.65	15.39	6.75	11.46
Fruit length (cm)	10.02	9.40	5.70	4.56	14.40	6.44
Fruit diameter (cm)	8.24	14.47	4.29	2.96	8.46	4.40
Fruit weight (g)	266.1	34.62	93.97	8.40	652.40	18.36
Number of fruits per tree	22.2	23.37	20.68	11.67	23.44	12.59
Yield per tree (kg)	5.97	46.55	1.94	12.37	15.20	21.77
Number of flakes per fruit	73.97	19.66	59.81	14.91	153.24	9.92
Number of seeds per fruit	65.03	19.59	26.69	16.80	52.16	8.24
Seed weight per fruit	17.21	8.61	7.40	8.99	16.02	7.49
Seed length (mm)	14.06	8.74	14.39	4.65	16.70	4.13
Seed breadth (mm)	6.14	16.18	4.85	12.69	6.73	7.51
Shelf life (days)	3.00	23.16	5.18	14.46	4.12	17.61
TSS (^{0}Brix)	14.86	5.77	18.92	2.61	13.30	4.25
Acidity (%)	0.24	21.86	0.19	9.95	0.36	1.69
Reducing sugar (%)	9.53	4.47	10.86	4.65	7.55	6.56
Non reducing sugar (%)	0.96	9.85	0.97	8.32	1.00	8.24
Total sugar (%)	10.5	3.82	11.83	3.99	8.56	5.56
Antioxidant activity (mg of ascorbic acid/g of sample)	2.29	19.45	2.54	16.54	4.06	6.95

accession AR 30 recorded maximum tree height and AR 22 recorded the minimum height. Chopra *et al*. (1998) reported that the tree grows up to 10 m. The spread of the trees varied from 5.4 to 7.70 m. It was maximum in AR13 and AR 30 and minimum in AR 22. The mean value of canopy spread was 6.72 m. Whereas in Konkan region, the mean canopy spread was 8.90 m (Ghavale *et al*., 2016). Most of the tress of bullock's heart was semi spreading (66.66 %) or erect (33.33 %) type with a two branched (50 %) pattern. There was no pubescence observed on the shoots of the tree. While considering the orientation of leaf, most of them were oriented upright (60 %) and others were semi upright.

In *A.squamosa* trees were in the age of 4 to 6 years and the trees of *A. muricata* were in the age of 4 to 7 years. The tree height was in the range of 1.5 to 3 m. The maximum tree height was noticed in accessions AS6, AS 8, AS 11, AS 12 and AS 14 and minimum in AS 4, AS 7 and AS 16. The tree height was less compared to the observations reported by Farre *et al.* (1999). It may be due to influence of soil and environmental factors on the growth of the trees. The tree spread was in the range of 2.36 to 3.95 m. In which it was maximum in the accession AS 9 and minimum in AS 7. The mean plant height and spread was observed to be less compared to Balanagar cultivar with 2.4 m and 5.3 m respectively (Rao and Subramanyan, 2011). All the trees studied were erect in nature with two branches (68.75 %) and a few were with three or more branches (31.25 %). In these trees there was no pubescence in their shoots. The orientation of leaf was upright (75 %) and in some accessions the leaves were oriented semi upright (25 %).

Trees of *A. muricata* were in the age of 4-7years with height in the range of 3 to 4.6 m. The maximum tree height was in the accession AM 10 and minimum in AM 9 and AM 12. Nakasone and Paull (1998) reported that the factors like climate, soil and crop management can cause variability in tree height in this species. While considering spread of the tree, it varied from 3.42 to 5.4 m. Compared to all the accessions, AM 11 was having maximum spread and AM 2 were with minimum spread. The trees were observed to erect (60 %), semi

spreading (28 %) or spreading (12 %) types with one branch (76 %). Some of the accessions were of two branched without pubescence. Leaf orientation was horizontal (72 %) as well as in semi upright (28 %) positions.

The mean tree height and spread of the trees was high for *A. reticulata* (7.08 m and 6.72 m) and it was low for *A. squamosa* accessions (2.28 m and 3.29 m). With respect to tree height and spread, the trees of *A. muricata* were intermediate. The CV was high for tree height compared to spread of the tree for all the species (Table 42).

5.3. Leaf characters

Leaf was lanceolate with acuminate apex, acute base, entire leaf margin and glabrous in *A.reticulata*. Similarly Chopra *et al*. (1998) reported that the leaves are lanceolate and glabrous. Leaf length was in the range of 17.9 to 23.9 cm, with maximum leaf length in the accession AR 2 and minimum in AR 4. Leaf breadth of the accessions also varied from 4.2 to 6.8 cm with maximum leaf breadth in AR 3 and minimum in AR 20. The mean of leaf length and breadth was more or less similar to the observation reported by Ghavale *et al.* (2016).

The petiole and vein colour was light green (50 %) and dark green (50 %) in the accessions. Colour of young as well as mature leaves exhibited variation. The young leaves were light predominantly light green (87.66 %) in colour and some leaves were with green colour (23.33 %). In mature leaves the predominant leaf colour was green (80 %) and few accessions were with dark green leaves (20 %). Surendra *et al*. (2013) reported that pale green leaves are noticed in *A. reticulata* accessions. Pubescence was absent in the both upper and lower surface of leaves.

In *A.squamosa,* leaf blade was lanceolate in most of the accessions but it was elliptic in some of the accessions. The leaves were with acute apex, rounded base, entire margin and glabrous. Similarly, Oschse *et al*. (1974) reported elliptic shape for the leaves. Leaf length varied from 8.3 to 15.2 cm. With regard to leaf

breadth, it ranged from 2.2 to 5.4 cm. The accession AS 3 recorded maximum leaf length and breadth. The minimum leaf length and breadth was recorded in AS 4. Chopra *et al.* (1998) reported the leaves were 5 to 15 cm long and 1.9 to 3.8 cm wide. The variation in leaf length and breadth may be due to the soil factors or influenced by rainfall. The petiole and vein colour was light green (81.25%) in most of the accessions and dark green (18.75 %) in other accessions. The young leaves were light green (87.5 %) in colour but some accessions were with green leaves (12.5 %). In mature leaves the predominant colour was light green (56.25%) and others were with dark green colour (43.75 %). Compared to other two species, pubescence was noticed on lower surface of young leaves.

The accessions of *A. muricata* were with obovate leaf blade, acuminate as well as acute leaf apex, acute leaf base, entire leaf margin and glabrous. Leaf length and breadth varied from 12.4 to18.1 cm and 5.7 to 8.2 cm. The maximum leaf length was noticed in the accessions AM 6 and AM 24. Whereas leaf breadth was maximum in AM 6. The minimum leaf length and breadth was observed in AM 7. Manigandan (2014) reported leaf length and breadth variability among the accessions studied at Tamil Nadu. It was less compared to the observations recorded in present study any may be due to difference in soil and climatic factors. The petiole and vein colour was dark green (80 %) in most of the accessions and green (20 %) in other accessions. The leaf colour at young age and maturity also exhibited variability among accessions. Colour of young leaves was light green in all accessions. But in mature leaves predominant colour was dark green (88 %) and others were with green leaves (12 %). There was no pubescence in the leaves of all the accessions.

The mean leaf length was the highest for *A. reticulata* (20.87 cm) but mean leaf breadth was the highest for *A. muricata* accessions (6.75 cm). The CV was observed to be high for leaf breadth in all the species compared to leaf length.

5.4. Inflorescence and flowering pattern

In Kerala conditions, flowering season exhibited wide variability among three species irrespective of districts. The flowering commenced from August in *A.reticulata* and it was extended till March. This observation was similar to the flowering reported from Mexico (Pinto *et al*., 2005). The harvest of fruits was three months after flowering. Peak flowering was noticed during December (36.66 %) and in some accessions it was during November (33.33 %) October (13.33 %), January (10 %) and February (6.66 %). Flowering was uniform in all the accessions and the flowers were borne as solitary (86.66 %) as well as in clusters (13.33 %) on current season shoots of laterals.

In *A.squamosa*, flowering was observed from January to June. The peak flowering was noticed during March (37.5 %), April (37.5 %) and February (25 %). Similar observation for flowering was noticed in Mexico and Brazil (Pinto *et al*., 2005). The harvest of fruits was done two and half months after flowering. Early bearing was not specifically observed among the accessions. The flowers were borne on laterals of current season growth as solitary and small clusters (56.25 %) of 3-4 flowers.

In *A. muricata*, the flowering was noticed from August to March in which peak flowering was noticed during December (44 %), November (24 %), October (20 %) and February (12 %). In Brazil the flowering was reported during the same months (Bueso, 1980). The harvest of fruits was observed from three and half months after flowering. The flowering was noticed in laterals and on trunk. Usually the flowers are solitary, borne in older shoots and are cauliflorous in nature.

5.5. Fruit characters

All the trees studied in *A. reticulata* were regular bearers. In them, fruiting was noticed from September to May. Pinto *et al*. (2005) reported fruiting from March to April but in Kerala the fruiting season exhibited variability. The

accession AR 12 from Thrissur recorded two flowering and fruiting season in which fruiting was observed from November to January and March to June. The fruits were mostly cordate (86.66 %) and in few accessions broadly cordate (13.33 %) fruits were also observed. Fruit surface was laevis (80 %) in most of the accession and impressa (20 %) in other accessions. Similar observation on fruit shape and fruit surface was reported by Ghavale *et al*. (2016).

Fruit length in *A. reticulata* accessions varied from 7.4 to 11.4 cm. The maximum fruit length was noticed in AR 23.The minimum fruit length was observed in AR 15. The fruit diameter varied from 6.6 to 10.6 cm among the accessions. It was maximum on the accession AR 11 and minimum fruit diameter was noticed in the accession AR 20 and AR 26. Ghavale *et al*. (2016) reported mean fruit length as 8.63 and 8.80 cm. The mean fruit length and breadth was higher in observations done on this study. This may be due to variability in genetic constitution of the trees. Fruit weight varied from 110 to 435 g, with maximum in the accession AR 9. The minimum fruit weight was observed in AR 14 (Fig. 23).

Based on the fruit weight, the fruits of accessions can be classified as large sized (>300 g), medium sized (150 g-300 g) and small sized (<150 g). The fruits of accessions AR 2, AR 9, AR 11, AR 12, AR 17, AR 18, AR 19, AR 21, AR 23 and AR 24 were large sized, AR 1, AR 3, AR 4, AR 6, AR 8, AR 10, AR 13, AR 15, AR 20, AR 22, AR 25, AR 26 and AR 28 were medium sized and AR 5, AR 7, AR 14 and AR 27 can be classified as small sized fruits. The relative percentage was high of 43.33 for the accessions with medium fruits.

The number of flakes in *A. reticulata* fruits varied from 46 to 114 in which maximum was observed in AR 18. The minimum number of flakes is noticed in AR 14.The fruit colour varied among accessions at different stages of fruit development. It was light green at maturity and later turned to reddish yellow or yellowish green at ripening stage similar observation was reported by Ghavale *et al.* (2016).

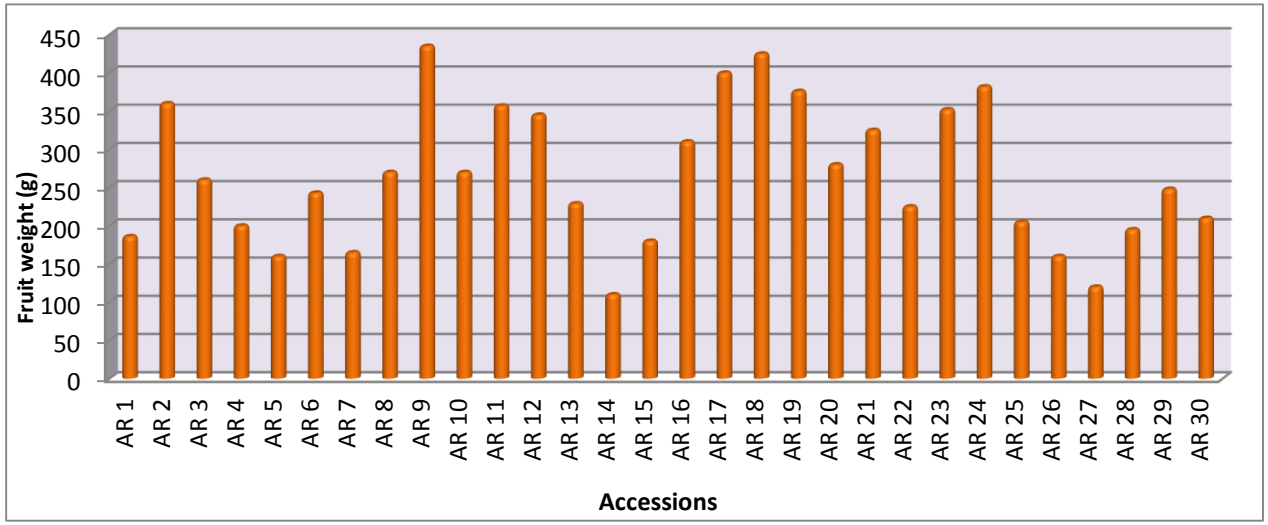


Fig.23. Mean fruit weight of *A. reticulata* accessions

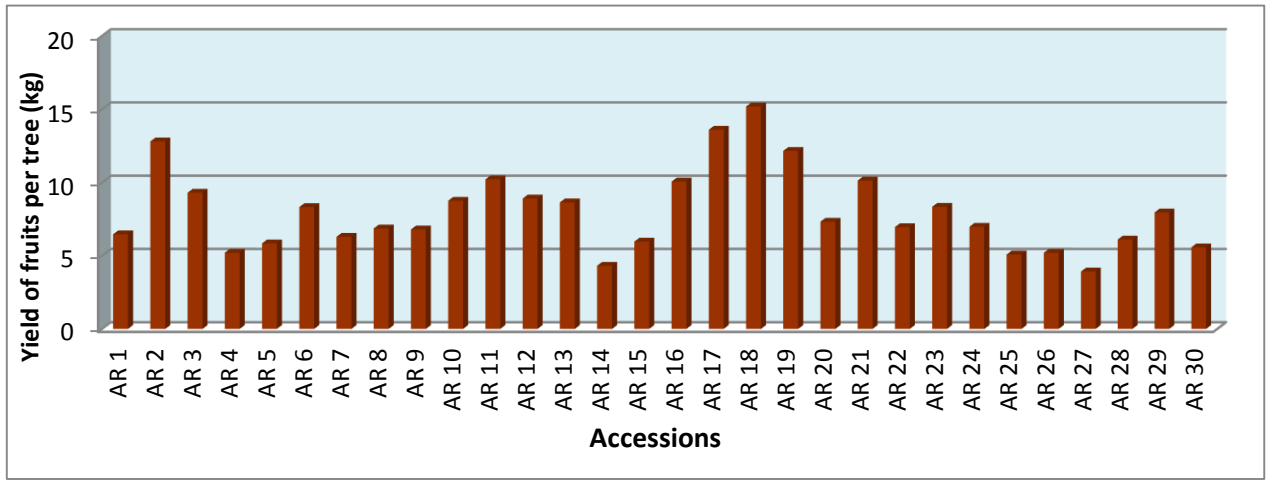


Fig.24. Yield of fruits per tree of *A. reticulata* accessions

Based on this the trees can be classified as high yielders (> 10 kg), medium yielders (5-10 kg) and low yielders (<5 kg). Thus the accessions AR 2, AR 11, AR 16, AR 17, AR 18, AR 19 and AR 20 were observed to be high yielders. The accessions AR 14 and AR 27 were observed to be low yielders (Fig. 24). The shelf life of fruits varied from 2-4 days.

In *A. squamosa* accessions, all the trees were regular bearers. The fruiting was observed from February to August. The fruits were cordate with umbonata surface. Fruit length and diameter varied from 5.36 to 6.08 cm and 5.34 to 5.79 cm respectively. The fruit length was maximum in the accession AS 16 and minimum fruit length was noticed in AS 12. The fruit diameter was maximum in AS 8 and it was minimum in AS 12. The fruit weight varied from 81.5 to 116.9 g. It was maximum in the accession AS 16 and minimum fruit weight was noticed in the accession AS6 (Fig. 25).Here the fruit weight was small and of uniform size which ranged from 80 – 120 g. The fruit weight was higher some of the landraces studied by Bhatnagar *et al.* (2012). Since fruit weight is a genetically controlled character such a variation was observed in the fruits.

Number of flakes per fruit in *A. squamosa* varied from 33 to 62, with maximum in AS 16 and minimum number of flakes in AS 6. Bakane *et al*. (2015) reported a higher number of flakes. Fruits were light green in most of the fruits and green in other accessions at maturity stage. At ripening, the fruits were yellowish green and few accessions were light green in colour. The number of fruits per tree in the accessions varied from 18 to 26. The maximum number of fruits was observed in AS 9. The accessions AS 2, AS 4, AS 19 and AS 16 recorded minimum number of fruits. The fruit yield per tree varied from 1.54 to 2.29 kg. In which the maximum yield was noticed in AS 9 and minimum in AS 6 (Fig. 26). The variability in yield was limited, which ranged between 1.5-2.3 kg compared to *A. reticulata*. Shelf life of fruits varied from 4 to 6 days, it may be due to the thick rind seen in the fruits compared to other two species.

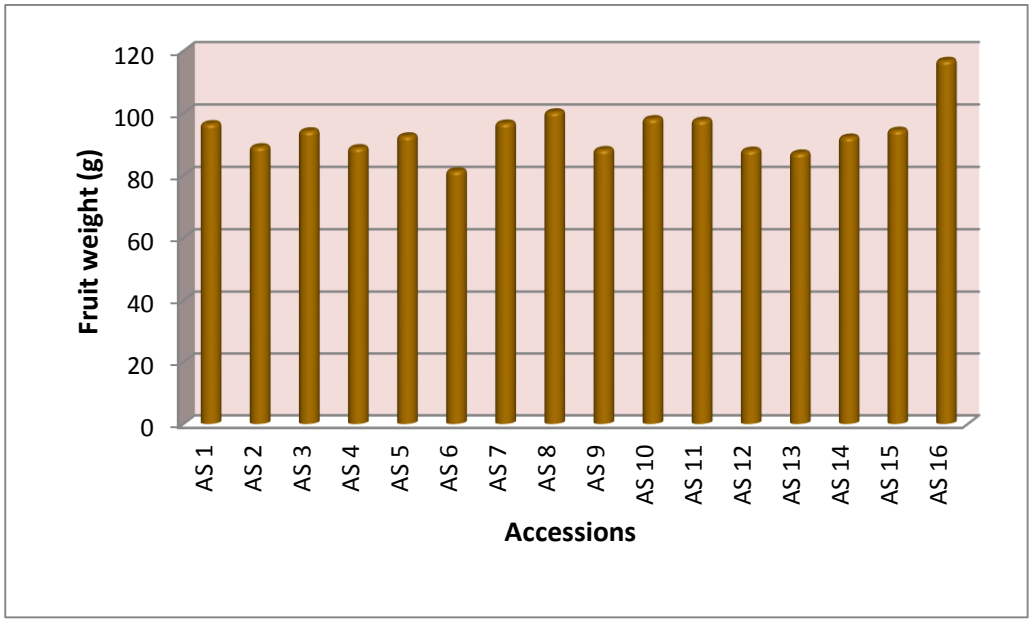


Fig.25. Mean fruit weight of *A. squamosa* accessions

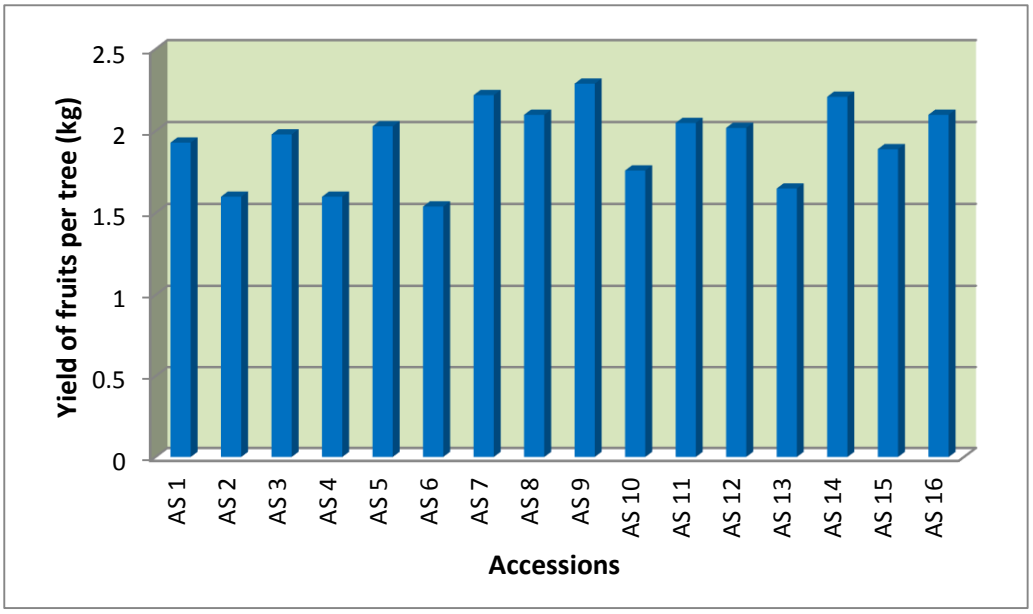


Fig.26. Yield of fruits per tree of *A. squamosa* accessions

In the accessions of *A. muricata,* fruiting was observed during September to May and the trees were regular bearers. The fruits were cordate (20 %) as well as broadly cordate (80 %) with tuberculata surface in the accessions. The fruit length varied from 12.1 to 16.8 cm. In the accession AM 14 recorded maximum and AM 2 recorded minimum fruit length.

Fruit diameter in *A. muricata* varied from 7.7 to 9.3 cm. It was maximum in AM 14. The minimum fruit diameter was noticed in the accession AM 8. Fruit weight in the accessions varied from 410 to 850g. It was maximum in the accession AM 18 and the accession AM 2 was with minimum fruit weight (Fig. 27). The accessions based on fruit weight could be classified as trees with large sized fruits (> 600 g) and medium sized fruits (400-600 g). The accessions AM 2, AM 6, AM 9, AM 10 belonged to medium sized and all others were with big sized fruits. The relative percentage of big sized fruits was 84 for all the samples. Manigandan (2014) reported more or less similar observation in fruit length, fruit diameter and fruit weight.

Number of flakes in *A. muricata* also varied from 132 to 189. The maximum number of flakes was recorded in AM 18 and it was minimum in AM 10. The fruit colour varied among accessions. It was green in most of the accessions and dark green in other accessions at maturity stage. Fruit colour at ripening, was yellowish green, light green and green colour. Similar observation was reported by Pinto and Silva (1996). The accessions recorded 18 to 30 fruits per tree with maximum number in AM 10 and minimum in AM 6. The yield of fruits per tree also varied from 8.82 to 22.68 kg. The accession AM 14 recorded maximum yield and AM 6 was poor yielder (Fig. 28). Based on yield of fruits per tree, the accessions can be classified as high yielders (>16 kg), medium yielders (10-16 kg) and low yielders (<10 kg). Thus the accessions AM 2, AM 20, AM 24 and AM 25 belong to medium yielders. And only the accession AM 6 was low yielder. All other accessions were high yielders. Shelf life of fruits varied from 3-5 days.

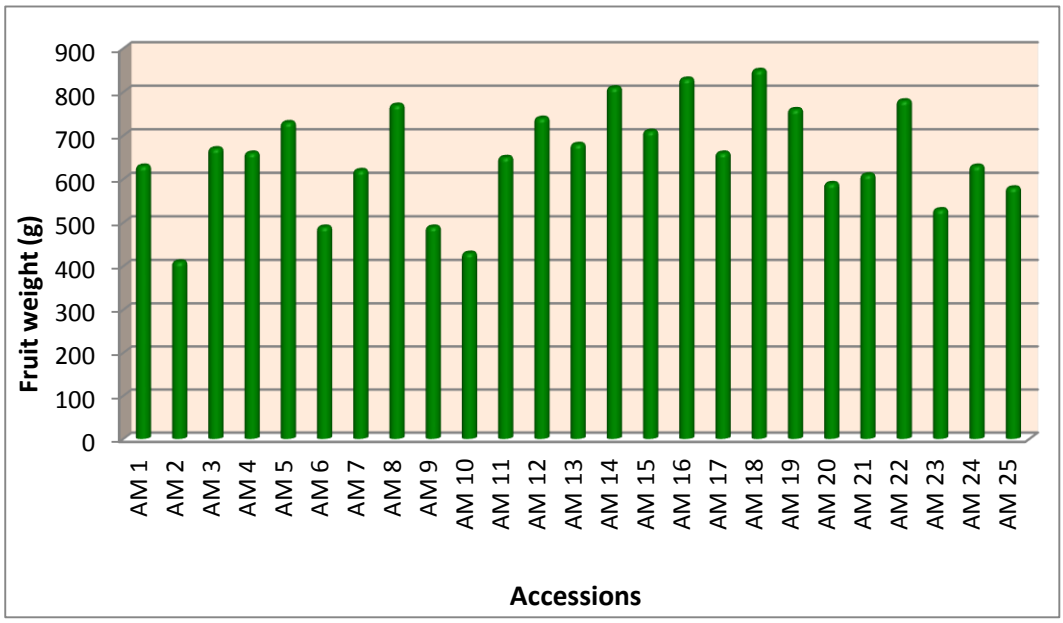


Fig.27. Mean fruit weight of *A. muricata* accessions

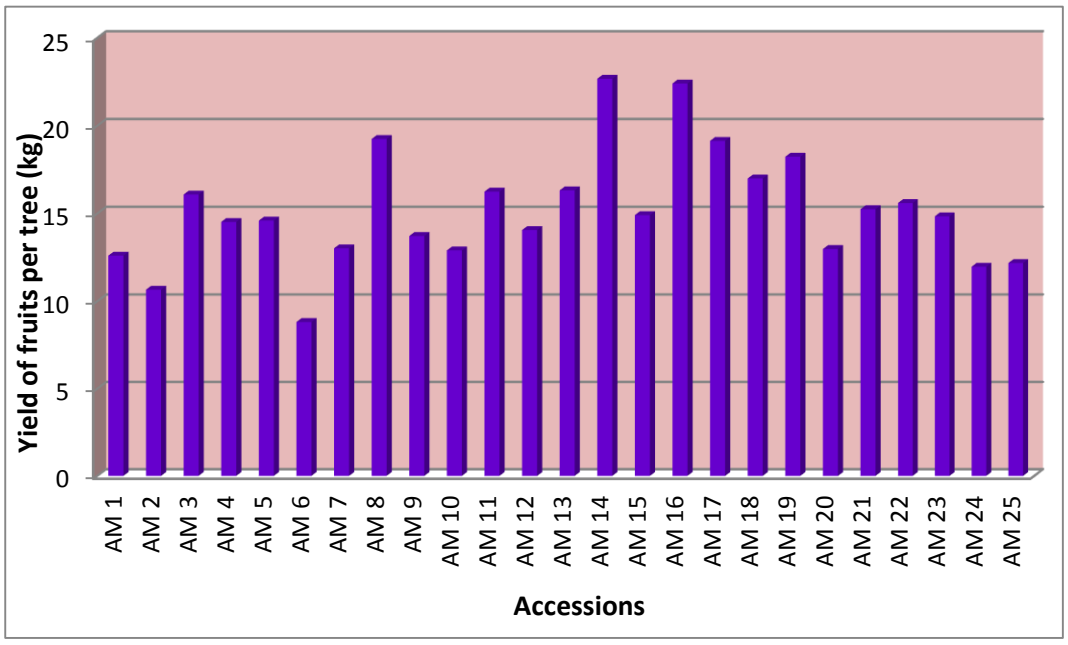


Fig.28. Yield of fruits per tree of *A. muricata* accessions

With regard to the mean value of characters, fruit length and diameter, fruit weight, number of fruits per tree, yield of fruits per tree and number of flakes was observed to be high in *A. muricata* compared to other two species. The shelf life was higher in *A. squamosa* accessions compared to other two species.

With regard to seed characters, the number of seeds per fruit in *A. reticulata* accessions, ranged from 43 to 93 within the accessions. It was maximum in AR 18 and minimum in the accession AR 14. Seed size *viz*., seed length and seed breadth varied among the accession from 12.1 to 16.6 mm and 4.1 to 8.4 mm respectively. The seed length was maximum in the accession AR 19. The minimum seed length was noticed in AR 28. In seed breadth the accession AR 4 was having maximum breadth whereas minimum was noticed in AR 6. The seed weight fruit ranged from 13.34 to 19.53 g with maximum in the accession AR 18.The accession AR 29 recorded minimum seed weight per fruit. Majority of the seeds were dark brown (75 %) in colour and few seeds were black (25 %). The mean percentage of edible portion was 78.75 per cent. These observations were more or less similar with the observations reported by Ghavale *et al*. (2016).

Number of seeds per fruit in *A. squamosa* varied from 11 to 29 with maximum number of seeds in AS 8. The accession AS 11 was with minimum number of seeds. Seed length and breadth varied from 13.1 to 15.7 mm and 4.1 to 5.9mm respectively. The maximum seed length was observed in AS 4 and minimum in AS 12. Similarly seed breadth was maximum in AS 9 and minimum in the accession AS 12. Seed weight per fruit was observed in the range of 6.44 to 8.97 g. The accession AS 8 recorded maximum seed weight and minimum was recorded in AS 14. Both the seed number and seed weight per fruit was lower compared to the observations reported by Bhatnagar *et al*. (2012). Most of the accessions were with dark brown seeds (75 %) except a few with black seeds (25 %). The mean percentage of edible portion was 54.07 per cent.

In *A. muricata* accessions, number of seeds per fruit varied from 42 to 59. It was maximum in the accession AM 16 and minimum in the accession AM 17. Seed size varied among the accessions. Seed length varied from 13.1 to 15.7 mm with maximum in AM 10 and AM 20. The minimum seed length was observed in the accession AM 6. Seed breadth ranged from 5.9 to 7.8 mm with maximum in AM 10 and minimum in AM 31. Seed weight per fruit varied from 13.95 to 18.29 g in which maximum was observed in AM 16 and minimum in AM 6. All the observations on seed characters were similar to the observations reported by Manigandan (2014). The seed colour varied in the accessions, with black coloured seeds (88 %) in most of the accessions and others with golden brown seeds (12 %). The mean percentage of edible portion was 74.47 per cent.

Considering the seed characters, mean value for number of seeds per fruit and seed weight per fruit was high in *A. reticulata* accessions. But the mean seed length and breadth was observed to be high in *A. muricata* accessions. (Table 42).

In sensory evaluation of *A.reticulata* accessions mean rank for organolepetic characters *viz*., appearance, texture, taste, aroma and sweetness varied from 2.80 to 28.40, 5.00 to 28.00, 1.30 to 28.20, 1.10 to 17.50 and 2.40 to 28.50 respectively. The accessions AR 23 and AR 11 was superior in appearance.AR 20 was superior in taste and with good aroma. The accession, AR 9 was good in appearance and texture. AR 3 was good in texture, taste and sweetness. AR 16 was the accession with good aroma and superior in sweetness. AR 21 was superior in aroma, good in taste and sweetness. The lowest mean rank was obtained for AR 7 and AR 15 in appearance and texture respectively.

The accession AR 18 was inferior in taste, aroma and sweetness. The accession AR 21 recorded highest total score of 127.3 followed by AR 3 with 124.6 and AR 16 with 121.1. Based on total score the accessions AR 21 (127.3) and AR 3 (124.6) were superior and they were highly preferred by panellist.

The sensory evaluation of *A. squamosa* accessions for the characters *viz*., appearance, texture, taste, aroma and sweetness recorded the mean rank in the range of 2.10 to 15.00, 1.08 to 13.50, 3.00 to 14.70, 3.40 to 12.50 and 3.10 to 15.10 respectively. The accession AS 16 was superior in appearance, texture, taste and sweetness. Similarly the accession AS 8 was superior in appearance, taste, aroma and sweetness. The accession AS 3 was with good aroma and taste. The accessions AS 12 and AS 6 were inferior with respect to appearance and texture respectively. The accession AS 14 was inferior in taste and AS 5 in aroma and sweetness. The total score of AS 8 was highest with 65.8 followed by AS 16 (65.5) and AS 7(52.2). These two accessions are more preferred by panellist.

The accessions of *A. muricata* recorded mean rank for the characters *viz*., appearance, texture, taste, aroma and sweetness ranged from 3.50 to 23.10, 2.50 to 22.40, 3.20 to 25.00, 4.00 to 24.20 and 4.30 to 23.40 respectively. The accession AM 19 was superior in taste, aroma and sweetness. AM 17 was good in taste and sweetness. The accession AM 14 was superior in texture and was with good appearance. AM 18 was with good appearance and texture. The total score was highest in AM 19 (104.9) followed by AM 12 (99.6) and AM 15 (86.9). These accessions were having more preference among the panellist.

5.6. Quality parameters

The TSS of the fruit samples of *A. reticulata* varied from 13.4 to 16.6 ^{0}Brix. The accessions AR 6 recorded maximum TSS and AR 8 was with minimum TSS (Fig. 29). There was low variability within the accession on TSS. With regard to acidity it ranged from 0.16 to 0.29 per cent in the accessions. The maximum was recorded in the accessions AR 7, AR 15, AR 24 and AR 30.The minimum acidity was noticed in AR 3, AR 8, AR 13, AR 16, AR 20, AR 21, AR 23 and AR 29.

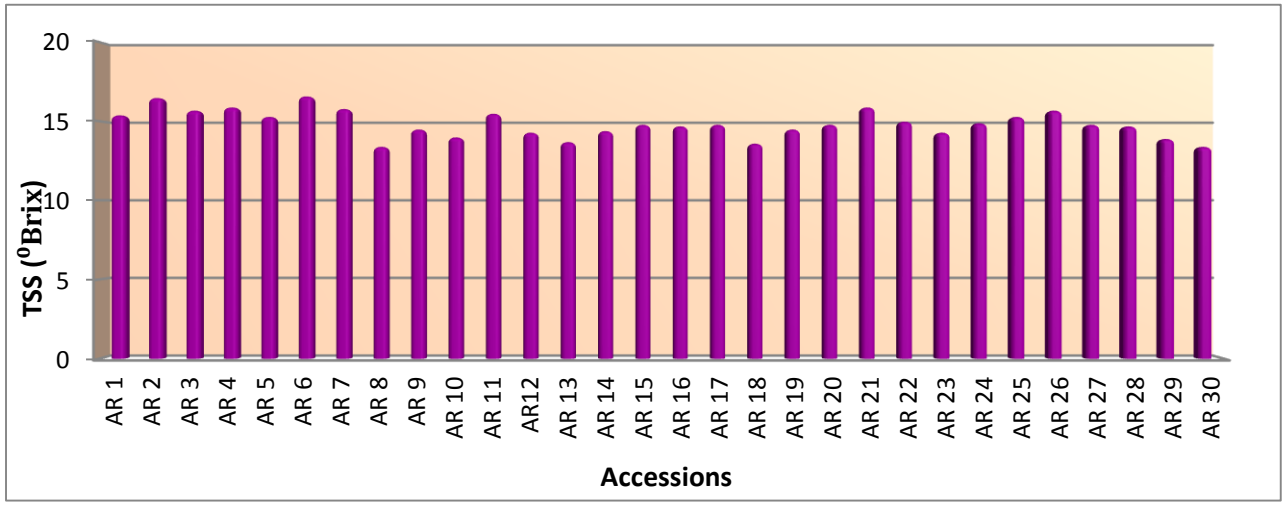


Fig. 29. TSS of *A. reticulata* accessions

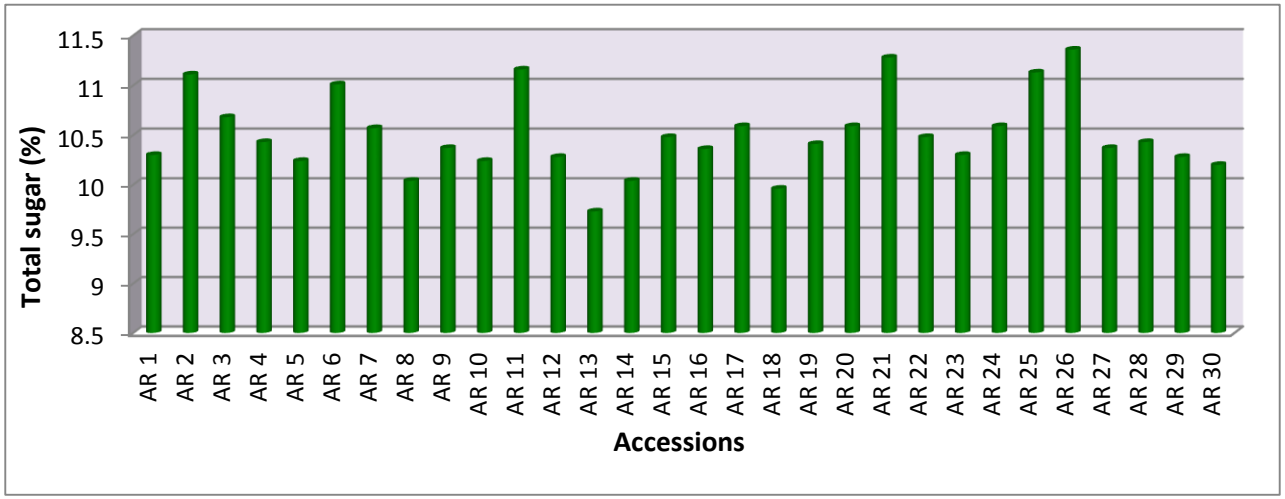


Fig.30. Total sugar of *A. reticulata* accessions

Reducing sugar in fruit samples varied from 8.74 to 10.41 per cent. It was maximum in AR 21 and minimum in AR 13 whereas non reducing sugar varied from 0.82 to 1.18 per cent. It was maximum in AR 8 and minimum in AR 16. Total sugar in the fruits varied from 9.73 to 11.36 per cent. The maximum value was recorded in AR 26 and minimum in AR 13 (Fig. 30). Based on total sugar content, the accessions can be classified as high (> 11 %), medium (10-11 %) and low (< 10 %). The accessions AR 2, AR 6, AR 11, AR 21, AR 25 and AR 26 were with high total sugar content. The accessions AR 13 and AR 18 were with low total sugar. All the quality parameters were found to be minimum when compared to the observations reported by Ghavale *et al*. (2016). This variation may be due to soil factors. The antioxidant activity of the fruits varied from 1.26 to 2.86 mg of ascorbic acid/g of sample. The maximum was recorded in the accession AR 6 and minimum in AR 7 (Fig. 31). Classification of the accessions based on high (> 2.5 mg of ascorbic acid/ g of sample), medium (1.5 – 2.5 mg of ascorbic acid/ g of sample) and low (<1.5 mg of ascorbic acid / g of sample) antioxidant activity, revealed that AR 7 and AR 22 are having low antioxidant activity. The accessions AR1, AR 4, AR 6, AR 10, AR 12, AR 13, AR 15, AR17, AR 26, AR 27 and AR 28 were with high antioxidant activity.

In *A. squamosa* accessions, TSS of the samples varied from 18.23 to 19.9 ^{0}Brix. The accession AS 7 recorded maximum and AS 8 recorded minimum TSS (Fig. 32). The accessions AS 2, AS 8 and AS 11 belong to the group with high TSS (> 19.5 ^{0}Brix). The accessions AS 3, AS 5, AS 13 and AS 16 were with low TSS (< 18.5 ^{0}Brix). All other accessions were with medium TSS (18.5-19.5 ^{0}Brix). Acidity of the fruits ranged from 0.16 to 0.22 per cent with maximum in AS 4 and AS 14. Bhatnagar *et al*. (2012) reported a lesser TSS and higher acidity. The variability in observations may be due to inherent genetic variation among the fruits. The minimum acidity was observed on the accessions AS 8 and AS 16. The reducing sugar of the samples varied from 10.16 to 11.79

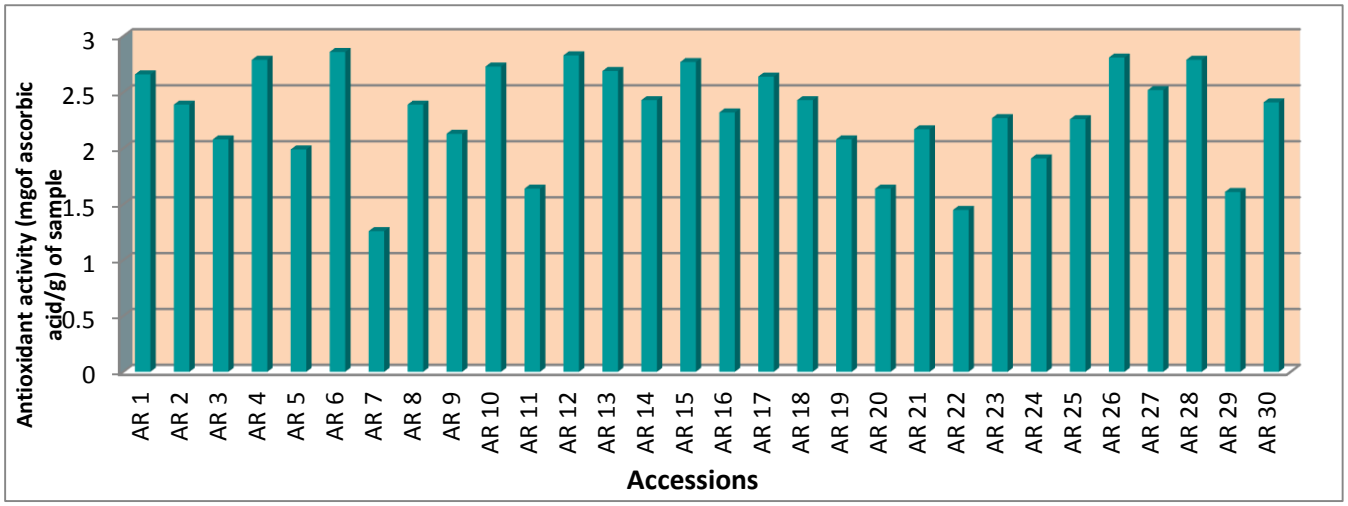


Fig.31. Antioxidant activity of *A. reticulata* accessions

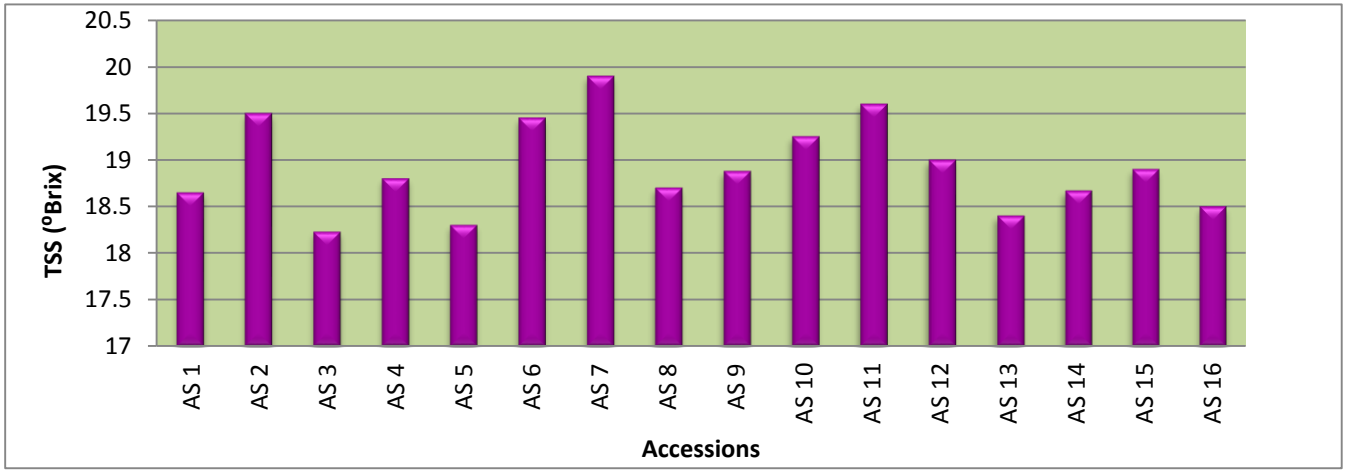


Fig.32. TSS of *A. squamosa* accessions

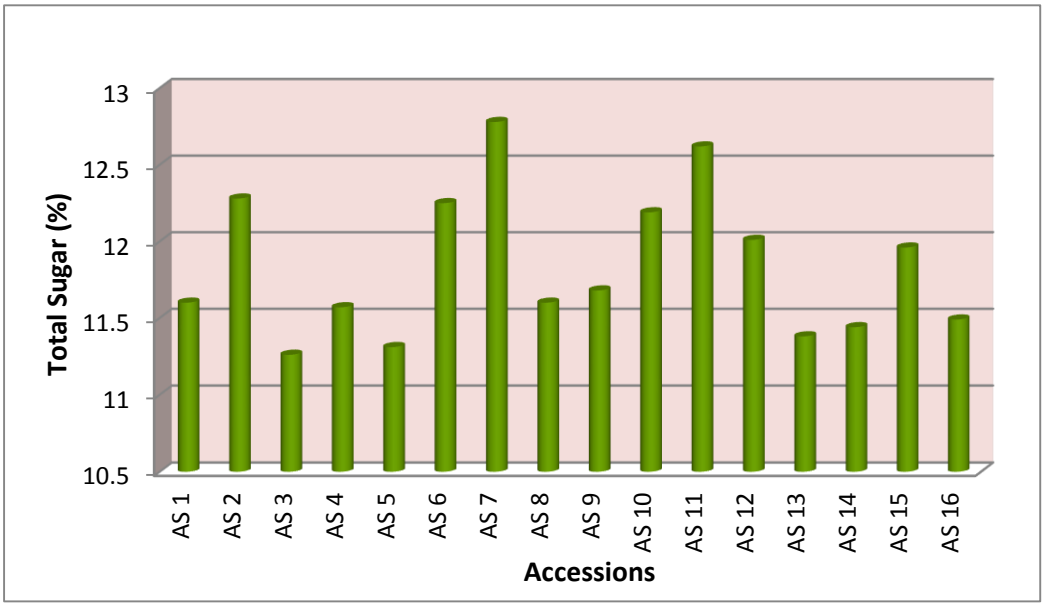


Fig.33. Total sugar of *A. squamosa* accessions

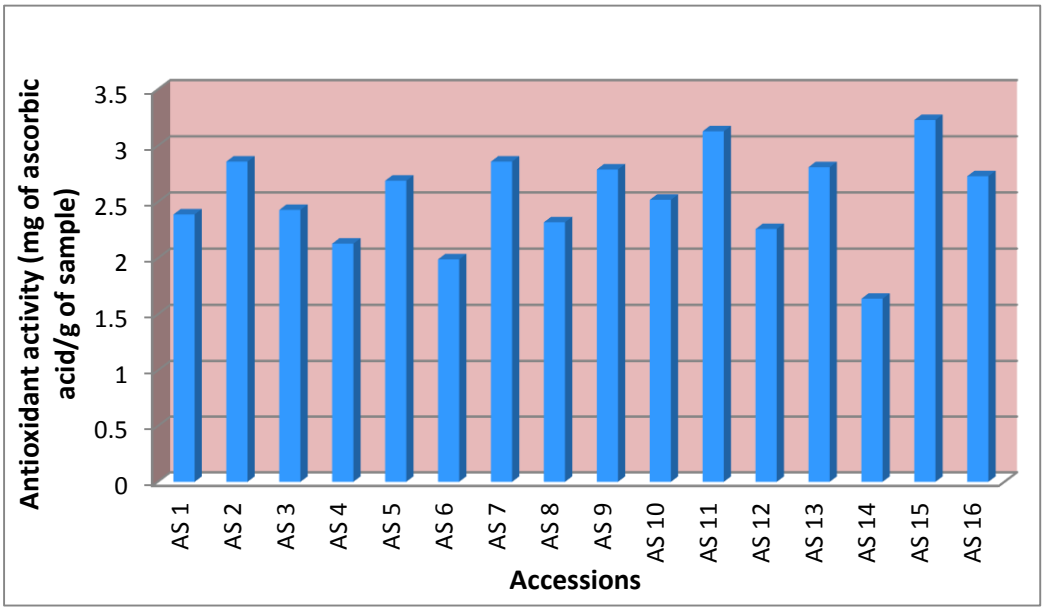


Fig.34. Antioxidant activity of *A. squamosa* accessions

per cent with maximum in AS 7 and minimum in AS 3. Non reducing sugar also varied from 0.82 to 1.1 per cent with maximum in AS 3 and minimum in AS 2.

In the accessions total sugar varied from 11.26 to 12.78. It was maximum in AS 7 and minimum in AS 3 (Fig. 33). The accessions AS 7 and AS 11 were with high total sugar content (>12.5 %) and the accessions AS 3, AS 5, AS 13, AS 14 and AS 16 were with low total sugar content (< 11.5 %). The antioxidant activity of fruit samples varied from 1.64 to 2.86 mg/g of sample in the accessions. It was maximum in AS 2, AS 7 and minimum in AS 14 (Fig. 34). There was low variability within the accessions regarding antioxidant activity.

The accessions of *A. muricata,* recorded TSS in the range of 12.2 to 14.9 ^{0}Brix. It was maximum in AM 19 and minimum in AM 16 (Fig. 35). The acidity of fruits varied from 0.36 to 0.38 per cent. The highest acidity was recorded in AM 3 and minimum in most of the accessions. Reducing sugar in the accessions varied from 6.62 to 8.62 per cent with maximum in AM 19 and minimum AM 23. With regard to non reducing sugar, it varied from 0.86 to1.16 per cent. It was maximum in the accession AM 14 and minimum in AM 9. Total sugar in samples varied from 7.72 to 9.57 per cent in the accessions with maximum in AM 19 and minimum in AM 2 (Fig. 36). The antioxidant activity varied from 3.52 to 4.52 mg/g of sample with, maximum in AM 25 and minimum in AM 2 (Fig. 37). There was very low variability in TSS, total sugar and antioxidant activity within the accessions. In a study by Singh *et al*. (2014), the reducing sugar and total sugar was higher compared to the observed values. This may be due to soil factors as well as genetic constitution of the fruits.

Quality parameters are important while considering a fruit. Hence it was observed that Annona *squamosa* is superior in TSS and total sugar. With regard to antioxidant activity *A. muricata* fruits were superior (Fig. 38). The mean acidity and non reducing sugar was high in *A. muricata* accessions (Table 42).

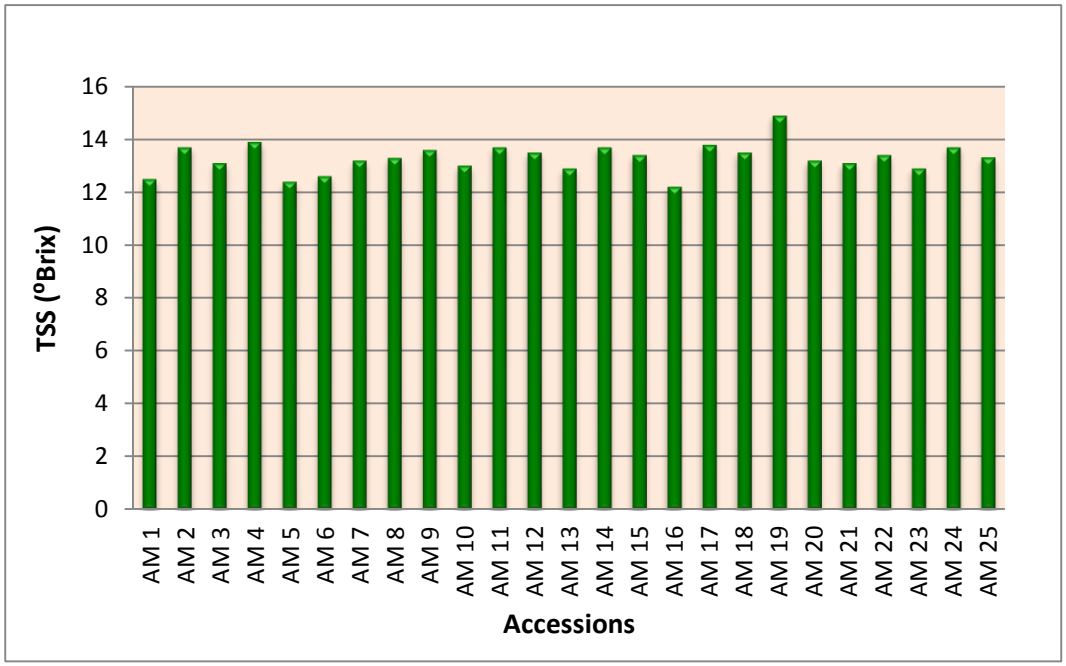


Fig.35. TSS of *A. muricata* accessions

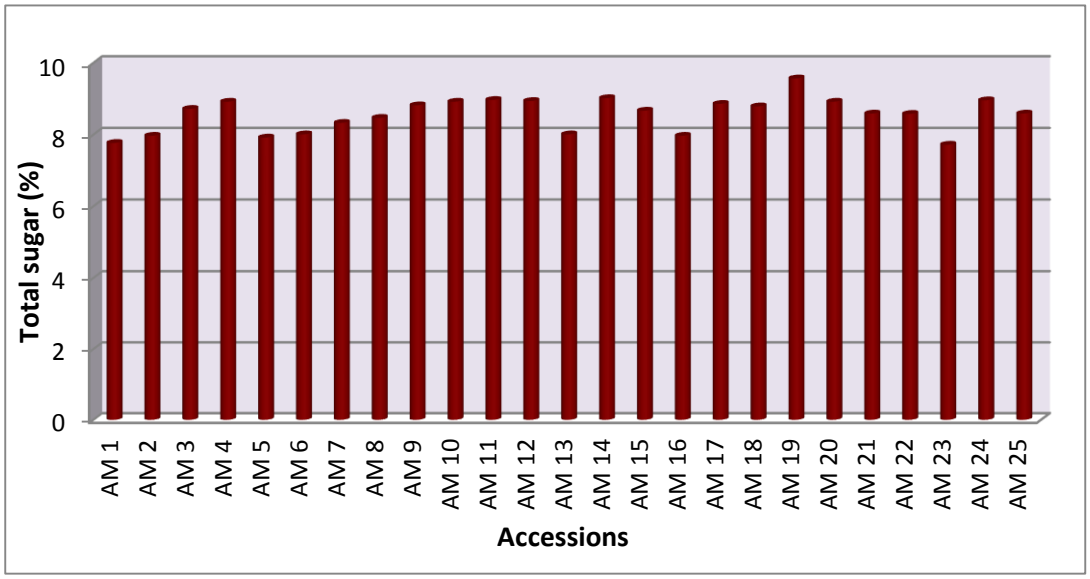


Fig.36. Total sugar of *A. muricata* accessions

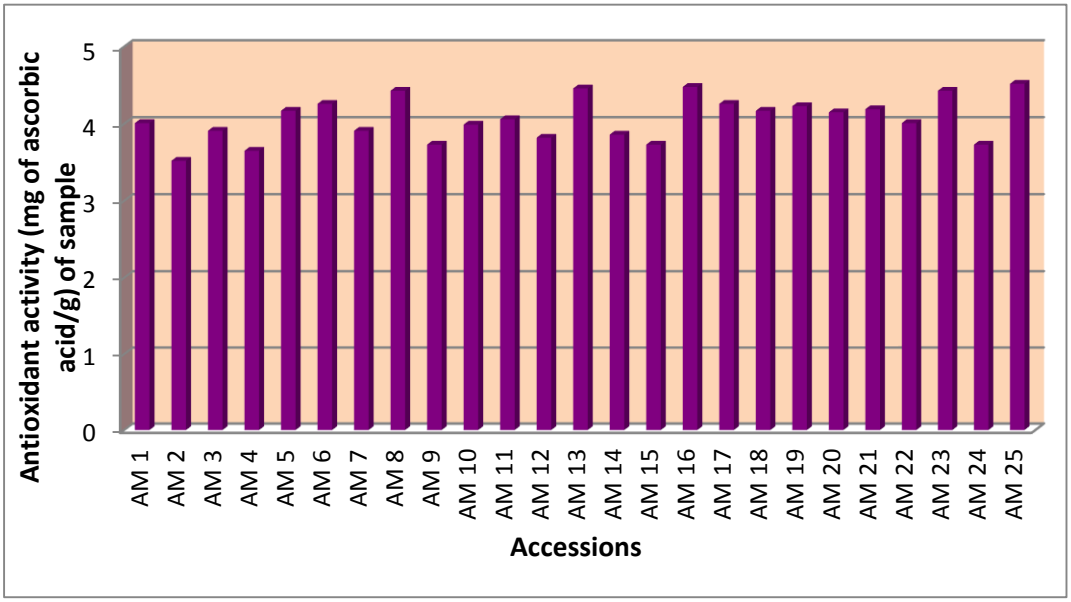
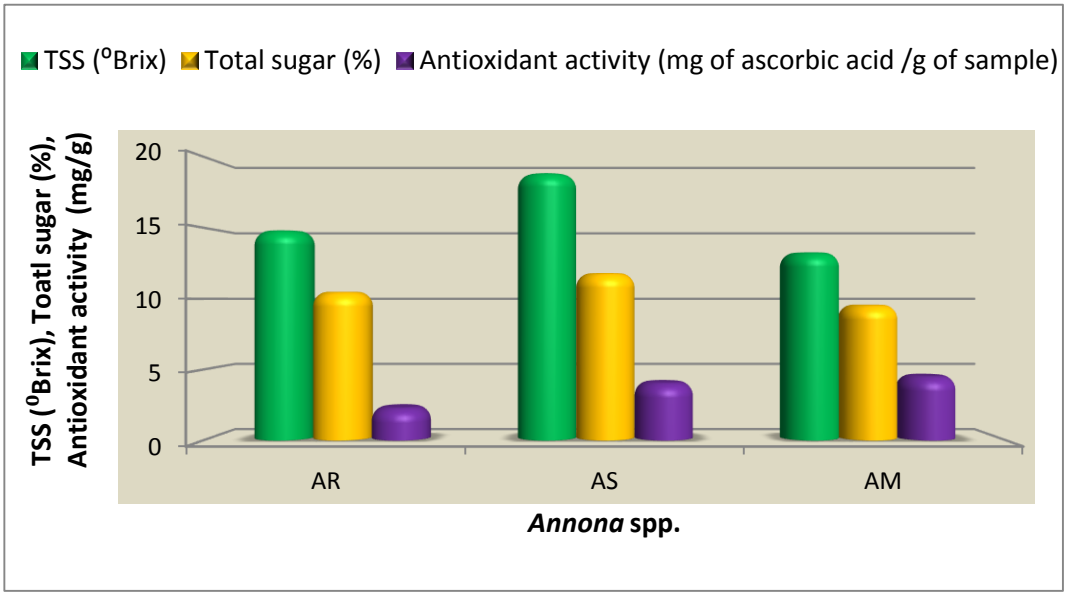


Fig.37. Antioxidant activity of *A. muricata* accessions



AR - *Annona reticulata*, AS - *A.squamosa*, AM - *A. muricata

Fig.38. Comparison of mean TSS, total sugar and antioxidant activity of *Annona* spp.

5.7. Cluster analysis for elite accessions

A. reticulata accessions are the most preferred fruit for consumption hence the preference was given for its quality as well as yield. Thus cluster XVIII was found to be best with the accession AR 2. The yield per tree was 10.80 kg, number of flakes was 94. The quality parameters *viz,* TSS and total sugar was good with a value of 16.5 ^{0}Brix and 11.11 per cent respectively. The cluster mean for antioxidant activity was higher in cluster XVI with the accession AR 6 (2.86 mg of ascorbic acid/g of sample).

Generally, less number of seeds and low acidity are preferred in fruits. The cluster V with AR 14 was observed with less mean number of seeds (43) and cluster I (AR 13) and II (AR 8) was with low acidity. But all other characters were found to be inferior in these clusters.

The *A. squamosa* accession, having commercial importance is preferred for fresh fruit consumption and utilised in processing industry. Hence the quality parameters are given priority. The cluster I with the accessions AS 7 and AS 11 was having mean fruit weight of 97.25 g, yield per tree of 2.13 kg, TSS of 19.75 ^{o}Brix, total sugar of 12.7 per cent and antioxidant activity of 2.99 mg of ascorbic acid/g of sample. Number of flakes was higher in cluster X with the accession AS 16 (72). The number of seeds was minimum in cluster XI with the accession AS 14. The cluster IX and X with AS 8 and AS 16 (0.16 %) recorded low acidity.

The *A. muricata* accessions which are usually sour in taste and hence preference is given for sweet types as well as with good medicinal property. Thus the cluster V with AM 8 was selected as a promising type for cultivation. The cluster mean for the characters are fruit weight of 770 g, yield per tree of 19.25 kg, number of flakes as 165 and number of seeds per fruit as 49. The cluster mean of quality parameters are TSS of 13.3 ^{0}Brix, acidity of 0.364 per cent and antioxidant activity of 4.43 mg of ascorbic acid /g of sample.

Table 43. Promising types identified in *Annona* spp.

Character	Based on observation	Based on PCA
Annona reticulata		
Fruit weight (g)	AR 9 (435), AR 18 (425)	AR 18 (425), AR 17 (400)
Yield per tree (kg)	AR 18 (15.18), AR 17 (13.60)	AR 18 (13.18), AR 17 (11.6)
TSS (^{0}Brix)	AR 6 (16.6), AR 2 (16.5)	AR 6 (16.6), AR 2 (16.5)
Total sugar (%)	AR 26 (11.36), AR 21 (11.228)	AR 11 (11.22), AR 2 (11.11)
Antioxidant activity (mg of ascorbic acid/g of sample)	AR 6 (2.86), AR 12 (2.83)	AR 6 (2.86), AR 4, AR 28 (2.79)
A. squamosa		
Fruit weight (g)	AS 16 (116.9), AS 8 (100.4)	AS 16 (116.9), AS 8 (100.4)
Yield per tree (kg)	AS 9 (2.29), AS 7 (2.22)	AS 7, AS 11 (97.25)
TSS (^{0}Brix)	AS 7 (19.9), AS 11 (19.6)	AS 7, AS 11 (19.75)
Total sugar (%)	AS 7 (12.78), AS 11 (12.62)	AS 7, AS 11 (12.70)
Antioxidant activity (mg of ascorbic acid/g of sample)	AS 2, AS 7 (2.86)	AS 7, AS 11 (2.99)
A. muricata		
Fruit weight (g)	AM 18 (850), AM 16 (830)	AM 18 (850), AM 16 (830)
Yield per tree (kg)	AM 14 (22.68), AM 16 (22.41)	AM 14 (22.68), AM 16 (22.41)
TSS (^{0}Brix)	AM 19 (14.9), AM 4 (13.9)	AM 19 (14.90), AM 9, AM 24, AM 4 (13.73)
Total sugar (%)	AM 19 (9.57), AM 14 (9.07)	AM 19 (9.57), AM 14 (9.07)
Antioxidant activity (mg of ascorbic acid/g of sample)	AM 25 (4.50), AM 16 (4.48)	AM 16 (4.48), AM 8 (4.43)

Promising types based on observation and PCA is presented in table 43. Considering individual cluster mean for each character in *A. reticulata*, the accession AR 18 and AR 17 were found to be superior with respect to fruit weight and yield per tree. The accessions AR 6 and AR 2 recorded high TSS. With regard to total sugar, the accessions AR 26 and AR 11 was superior. The antioxidant activity was high for AR 6 based on observation and principal component analysis. In *A. squamosa* the accession AS 16 and AS 8 were superior in fruit weight. The accessions, AS 7 and AS 11 were superior with regard to yield per tree, TSS, total sugar and antioxidant activity on observation and principal component analysis. The accession AM 18 and AM 16 were superior in fruit weight, AM 14 and AM 16 were superior in yield per tree in *A. muricata* accessions. TSS and total sugar was high for AM 19 on observation and principal component analysis. But the antioxidant activity was high in AM 25 on observation and AM 16 on principal component analysis.

Considering fruit and quality parameters the promising accession in *A. reticulata* is AR 2, in *A. squamosa* are AS 7 and AS 11 and in *A. muricata* is AM 8 (Plate 18). In sensory evaluation, the accessions AR 21 and AR 3 of *A. reticulata*, AS 8 and AS 16 of *A. squamosa* and AM 19 and AM 12 of *A. muricata* were preferred by the panellist. The accession AM 19 was a sweet type in *A. muricata* identified from Ernakulam district.

The study revealed that the three different species of Annona had wide variability in terms of their growth, vegetative, flowering and fruit characters. Performance of the identified promising types is to be evaluated in the succeeding 3-4 years so as to confirm the performance. There is also a scope for extending the studies to other districts so as to make an account of the total variability available and to select the most promising types in each species suited for Kerala condition.

AR 2

AS 7

AS 11

AM 8

Plate 18: Promising types in *Annnona* spp.

Summary

6. SUMMARY

The study entitled 'Assessment of variability in Annona spp.' was carried out at the College of Horticulture, Vellanikkara, during 2014 to 2016. The main objectives of the study were to assess the variability in three Annona spp. *viz*., *Annona reticulata*, *A. squamosa* and *A. muricata* in central zone of Kerala and to select the promising types. The salient findings are summarized below:

Variability was observed among the accessions of all the three species studied for qualitative and quantitative characters.

- ***A. reticulata***

In *A. reticulata*, most of the trees were erect (33.33 %) or semi spreading (66.66 %) type with a two branched pattern. There was no pubescence observed on the shoots of the tree. While considering the orientation of leaf, most of them were oriented upright (60 %) and others were semi upright (40 %). Tree height and spread was in the range of 5.2 to 8.8 m and 5.4 to 7.70 m respectively. The highest plant height and spread was recorded in AR 30 (8.8 m) and AR 13, AR 30 (7.70 m). The minimum plant height and spread was recorded in AR 22 (5.2 m) and AR 22 (5.4 m). Leaf was lanceolate with acuminate apex, acute base, entire leaf margin and glabrous. Leaf length and breadth ranged from 17.9 to 23.9 cm and 4.2 to 6.8 cm. It was the highest in AR 2 (23.9 cm) and AR 3 (6.8 cm). The accessions AR4 (17.9 cm) and AR 20 (4.2 cm) recorded the lowest leaf length and breadth respectively. The leaves were having light green as well as with green petiole and vein colour. The predominant leaf colour was light green and green at young and maturity stage. Pubescence was absent on leaves.

The flowering was observed from August to March with peak flowering during December and November. The fruiting started from September to May. The fruits were harvested after 90-100 days after flowering. The flowers were observed to be in clusters on laterals of current season shoots. Two flowering

seasons were noticed in AR 12 located at Thrissur. Most of the fruits had cordate shape with laevis (smooth surface) surface and reddish yellow colour on ripening. The fruit length and breadth ranged from 7.4 to 11.4 cm and 6.6 to 10.6 cm respectively. The highest fruit length and breadth was recorded by AR 3 (11.4 cm) and AR 11(10.6 cm). The accessions AR 15 (7.4 cm) and AR 20, AR 26 (6.6 cm) recorded the lowest fruit length and breadth. Fruit weight and number of flakes varied from 110 to 435 g and 46 to 114, with maximum in the accession AR 9 (435 g) and AR 18 (114). The minimum fruit weight and number of flakes were observed in AR 14 (110 g and 46 flakes).Number of fruits per tree and yield per tree varied from 31 to 51 and 3.92 to 15.18 kg respectively. The highest number of fruits and yield was recorded in AR 18 (51 fruits and 15.18 kg). The minimum number of fruits and yield per tree was noticed in the accession AR 9 (31) and AR 27 (3.92 kg) respectively. The number of seeds per fruit and seed weight per fruit, ranged from 43 to 93 and 13.34 to 19.53 g, out of which, the maximum number of seeds (93 seeds) and fruit weight of 19.53 g was recorded in AR 18. The minimum number of seeds was noticed in the accession AR 14 (43 seeds) and fruit weight in AR 29 (13.34 g). The mean percentage of edible portion of the fruits was 78.75 per cent. The shelf life of fruits varied from 2-4 days. Sensory evaluation revealed that the accession AR 21 and AR 3 with higher total score of 127.3 and 124.6 were found to be superior.

The TSS of the fruit samples varied from 13.4 to 16.6 ^{0}Brix. The accession AR 6 (16.6 ^{0}Brix) recorded maximum TSS and AR 8 (13.4 ^{0}Brix) had minimum TSS. With regard to acidity it ranged from 0.16 to 0.29 per cent. Reducing sugar, non reducing sugar and total sugar in fruit samples varied from 8.74 to 10.41 per cent, 0.82 to 1.18 per cent and 9.73 to 11.36 per cent respectively. The total sugar was maximum in the accessions AR 26 (11.36 %) and minimum in AR 13 (9.73 %). The antioxidant activity of the fruits varied from 1.26 to 2.86 mg of ascorbic acid /g of sample. The maximum was recorded in the accession AR 6 (2.86 mg of ascorbic acid/g of sample) and minimum in AR 7 (1.26 mg of ascorbic acid /g of sample).Cluster analysis of the accessions

revealed that the cluster XVIII contained superior accession which includes most promising type AR 2. The accessions AR 11, AR 21 and AR 17 were also found to be superior.

- ***A. squamosa***

The tree height and spread in *A. squamosa* accessions were in the range of 1.5 to 3.0 m and 2.36 to 3.95 m respectively. The maximum tree height was noticed in accessions AS6, AS 8, AS 11, AS 12 and AS 14 and minimum in AS 4, AS 7 and AS 16. Whereas maximum spread of the tree was observed in AS 9 (3.95 m) and minimum in AS 7 (2.36 m). The trees are erect in nature with two branches (68.75 %) and a few of them were with three or more branches (31.25 %). There was no pubescence in their shoots. The orientation of leaf was upright (75 %) as well as semi upright (25 %) in the accessions. Leaf blade was lanceolate (62.5 %) and elliptic (37.5 %) in the accessions. The leaves were with acute apex, rounded base, entire margin and glabrous in nature. Leaf length and breadth varied from 8.3 to 15.2cm and 2.2 to 5.4 cm. The accession AS 3 recorded maximum leaf length and breadth. The minimum leaf length and breadth was recorded in AS 4. The petiole and vein colour was light green (81.25 %) and dark green (18.75 %) with light green colour for both young and mature leaves.

Flowering was observed from January to June. The peak flowering was noticed during March and April. The fruiting was noticed from February to August. The fruits are harvested 75- 80 days after flowering. The flowers were borne on laterals of current season growth as small clusters of 3-4 flowers. All the fruits were cordate with umbonata (small protrusion) surface. Length and diameter varied from 5.36 to 6.08 cm and 5.34 to 5.79 cm respectively. The highest fruit length and diameter was observed in AS 16 (6.08 cm) and AS 8 (5.79 cm) respectively. The lowest fruit length and breadth was noticed in AS 12 (5.36 cm and 5.34 cm). The fruit weight and number of flakes ranged from 81.5 – 116.9 g and 33 to 62 respectively. It was maximum in the accession AS 16

(116.9 g and 62 flakes) and minimum in the accession AS6 (81.5 g and 33 flakes). At ripening, the fruits were yellowish green colour and few accessions were light green in colour. The number of fruits per tree and yield per tree in the accessions varied from 18 to 26 and 1.54 to 2.29 kg respectively. The maximum number of fruits as well as yield was recorded in AS 9 (26 fruits and 2.29 kg).

Number of seeds per fruit in *A. squamosa* varied from 11 to 29 with maximum number of seeds in AS 8. The accession AS 11 had the lowest number of seeds. Seed weight per fruit was observed in the range of 6.44 to 8.97 g. The accession AS 8 recorded maximum seed weight and minimum was recorded in AS 14. The mean percentage of edible portion was 54.07 per cent. Shelf life of fruits varied from 4 to 6 days. The total score of the accessions AS 8 (65.8), AS 19 (65.5) and AS 7 (52.2) were found to be superior after sensory evaluation.

TSS in fruits varied from 18.23 to 19.9 ^{0}Brix. The accession AS 7 (19.9 ^{0}Brix) recorded maximum and AR 8 (18.23 ^{0}Brix) recorded minimum TSS. Acidity of the fruits ranged from 0.16 to 0.22 per cent. The reducing sugar, non reducing sugar and total sugar varied from 10.16 to 11.79 per cent, 0.82 to 1.1 per cent and 11.26 to 12.78 per cent respectively. Reducing sugar and total sugar was the highest in AS 7 (11.79 % and 12.78 %) and the lowest in AS 3 (10.16 % and 11.26 %). But the non reducing sugar was the highest in AS 3 (1.1 %) and the lowest in AS 2 (0.82 %). The antioxidant activity of fruit samples varied from 1.64 to 2.86 mg of ascorbic acid/g of sample in the accessions. It was maximum in AS 2, AS 7 (2.86 mg of ascorbic acid/ g of sample) and minimum in AS 14 (1.64 mg of ascorbic acid/ g of sample).Cluster analysis indicated that the accessions AS 7 and AS 11 belonging to cluster I were found to be promising compared to all other accessions.

- ***A. muricata***

Tree height in the *A. muricata* accessions was in the range of 3.0 to 4.6 m. The maximum tree height was in the accession AM 10 (4.6 m) and minimum

in AM 9and AM 12 (3 m). The spread of tree varied from 3.42 to 5.4 m. Compared to all other accessions, AM 11 (5.4 m) had maximum spread and AM 2 (3.42 m) had minimum spread. The trees were of erect (60 %), spreading (28 %) or semi spreading (12 %) nature with one branch. Some of the accessions were two branched without pubescence. Leaf orientation was horizontal (72 %) as well as in semi upright (28 %) positions. Leaves were obovate, with acuminate and acute leaf apex, acute base, entire leaf margin and glabrous. Leaf length and breadth ranged from 12.4 to18.1 cm and 5.7 to 8.2 cm. The maximum leaf length was observed in the accessions AM 6 and AM 24 (18.1 cm). Whereas, the leaf breadth was maximum in the accession AM 6 (8.2 cm). The minimum leaf length and breadth was observed in AM 7 (12.4 cm and 5.7 cm). The petiole and vein colour was dark green with light green and dark green leaves at young and mature stage. The leaves were without pubescence on their surface.

In *A. muricata*, the flowering was noticed from August to March in which peak flowering was noticed during December and October. Fruiting was observed from September to May. The fruits are harvested within 105 to 125 days after flowering. The flowers are solitary, borne laterally on older shoots and also cauliflorous in nature. The fruits are cordate and with tuberculata surface (medium protrusion). The fruit length and breadth varied from 12.1 to 16.8 cm and 7.7 to 9.3 cm. The accession AM 14 (16.8 cm and 9.3 cm) was having maximum fruit length and diameter. The fruit length and breadth was minimum in AM 2 (12.1 cm) and AM 8 (7.7 cm) respectively. Fruit weight and number of flakes in the accessions varied from 410 to 850 g and 132 to 189. The highest fruit weight and number of flakes was observed in AM 18 (850 g and 189 flakes). The lowest fruit weight and number of flakes was recorded by AM 2 (410g) and AM 10 (132 flakes). The number of fruits per tree and yield per tree varied from 18 to 30 and 8.82 to 22.68 kg respectively. The maximum number of fruits was noticed in AM 10 (30 fruits) and yield was observed in AM 14 (22.68 kg). The accession AM 6 (18 fruits and 8.82 kg) was with minimum number of fruits and yield. Shelf life of the fruits varied from 3 to 5 days.

The number of seeds per fruit and seed weight per fruit varied from 42 to 59 and 13.95 to 18.2 9 g. The maximum was in AM 16 (59 seeds and 18.92 g) and minimum number of seeds in AM 17 (42) and seed weight in AM 6 (13.95 g). The mean percentage of edible portion was 74.47 per cent. On sensory evaluation, AM 19 (104.9), AM 12 (99.6) and AM 15 (86.9) were found to be superior.

With regard to quality parameters, TSS varied from 12.2 to 14.9 ^{0}Brix and acidity from 0.36 to 0.38 per cent. The highest TSS was observed in AM 19 (14.9 ^{0}Brix) and lowest in AM 16 (12.2 ^{0}Brix). The reducing sugar, non reducing sugar and total sugar varied from 6.62 to 8.62 per cent, 0.86 to 1.16 per cent and 7.72 to 9.57 per cent respectively. The highest reducing and total sugar was observed in AM 19 (8.62 % and 9.57 %). The lowest reducing sugar was observed in AM 23 (6.62 %) and total sugar in AM 9 (7.72 %). The non reducing sugar was maximum in the accession AM 14 (1.16 %) and minimum in AM 9 (0.86 %). The antioxidant activity varied from 3.52 to 4.52 mg of ascorbic acid/g of sample with, maximum in AM 25 (4.52 mg of ascorbic acid/g of sample) and minimum in AM 2 (3.52 mg of ascorbic acid/ g of sample).With respect to yield and quality parameters, cluster V with AM 8 was found superior. AM 19 was identified as a sweet type.

The promising accession in *A. reticulata* is AR 2, in *A. squamosa* are AS 7 and AS 11 and in *A. muricata* is AM 8. In sensory evaluation, the accessions AR 21 and AR 3 of *A. reticulata*, AS 8 and AS 16 of *A. squamosa* and AM 19 and AM 12 of *A. muricata* were preferred by the panellist.

Annona fruits are receiving importance due to their nutritional and medicinal values. Comparing the fruits of *A. reticulata*, *A. squamosa* and *A. muricata* maximum variability was observed in *A. reticulata* and minimum in *A. squamosa*. Fruit quality parameters and organoleptic parameters were maximum for *A. squamosa* and antioxidant activity was maximum in *A. muricata*.

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Appendices

APPENDIX 1

Name of the scorer

Please score the given fruit samples using 9 point hedonic scale.

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

Treatments	Appearance	Texture	Taste	Aroma	Sweetness	Overall acceptability

Remarks:

APPENDIX II

Details of accessions in three districts in Central Zone of Kerala

Districts	Accessions
Thrissur (35 trees)	AR 1 – AR 12, AR 14 - AR 18, AR 20, AR 21
	AS 2- AS 7
	AM 1, AM 2,AM 7- AM 9, AM 11, AM 12, AM 16, AM 20, AM 21
Ernakulam (19 trees)	AR 13, AR 19, AR 22, AR 23, AR 27
	AS 1, AS 8, AS 12- AS 14
	AM 3- AM 6, AM 14, AM 15, AM 19, AM 22, AM 25
Palakkad (17 trees)	AR 24 – AR 26, AR 28 - AR 30
	AS 9- AS 11, AS 15, AS 16
	AM 10, AM 13, AM 17, AM 18, AM 23, AM 24

ASSESSMENT OF VARIABILITY IN

Annona spp.

By

Jyolsna M

(2014-12-108)

ABSTRACT OF THE THESIS

Submitted in partial fulfillment of the requirement for the degree of

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ABSTRACT

Annona spp. is a group of underutilized fruit crops with tremendous potential. Among these, *Annona reticulata*, *A. squamosa*, and *A. muricata* are seen as a homestead crop in Kerala. Since *Annona* spp. is cross pollinated as well as a seed propagated fruit crop, there exists wide variability indicating scope for selection of promising types.

In a purposive sample survey, 71 trees comprising of 30 trees of *Annona reticulata*, 16 trees of *A. squamosa* and 25 trees of *A. muricata* were identified from the homesteads of Ernakulam, Thrissur and Palakkad districts of Kerala. The accessions were notated as AR for *A. reticulata*, AS for *A. squamosa* and AM for *A. muricata*. They were further evaluated for their morphological, biochemical characters as well as for sensory evaluation. Tree characters, leaf characters, inflorescence characters, fruit characters and quality parameters were recorded as per IPGRI crop descriptor.

Morphological characters such as tree, leaf, floral and fruit characters were distinct for the three species. Flowering and fruiting seasons exhibited wide variability among the three species irrespective of districts. In *A. reticulata* and *A. muricata,* flowering was from August to March and fruiting was from September to May. In *A. squamosa,* flowering was observed from January to June and fruiting was from February to August.

Wide variability was observed in fruit characters and quality parameters of *A. reticulata* accessions. The fruit weight ranged from 110 g (AR 14) to 435 g (AR 9).TSS, titratable acidity, total sugar and antioxidant activity of the fruits ranged from 13.4 ^{0}Brix (AR 8) to 16.6 ^{0}Brix (AR 6), 0.16 to 0.29 per cent, 9.7 (AR 13) to 11.36 per cent (AR 26) and 1.26 mg (AR 7) to 2.86 mg (AR 6) of ascorbic acid per g of sample respectively.

In *A. squamosa*, individual fruit weight varied from 81.5 g (AS 6) to 116.9 g (AS 16). The TSS, titratable acidity, total sugar and antioxidant activity of the fruits ranged from 18.23 ^{0}Brix (AS 3) to 19.9 ^{0}Brix (AS 7), 0.16 to 0.22 per cent, 11.26 (AS 3) to 12.78 per cent (AS 7) and 1.64 mg (AS 14) to 2.86 mg (AS 2 and AS 7) of ascorbic acid per g of the sample respectively.

Fruit weight in *A. muricata* ranged from 410 g (AM 2) to 850 g (AM 18).TSS of the fruit samples varied from 12.2 ^{0}Brix (AM 16) to 14.9 ^{0}Brix (AM 19). The titratable acidity, total sugar and antioxidant activity ranged from 0.36 to 0.38 per cent, 7.72 (AM 23) to 9.57 per cent (AM 19) and 3.52 mg (AM 2) to 4.52 mg (AM 25) of ascorbic acid per g of sample respectively.

The principal component analysis of accessions based on all quantitative observations separately for the three species revealed variability existing between them. The common and distinct characters of the species were fruit weight, number of flakes per fruit and shelf life.

The principal component analysis for three species was performed separately to determine promising types based on the characters such as fruit weight, yield of fruits per tree, number of seeds per fruit, TSS, acidity, total sugar and antioxidant activity. The clustering of the three species done separately using score plot confirmed that the promising accession in *A. reticulata* is AR 2, in *A. squamosa* are AS 7 and AS 11 and in *A. muricata* is AM 8. In sensory evaluation, the accessions AR 21 and AR 3 of *A. reticulata*, AS 8 and AS 16 of *A. squamosa* and AM 19 and AM 12 of *A. muricata* were preferred by the panelist.

The study revealed that the three different species of Annona had wide variability in terms of their growth, vegetative, flowering and fruit characters. Among the three species, with regard to fruit quality parameters, *Annona squamosa* was

superior in TSS and total sugar whereas fruits of *Annona muricata* were superior with respect to antioxidant activity.

Performance of the identified promising types is to be evaluated for another 3-4 years so as to ascertain the performance. There is also a scope for extending the studies to other districts so as to make an account of the total variability available and to select the most promising types in each species suited for Kerala condition.