VARIABILITY STUDIES IN RAMBUTAN

(*Nephelium lappaceum* L.)

by

SAMEER MUHAMED

(2014-12-109)

THESIS

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DECLARATION

I, hereby declare that the thesis entitled **"Variability studies in rambutan (*Nephelium lappaceum* L.)"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

Vellanikkara
01/09/2016

Sameer Muhamed.
(2014-12-109)

CERTIFICATE

Certified that the thesis entitled **"Variability studies in rambutan (*Nephelium lappaceum* L.)"** is a record of research work done independently by **Mr. Sameer Muhamed. (2014-12-109)** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, associateship or fellowship to him.

Dr. Sajan Kurien
Chairman, Advisory Committee
Professor (Horticulture) &
Director of Research
Kerala Agricultural University

Vellanikkara
01/09/2016

CERTIFICATE

We, the undersigned members of the advisory committee of **Mr. Sameer Muhamed. (2014-12-109)** a candidate for the degree of **Master of Science in Horticulture**, with major field in Pomology & Floriculture, agree that the thesis entitled **"Variability studies in rambutan (*Nephelium lappaceum* L.)"** may be submitted by Mr. Sameer Muhamed. (2014-12-109), in partial fulfillment of the requirement for the degree.

1/9/16

Dr. Sajan Kurien
(Chairman, Advisory Committee)
Professor (Horticulture) &
Director of Research
Kerala Agricultural University

1.9.2016

Dr. C.K Geetha
(Member, Advisory Committee)
Professor and Head
Department of Pomology and Floriculture
College of Horticulture, Vellanikkara

1/9/16

Dr. K.B Sheela
(Member, Advisory Committee)
Professor and Head
Department of Processing Technology
College of Horticulture, Vellanikkara

1/9/16

Dr. S Krishnan
(Member, Advisory Committee)
Professor and Head
Department of Agricultural Statistics
College of Horticulture, Vellanikkara

EXTERNAL EXAMINER

Dr. S Rajan
ADG (Retired), ICAR

1/9/16

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Sameer Muhamed

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Dedicated to all rambutan growers

Introduction

1. INTRODUCTION

Rambutan (*Nephelium lappaceum* L.) as it is commonly referred to 'hairy litchi" is a medium-sized evergreen tropical tree belonging to Sapindaceae, a family that includes other fruit crops such as litchi (*Litchi chinensis* Sonn.), longan (*Dimocarpus longan* Lour) and pulasan (*Nephelium mutabile* Blume). Native to Indonesia and Malaysia, rambutan is now commonly grown throughout South East Asia. This crop has also established itself as a crop of warm humid tropics that adapts to various kinds of soil from low land-heavy soils to upland-hilly soil. Currently, Thailand is the world's leading producer of rambutan. However, Indonesia, Malaysia, Australia, China, Philippines and some other countries in the western hemisphere are also centres of commercial production.

Rambutan trees are either male (producing staminate flowers only), female (producing flowers that are only functionally female),or hermaphrodite (producing flowers that are female with a small percentage of male flowers). Most of the commercially cultivated varieties are hermaphrodite. Rambutan can be propagated vegetatively as well as by seeds. However, to obtain quality true- to-type bearing trees and to achieve early bearing, vegetative propagation techniques are normally resorted to. Seedling progenies show high variability due to heterozygosity. Secondly, there is a chance that such plants raised could be a male leading to no fruit yield at all and thirdly they have a high gestation period of nearly 4-6 years. There is also wide morphological variations observed among plants grown as a consequence of which little uniformity is observed in the orchards and also the fruits realized from them.

In India, rambutan is mostly confined to two districts of Pathanamthitta and Kottayam of state of Kerala. The crop has also become one of the most treasured fruit particularly as a 'courtyard crop' or on its fringes in the homegardens of Kerala. Available information on the subject is scanty but it is certainly a crop with tremendous potential for cultivation in the whole state of Kerala..

A recently held state level workshop sponsored by National Bank for Agriculture and Rural Development (NABARD) and National Horticulture Board

(NHB) of Govt. of India, concluded that there exist very high variability among the seedling progenies cultivated . Some of the types showcased were much more superior than the established cultivars of South East Asiatic countries revealing that there is sufficient scope for selection of elite/promising types. (Sijimon, 2009).

This study was taken up with the prime objectives of showcasing the existing variability and genetic wealth available in the important rambutan growing tracts of Kerala (Pathanamthitta, Kottayam, Idukki and Thrissur). It also aims at comparing the different types available by analyzing the physiochemical traits of fruits and conducting sensorial perceptions to evaluate the consumer preference of identified promising types. Finally, the outcome of the project is expected to be in terms of identifying elite types with promising quality attributes which can be out-rightly recommended for cultivation.

Review of literature

2. REVIEW OF LITERATURE

Rambutan (*Nephelium lappaceum* L.), native to Indonesia and Malaysia is a crop of the warm humid tropics and sub-tropical regions and is widely cultivated throughout South - East Asia. There exists great variability in rambutan because of the natural cross pollination and sexual propagation. In this chapter, an attempt is made to review the relevant literature that has been reported in rambutan and is presented in a chronological order under various subheads such as variability in vegetative characters, reproductive characters, yield studies, fruit characters, quality parameters, postharvest management, value addition and pests, diseases and physiological disorders.

2.1 Variability in rambutan

Conventional orchards show large phenotypic variability beginning from tree form to fruit and quality attributes due to seed propagation which was in practice. On the contrary, domestication of improved types forced orchardists to resort to vegetative propagation to preserve fruit quality characters. However, this aspect falls outside the ambit of the review.

2.1.1 Vegetative characters

Naturally occurring rambutan trees are fairly large, grow up to a height of 20 m and clonal cultivars are small, 4-7 m tall with spreading habit. Leaves are alternate, paripinnate, ovate to obovate leaflets with a dimension of 5-28cm x 2-10.5 cm, usually glabrous above, sometimes hairy beneath (Tindall, 1994).

Andrade *et al*. (2009) conducted a study with the objective of morphological characterization and grouping of rambutan plants. They evaluated the morphological characters like plant height, geometry, diameter, leaves and leaflet size, leaflet number, length of petiole, leaf area, leaflet colour *etc* and claimed that morphological descriptors can be efficiently used in determining the genetic divergence whereas visual distinction is not possible, because no outstanding characteristic exists.

The study conducted to characterize the rambutan plants using foliar aspects like leaf and leaflet size, leaflet area, number of leaflets, rachis length, leaflet colour *etc* concluded that there exists low genetic divergence between the plants studied and it is not possible to distinguish plants of the same sex based on the foliar aspects (Barreto *et al.*, 2015).

Flushing normally start soon after harvest on shoots which have already borne fruits. Lateral buds seen below the desiccated panicles give rise to flushes. About 57 per cent of the shoots produce flowers and fruits on previously non-bearing twigs, but only 22 per cent produce flowers on twigs which have borne fruits previously (van Welzen and Verheij, 1991). Vegetative flushing is stimulated by external environmental conditions like rainfall, heavy irrigation and practices such as pruning and harvest. Flushing will be reduced by cool weather in the presence of heavy rainfall. Hawaii experiences steady rainfall and warm temperatures, which allows rambutan trees to grow and flush year- round as a consequence of which terminal maturation is non-synchronous within the tree and is very difficult to acquire synchrony in flowering, fruit set, and harvest in orchard (Kawabata *et al.*, 2005).

2.1.2 Reproductive characters

Rambutan flowering is stimulated by water stress, and symptoms of water stress in trees can be observed when leaves curl inward along the margins. In Hawaii rambutan flowers twice a year during the months of March-May and July-August in response to two short periods of dry weather followed by occasional showers (Kawabata *et al.*, 2005). Two flowering periods can also occur in Malaysia from March-May and August-October depending on the prevailing climatic condition. The flowering and fruiting are observed to be a function of weather conditions and the status of the stored food reserves within the trees (Shaari *et al.*, 1983).

The inflorescences of rambutan are erect and widely branched with many flowers, and are produced mainly on shoot tips (Shaari *et al.*, 1983). Rambutan is

androdioecious with separate male and hermaphrodite trees. According to the flower characteristics rambutan trees are classified into three groups (Valmayor *et al.*, 1970): a) trees producing only staminate flowers (male trees), 40-60 per cent of any seedling population b) trees producing hermaphroditic flowers functioning as female (HF) and c) trees producing both hermaphroditic female (HF) and hermaphroditic male (HM) flowers, the most common type in cultivar selections.

Cultivars have been selected for their high percentage of HF flowers and low percentage of HM flowers. The percentage of HM flowers is as low as 0.05-0.90per cent of the total flowers (Almeyda *et al.*, 1979; Chin and Phoon, 1982; Tindall, 1994; Nakasone and Paull, 1998). On panicles having both HF and HM flowers, HM flowers usually open first and are found in highest frequency during the first three weeks of anthesis, but as anthesis progresses nearly all of the remaining flowers are HF flowers (Kawabata *et al.*, 2005).

Rambutan flowers open at all times of the day but the majority of them do so at about 6.30 am. Anthesis in hermaphrodite flower is indicated by recurving of the bifid stigma whereas that of male flower by parting of the calyx. Open flowers usually persist on panicles for 7-10 days, if insects are excluded. The greenish white stigma remains active for a day, becomes dull on the second, and thereafter turns from brown to black (Tindall, 1994).

Panicles of male trees take approximately 24-46 days to complete anthesis, which act only as pollenizer and do not produce fruit. Anthers of male flowers release pollen, disperse through insects and wind and pollinate trees bearing HF flowers. The HF flowers have an ovary and stigma, but their anthers do not dehisce to release the well developed pollen grains whereas HM anthers shed pollen during athesis. Thus the HM and true male flowers are the source of pollen grains for effective pollination and subsequent fruit set (Ravishankar and Sakthivel, 2014). Tindall (1994) recommended to plant one male tree for every ten trees for getting adequate fruit set in cultivars which lack staminate flowers.

Rambutan is a cross pollinated crop and depends on insects for pollination and fruit set (Free, 1993; Zee, 1993). Aromatic rambutan flowers are highly attractive to many insects like bees (*Apis spp* and *Trigona spp.*), butterflies, and flies (*Eristalis spp.* and *Lucilia spp.*) (Chin and Phoon, 1982;Lim, 1984). The study conducted at Central Horticultural Experiment Station (CHES), Chettali confirmed that stingless bee (*Trigona iridipennis*) and Indian honeybee (*Apis cerana indica*) were the most dominant foragers in rambutan with a mean visitation of 3.81 and 3.54/panicle/10 minutes. Other foragers included *A. florea*, *A. dorsata*, an unidentified wasp and calliphorid flies. Peak activity of all the pollinating insects to the flowers were between 10.00-11.00 am. Bagged flowers completely failed to set fruits while open pollinated panicles set about 29.35 fruits/panicle (Shivaramu *et al.*, 2012).

Uji (2015) found that the bees *Apis cerana indica*, *Trigona itama*, *T. nitidiventris*, *T. canifrons, T. iridipennis* and *T. atripes* are the potential pollinators of rambutan. Rincon-Rabanales *et al.* (2015) in their experiment in Mexico on the effect of bee pollination on the yield of rambutan. They claimed that fruit production increased nearly ten fold in both stingless bee species in open pollination treatments and within cages. A superior fruit yield, in weight and size, was also obtained from selfing mediated by pollinators in caged trees.

2.1.3 Yield studies in rambutan

Individual tree yields of rambutan in Thailand are from 20 kg at 3 years from planting to more than 400 kg at 21 years from planting (Watson, 1983; Laksmi *et al.*, 1987). 'Amarillo' the first yellow coloured rambutan of Philippine gives an economic yield of 50-60 kg/tree at 10 years from planting in one fruiting season (Magdalita and Valencia, 2009a) whereas the red and sweet cultivar 'Roja' bears 70-80 kg of marketable fruits per tree in one fruiting season (Magdalita and Valencia, 2009b)

Yield of eight rambutan cultivars namely Benjai, Gula Batu, Jitlee, R-134, R-156Y, R-162, R-167 and Rongrein grown at two locations (Corozal and Isabela)

in Puerto Rico was evaluated for five years by Goenaga and Jenkins (2011). The average productivity recorded was 13, 826 kg/ha and 5149 kg/ha at Corozal and Isabela respectively.

2.1.4 Fruit characters

Fruit development starts shortly after anthesis. Initial fruit set may reach 25 percent but a high level of abortion contributes to a much lower level of production at harvest (1-3per cent) (Tindall, 1994).

Although 2 ovaries are present on a female flower, one ovary aborts leaving the other to develop into a normal fruit. Rarely, both ovaries develop resulting in two fruits on the same peduncle. Growth of rambutan fruits is observed as a typical sigmoidal pattern. Seed filling begins 8-10 weeks after anthesis, and aril development occurs 10-12 weeks after anthesis. Dry weather during this period will result in under-sized fruits. During the last few weeks before harvest, fruit colour intensifies and total soluble solids concentration increase (Kawabata *et al.*, 2005). Fruits normally ripen in about 110 days from flowering (16 weeks after anthesis). Rambutan is a non-climacteric fruit where both maturity and ripening coincides, hence harvesting must be done at the peak of ripeness for overall colour, texture and flavour appeal.

Rambutan fruits are produced in bunches, fruit shape varies from roundish to oval, 5-8 cm long, 4-6 cm wide, pericarp soft with many abundant hairy growths, which change colour from green to red (Kothagoda and Rao, 2012). Rambutan fruits are green when immature and eventually turn red or yellow which is cultivar dependent (van Welzen and Verheij, 1991). The hairy pericarp can be easily removed exposing the white to cream coloured edible pulp that surrounds the big central seed which may either stick to the seed or is detachable and tastes from sour to sweet (Kothagoda and Rao, 2012).

2.1.5 Quality parameters

Magdalita and Valencia (2004) found a wide variability for fruit weight, fruit length, total soluble solids (TSS), aril percentage and seed weight among 100

strains of rambutan evaluated for phenotypic characteristics in Philippine. The studies conducted by Vanderlinden *et al.* (2004) revealed that fruit weight, spintern appearance and colour, as well as fruit diameter and aril to fruit weight are the indicators for identifying fruit quality which are modified by environment and management practices.

Hiranpradit *et al.* (1992) set up quality standardisation of two commercial varieties of Thai rambutan, namely Rong-rien (RR) and See-chompoo (SC). They found that fruit size (width, length, thickness), rind weight and thickness, aril weight and thickness and seed weight are highly correlated with fruit weight whereas aril colour, flavour and texture are not correlated with fruit weight. They categorized the quality standardisation of RR and SC in to Extra, Class I and Class II. In case of RR, in Extra class the number of fruit specified per kilogram is <25, in Class I is 25-28 and in Class II it is <32, while in case of SC cultivar <28 includes Extra class, 28-32 in Class I and <36 in Class II. Further, all classes should satisfy certain basic requirements such as a) fresh appearance, clean and practically free from marked bruising, disease and insect damage. b) shape, smell and taste must be typical to the nature of the produce. c) general characteristics must be typical to the cultivar and d) the produce must be sufficiently developed and stay in satisfactory condition at the place of destination.

The rambutan tree bears ovoid fruits, that has dark red to yellow coloured pericarp covered with soft spinterns on its exterior, that vary in colour from green to yellow and red and internal fleshy aril. The fruit weight varies from 20 to 60 g, with 40-60per cent pericarp, 30-58per cent aril and 4-9per cent seed. The edible aril is white or translucent, sweet and juicy and clings to the testa of seed (Nakasone and Paul, 1998; Smith *et al.*, 1992; Wall, 2006; Sacramento *et al.*, 2013).

For export, the fruits of rambutan should satisfy the following quality specifications: uniform red colour, free from lesions, pests and diseases, clean, weight above 30 g, spines no longer than 1 cm, thick firm aril with very poor adherence to seed, and total soluble solid content of 16 to 18° Brix (Landrigan *et al.*, 1996; Kader, 2001). The fundamental attributes of fruit quality from the

consumer point of view are its visual aspects such as appearance, size, colour, texture, firmness and absence of defects, flavour, juiciness, poor attachment of aril to seed and nutrient content (Kader, 2001). According to Codex Standard (Codex Stan 246-2005), a size code of 1 is given for fruits weighing above 43g. The superior quality rambutan fruits are classified in the category 'extra', good quality fruits with some defects in Class I and fruits satisfying only minimum requirements in Class II (Codex Alimentarious, 2008).

Amarillo is the first Philippine yellow variety of rambutan with oblong shaped fruits, weighs 18.38 g and measures 52.65 mm long and 36.89 mm wide. The skin and spines are thick and leathery. The flesh is white, juicy, smooth, easily detachable from the seed and very sweet with a TSS of 22.35° Brix. The fruit has a relatively large edible portion (60.7per cent) and oblong seed which measures 25.40 mm long, 14.60 mm wide and 5.70 mm thick (Magdalita and Valencia, 2009).

Wall *et al.* (2006) estimated the ascorbic acid and mineral composition of rambutan cultivars grown in Hawaii. Average ascorbic acid content was 22.047 mg/100 g for the cultivars tested. There was no correlation between ascorbic acid and total soluble solids content. The rambutan fruit had 20per cent of the daily recommended intake (DRI) for Cu and 8-10per cent of the DRI for Mn.

2.1.6 Postharvest management and value addition

As a consequence of rapid desiccation and browning of the spinterns, rambutan fruit lose visual quality rapidly. Browning of the spinterns usually occurs within 4-5 days after harvest at ambient temperature and relative humidity (Landrigan *et al.*, 1994). Browning of the rind and spinterns are the major factors affecting the shelf life of rambutan which result in weight loss during storage and transportation. The major cause of browning is water loss (Landrigan *et al.*, 1996; Nathiwatthana, 1981; Mendoza *et al.*, 1972; Wells and Bagshaw, 1989).

The work of Landrigan *et al.* (1996a) confirmed that tissue browning in rambutan was preceded by water loss and associated decline in water potential of rind and spinterns. Decrease in weight and water potential of the rind were strongly

correlated with both rind and spinterns browning. Spintern browning was more strongly correlated with weight loss than rind browning. They observed a substantial weight loss of about 23per cent after the first 4 days of storage which increased to 35per cent on the eighth day of storage. Finally they concluded that a loss of membrane permeability due to plasmolysis allowed the browning processes to proceed. In both rind and spinterns vascular bundles are connected. Vascular bundles are also found close to the aril below the peel surface. Water moves from the rind to the tips of the spinterns and transpires through the stomata seen on the rind and spinterns which is influenced by the density of stomata. The rate of water loss from rambutan fruits is greatly affected by the stomatal density rather than the number and length of spinterns ((Yingsanga *et al.*, 2006).

The effect of relative humidity, mechanical damage and enzymatic action on rambutan fruits was studied by Landrigan *et al.* (1996b). Browning was significantly increased when fruits were stored at low RH irrespective of infiltration with enzyme inhibitors whereas browning was reduced significantly when infiltrated with enzyme inhibitors and stored at high RH compared to infiltration with water. Irrespective of infiltration, mechanical damage significantly increased browing processes. Browning in mechanically damaged fruits was reduced when infiltrated with enzyme inhibitors compared to infiltration with water. These observations led to the inference that enzymes were involved in browning damaged fruits under high RH and enzymes were ineffective at low RH as desiccation was the major cause of browning.

Fruits of three rambutan cultivars namely R162, Jit Lee and R156 were stored for 25 days at 0 to 20°C. Maximum shelf life of 15 days was observed for R162 all the three cultivars when stored at 7.5°C, 13 days for Jit Lee at 10°C and 11-12 days for R156 at 10°C under normal atmosphere. Chilling injury was noticed which was characterized by a dark-maroon colouration of the rind in red cultivars (R162 and Jit Lee) and bronzing in yellow cultivar R156. Cultivar R162 was observed to be more chill-tolerant than other cultivars. Shelf life of R162 was

extended by 4-5 days with decreased rate of colour loss when stored under enhanced carbon dioxide (9-12per cent) (O'Hare *et al.*, 1994a; O'Hare, 1995).

The effect of modified atmosphere on chilling injury and storage life of 'Rongrien' rambutan was investigated by Ketsa *et al.* (1995). Fruits of 'Rongrien' were sealed in polyethylene bags with 0, 1, 2 or 3 ventilation pores and stored at 10 and 12°C. Chilling injury appeared more rapidly at 10°C. Longest storage life of 18 days was obtained when fruits were stored at 12°C and sealed in bags with one ventilation pore. Storage life of 5 and 8 days was observed when unpacked fruits were stored at 10 and 12°C respectively.

Kanlayanarat *et al.* (2000) packed Rongrien rambutans in 0.01, 0.04 and 0.08 mm thick polyethylene (PE) films and stored at 13°C and 95-100per cent RH. The atmospheric compositions developed in the sealed bags were 15-16per cent O_2 and 2-3per cent CO_2 in 0.01 mm PE bags, 3-5per cent O_2 and 10-11per cent CO_2 in 0.04 mm, and 1-2per cent O_2 and 15-16per cent CO_2 in 0.08mm PE bags. Maximum storage life of 18 days was observed when fruits were packed with 0.01 and 0.04 mm thick PE bags compared with 16 days in fruits stored in 0.08 mm thick PE bags and 12 days in controls.

Boonyaritthongchai *et al.* (2003) studied the influence of controlled atmospheric storage on the quality of 'Rongrein' rambutan fruits. Fruits lasted for only 6 days at 20°C and 10 days at 13°C under normal atmosphere (0.03per cent CO_2). Under 10per cent CO_2 at 13°C storage life prolonged to 18 days with reduced rates of browning, weight loss, respiration and ethylene production. Quality of the fruits including total soluble solids, titratable acidity and ascorbic acid contents was not adversely affected in this controlled atmospheric storage.

Wongs-Aree and Kanlayanarat (2005) conducted an experiment to study the effect of $CaCl_2$ applications on storage quality of rambutan. Rambutan fruits were dipped in 0, 0.1, 1 and 4 per cent $CaCl_2$ for 5 min and then stored at 13°C at a RH of 90-95per cent. They concluded that applications of low concentrations of $CaCl_2$ can give a storage life of 10 days whereas at higher concentrations (4per cent)

browning of spinterns occur within 4 days of application. They also found that the application of $CaCl_2$ will retard the growth of many pathogens such as *Colletotrichum* sp., *Gliocephalotrichum* sp., and *Botryodiplodia* sp.

Siriphollakul *et al.* (2006) reported the use of antitranspirants in rambutan for maintaining freshness and improving shelf life. Use of antitranspirants such as abscisic acid (ABA) and salicylic acid (SA) delayed pericarp browning and thus prolonged the fruit shelf life. Antitranspirants reduced the rates of respiration, losses in ascorbic acid and titratable acids, and increase in soluble solids. They recommended the use of ABA at 10 µM or SA at 0.5 µl $litre^{-1}$ as an effective treatment to prolong the shelf life of rambutan fruits.

Shelf life of rambutan fruits increased from 4-6 days in the normal condition to 10-14 days in hydrocooled fruits. Hydrocooled fruits were charcacterized by reduced pericarp browning as compared to non-hydrocooled fruits. Greatest reduction in browning was observed at a water temperature of 10° C while lower water temperatures induced chilling injury shown as increases surface discoloration. Hydrocooling not only maintained the quality of fruits by delaying soluble solids increase and reducing titratable acid and ascorbic acid loss but also retarded the respiration rates (Nampan *et al.*, 2006).

According to YuanZhi *et al.* (2013) rambutan fruits packed with anti-moisture polyethylene and stored at 10°C were the most appropriate strategies to prolong the shelf life and to maintain the quality. Rambutan fruits packed with frozen gel maintained the freshness with minimal colour and weight loss as compared to the fruits packed without frozen gel (Latifah *et al.*, 2013).

The study conducted by Yingsanga *et al.* (2015) on storage quality of spinterned and non-spinterned 'Rongrein' rambutan concluded that shelf life and fruit quality changes of rambutan during storage were not affected by their spinterns. Compared to spinterned rambutan fruits non-spinterned fruits might be advantageous to extend the storage life by coating treatment and to improve postharvest management.

Rambutan fruit is primarily valued as fresh fruit for dessert. Fruits meant for export are preserved by canning in syrup. The roots, leaves and bark has many medicinal properties as they are used as poultice, astringent for treating tongue diseases and as decoction for treating fever (Coronel, 1986).

Consumer acceptance of rambutan pulpy juice was investigated by Sukasih and Setyadjit (2015). Pulpy juice rambutan with addition of both rambutan and citrus pulp were the most preferred juice by the panellist.

Thitilertdecha *et al.* (2008) noted that rambutan rind and seed possess both antioxidant and antibacterial activities. Antioxidant property of rambutan rind was revealed by Palaniswamy *et al.* (2008) as it has no pro-oxidant activity induced by transition metals, unlike ascorbic acid at higher concentrations. The ethanoloic extract of rambutan rind possesses high free radical scavenging activity which is much higher than that of grape seed and comparable with that of ascorbic acid and it is having 30per cent superoxide-scavenging ability. The phenolic content of ethanolic rind extract ranges from 762-822 mg/g GAE and it does not contain compounds that are cytotoxic to normal cells. The predominant bioactive compound in rambutan rind is geraniin. The rambutan rind extract appears to have the potential to inhibit the carbohydrate hydrolysing enzymes α-glucosidase and α-amylase in addition to the ability to control the development of diabetic complications by suppressing aldose reductase activity and the formation of advanced glycation end products. All these properties make rambutan rind extract a potential drug in the management of type 2 diabetes (Gorinstein *et al.*, 2010; Ruffino *et al.*, 2010; Palaniswamy *et al.*, 2011).

The extracted rambutan seed fat could be exploited in the manufacture of candles, soaps and fuels as well as a source of natural edible fat. Rambutan seed fat would be useful as a softer filling fat compatible with cocoa butter in chocolate manufacture (Lannes *et al.*, 2003; Issara *et al.*, 2014).

2.1.7 Pests, diseases and physiological disorders

2.1.7.1 Pests of rambutan

Although there are no reports on incidence of severe pest and disease attack but several problems are being monitored which can probably become a threat in the future. The incidence of pests like mealy bug (*Planococcus citri*), red borer (*Zeuzera sp.*), bostrichid beetle (*Sinoxylon sp.*) and fruit fly (*Bactrocera dorsalis* and *B. caryeaea*) have been reported from different rambutan growing tracts of South India (Mala *et al.*, 2015).

Osman and Chettanchitara (1987) have listed out seven insect pests of economic importance in other Asiatic countries: leaf minor (*Acrocercops cramerella*), armoured scale (*Phenacaspis* sp.), citrus mealy bug (*Planococcus citri*), yellow peach moth (*Conogethes punctiferalis*), oriental fruit fly (*Bactrocera dorsalis*) and driedfruit beetles (*Carpophilus dimidiatus*). Watson (1988) has reported banana spotting bug (*Amblypelia lutescens*), mealy bugs and mites as contributing to skin deterioration and discolouration in Australia.

2.1.7.2 Diseases of rambutan

Fungal pathogens of rambutan also affect both quality and quantity of the produce. The major diseases of rambutan are powdery mildew (*Oidium nephelii*) on young growth, pink disease (*Erythricium salmonicolor*) and sooty mould (*Meliola nephelii* var. *singalensis*). Postharvest diseases include various fruit rots (*Colletotrichum gloeosporioides*, *Gliocephalotrichum* sp., *Greeneria* sp., *Pestalotiopsis* sp., *Phomopsis* sp., *Dothiorella* sp.) (Keith *et al*,, 2011).

Farungsang *et al.* (1991) isolated *Pestalotiopsis* sp., *Phomopsis* sp., *Colletotrichum gloeosporioides and Glomerella* sp. as the pathogens causing fruit rots in Thailand. Also *Botryodiplodia theobromae, Gliocephalotrichum bulbilium* and *Colletotrichum* sp. reported as the three major causes of postharvest disease in Thailand (Chayasombat and Sangchote, 1983; Visarathanonth and Ilag, 1987). Sivakumar *et al.* (1997) identified anthracnose (*Colletotrichum gloeosporioides*), stem-end rot (*Botryodiplodia theobromae*) and brown spot (*Gliocephalotrichum*

michrochlamydosporum) as the common postharvest diseases in Malwana special selection 1, Malaysian yellow and Malaysian red cultivars of rambutan.

O'Hare *et al.* (1994b) reported the incidence of *Colletotrichum* sp., *Dothiorella dominicana, Fusarium* sp., *Penicillium* sp., *Pestalotiopsis* sp., *and Phoma* sp. in rambutan fruits stored at 0-20°C from Australia. In Malysia, Lam (1982) identified the yeast *Candida* sp. as the cause of pulp fermentation in rambutan fruits stored at 20°C.

2.1.7.3 Physiological disorders of rambutan

Physiological disorders like fruit cracking or fruit splitting in thin skinned cultivars like 'Rongrien', poor filling of fruit due to low adaptability of fruit to dry conditions (Lam and Tongumpai, 1987) and premature seed germination inside mature fruit associated with subsequent aril softening and flavour loss (Kosiyachinda and Salma, 1987) *etc* have been reported in rambutan.

Sudden uptake of water during the last stages of fruit development or heavy rains cause the aril to expand at a faster rate than the rind which in turn results in rind rupture (Lam and Tongumpai, 1987). Khadivi-Khub *et al.* (2015) reviewed the genetic, morphological, environmental and physiological aspects of fruit splitting. Cracking susceptibility varies with cultivars under the same environmental conditions. Fruit splitting is correlated with fruit traits such as fruit shape, fruit size, fruit firmness, anatomy and strength of the fruit skin, stomata in fruit skin, cuticular properties, osmotic concentration, water capacity of the fruit pulp and growth stages of the fruit. In addition, management practices such as irrigation and manuring and environmental factors such as temperature, wind and light will influence fruit splitting.

Materials and methods

3. MATERIALS AND METHODS

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The study pertaining to 'Variability studies in rambutan (*Nephelium lappaceum* L.)' was carried out from December 2014 to April 2016 in order to select the elite/promising types and to conserve the identified promising types to serve as a basis for promotion of cultivation of this exotic fruit in Kerala. The materials used and methodology adopted in this study are presented in this chapter.

3.1 Experimental site

The study was conducted in the major rambutan growing tracts of Kerala namely Pathanamthitta, Kottayam and Thrissur and a minor area in the plains of Idukki (Fig. 1). A preliminary survey was conducted in these tracts in consultation with Agricultural Officers of the concerned areas to locate the variable rambutan trees. The methodology adopted was purposive sampling. A total of 100 variable types of rambutan were located from these four districts (Pathanamthitta-40, Kottayam-37, Thrissur-18, Idukki-5). These 100 collections include 13 seedling progenies of rambutan maintained in the orchard of Dept. of Pomology and Floriculture, College of Horticulture, KAU, Vellanikkara, Trichur. Among these collections 86 trees were of seedling origin (natural types) and 14 trees were budded plants. All the collections were of productive and steady bearing nature except Col.003 and Col.011 which were male trees.

3.1.1 Location

The important rambutan growing areas of Kerala fall in four districts. Thrissur district lies at 10°53' N latitude, 76°2'E longitude and at an altitude of 2.83 m above mean sea level, Kottayam at a latitude of 9°59' N, longitude of 76°52'E and at an altitude of 3 m above mean sea level, Idukki at 9°89' N latitude, 76°72' E longitude and 40 m above mean sea level and Pathanamthitta at 9°26' N latitude, 76°78' E longitude and at an altitude of 31m above mean sea level.

3.1.2 Climate

All the areas enjoy the typical warm humid tropical climate of Kerala. The meteorological data during the period of study are given in Appendix I.

Fig. 1. Major rambutan growing tracts of Kerala

3.2 Morphological characterization

Growth characters, leaf characters, inflorescence characters, fruit characters and seed characters were recorded as per standard descriptors prescribed by IPGRI (2003).

3.2.1 Growth characters

3.2.1.1 Tree age (y)

Approximate age of the tree was noted in consultation with the respective growers and from the basic records maintained at the college.

3.2.1.2 Planting material

Information on the origin of each tree were collected to know whether the collection was of seedling origin or a buddling.

3.2.1.3 Trunk surface

Smoothness of trunk was observed and classified into three groups namely smooth, rough and very rough.

3.2.1.4 Crown shape

Crown shape of all the collections was observed and grouped into four categories namely oblong, broadly pyramidal, semicircular and spherical.

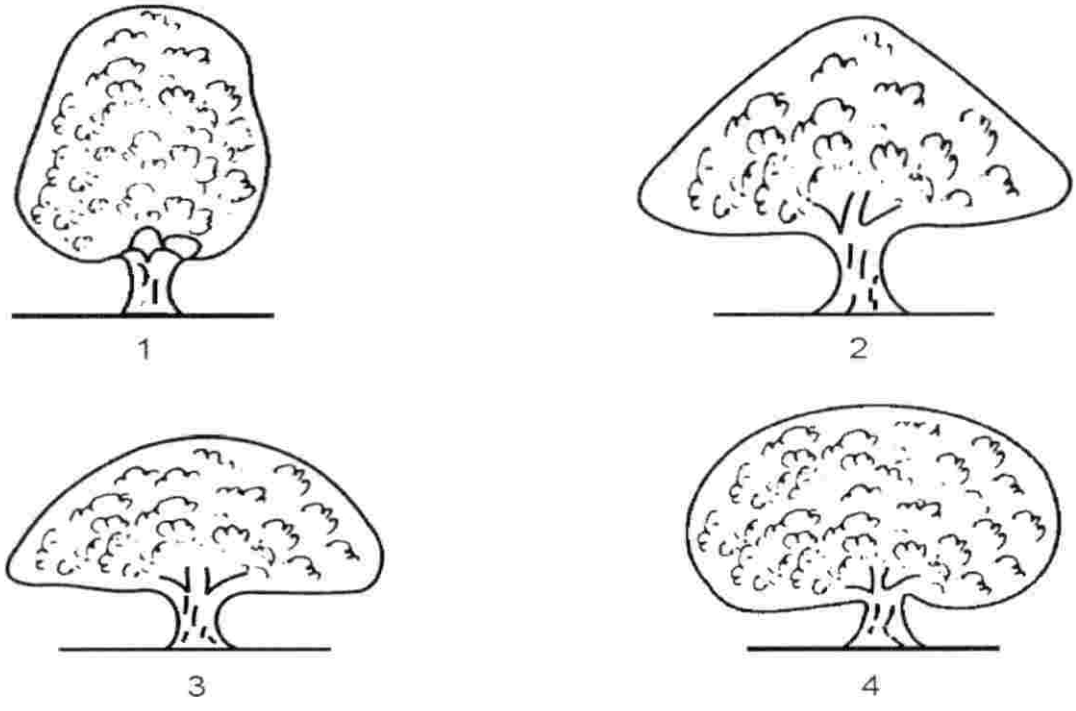

Fig. 2. Crown shape: (1)Oblong, (2)Broadly pyramidal, (3)Semicircular, (4)Spherical

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3.2.1.5 Branching pattern

Branching pattern of trees were noted and classified into three groups namely upright, horizontal and irregular.

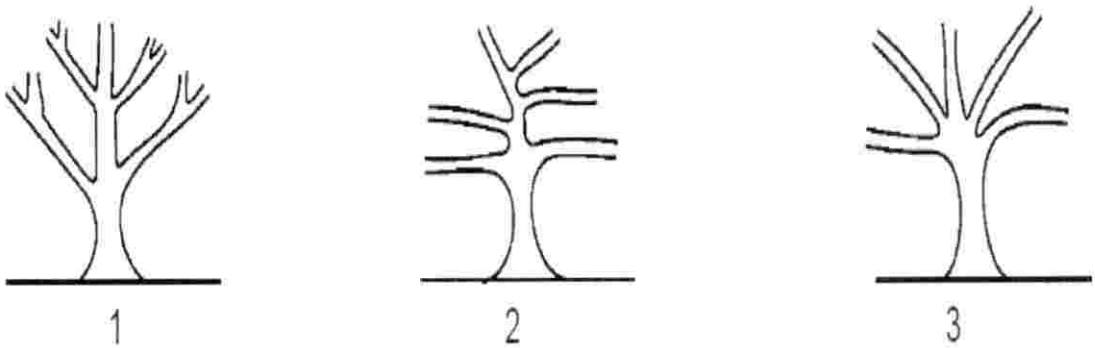

Fig. 3. Branching pattern: (1)Upright, (2)Horizontal and (3)Irregular

3.2.1.6 Young shoot pubescence

Young shoots of trees were observed to check whether it is pubescent or not.

3.2.2 Leaf characters

Quantitative leaf characters were recorded as the average of 20 fully expanded representative leaves, collected when shoots are lignified and for qualitative characteristics the predominant first pair of leaflets from terminal leaflet was used.

3.2.2.1 Leaf colour

Leaf colour was evaluated at mature stage on the adaxial side and were grouped into light green, green and dark green.

3.2.2.2 Number of leaflets per leaf

Average number of leaflets from 20 fully expanded representative leaves was recorded.

3.2.2.3 Rachis length

Length from stem to last leaflet was recorded and expressed in centimetre (cm).

3.2.2.4 Length of petiole

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Length from the rachis to the base of the leaflet was recorded and expressed in millimetre (mm).

3.2.2.5 Leaflet length

Average of 20 fully expanded representative leaves were measured from the base to the tip of the leaf blade and expressed in centimetre (cm).

3.2.2.6 Leaflet width

Average of the same 20 fully expanded leaves were used for the measurement of leaf length and it was measured at the widest point and expressed in centimetre (cm).

3.2.2.7 Leaflet shape

Shape of the leaf was determined and classified into three groups namely obovate, elliptic and lanceolate.

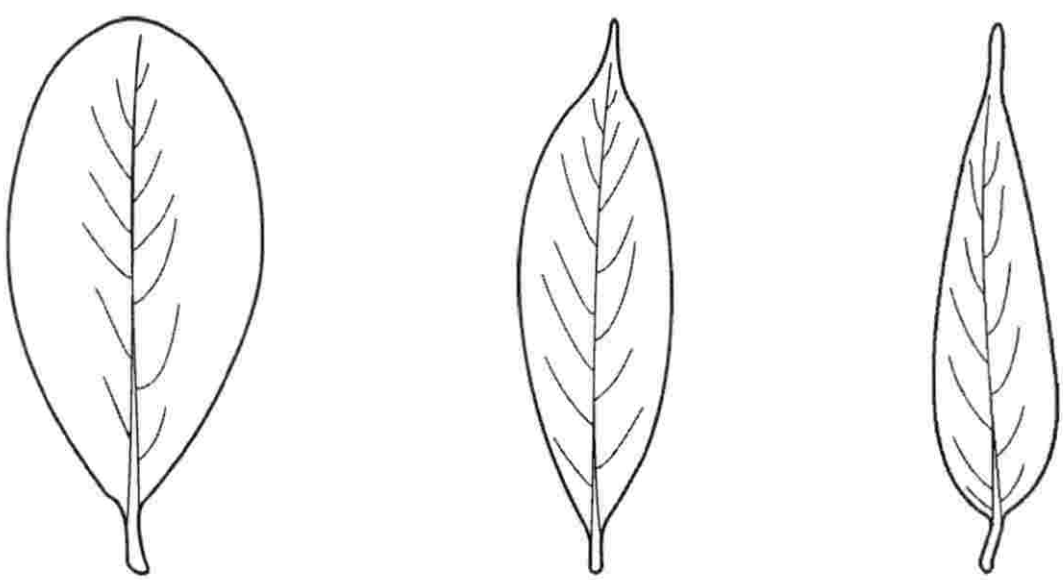

Fig. 4. Leaflet shape: (1)Obovate, (2)Elliptic and (3)Lanceolate

3.2.2.8 Leaflet surface

Surface of leaflet was observed and categorized as either smooth or pubescent.

3.2.3 Inflorescence characters

Inflorescence characters were recorded as the average of at least ten panicles from each collections at bloom period.

3.2.3.1 Flowering season

Flowering season was recorded as month from start to end of flowering.

3.2.3.2 Flower composition

Inflorescences were observed with the help of hand lens and presence of HFF (hermaphrodite flowers functioning as female), HFM (hermaphrodite flowers functioning as male), TM (true male flowers), both HFFand HFM in same panicle and panicle with all type of flowers (HFF, HFM and TM) were observed.

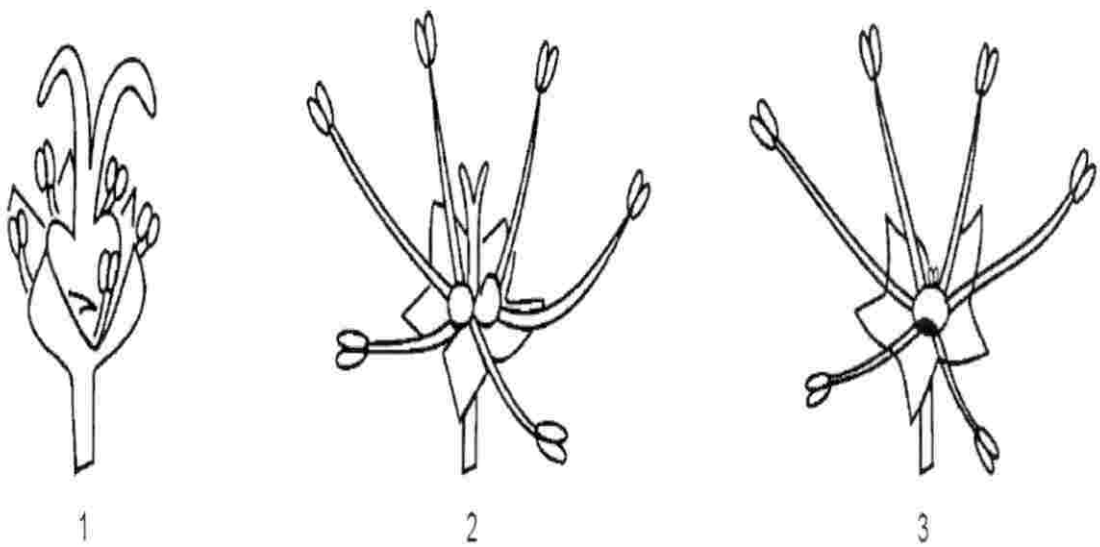

Fig. 5. Flower composition in inflorescence: (1)HFF, (2)HFM and (3)TM

3.2.3.3 Position of inflorescence

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Position of inflorescence was noted and grouped as terminal, axillary and both terminal and axillary.

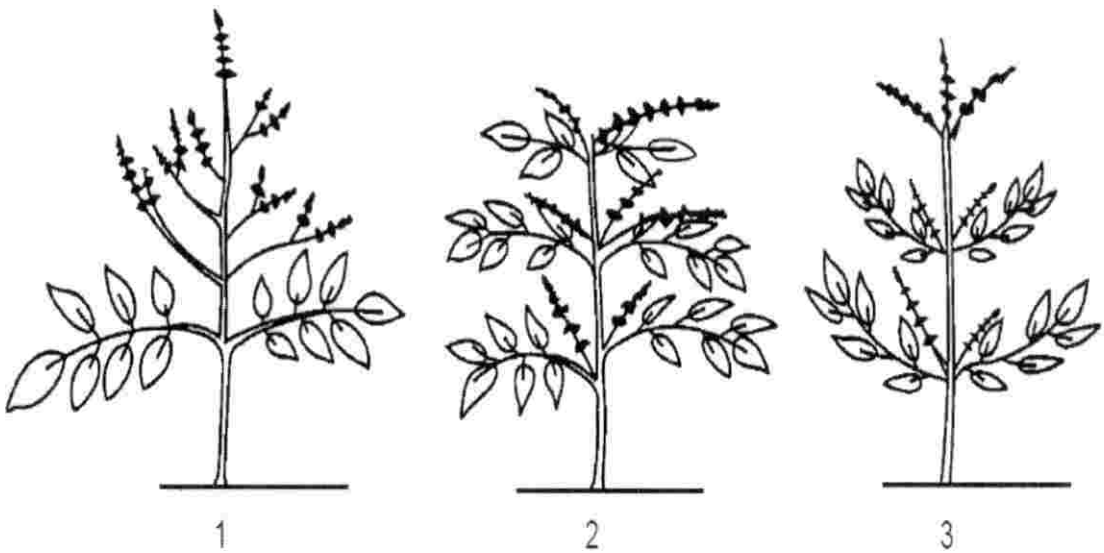

Fig. 6. Position of inflorescence: (1) Terminal, (2)Axillary and (3)Both terminal and axillary

3.2.3.4 Shape of inflorescence

Shape of inflorescence was observed and classified into three groups namely pyramidal, conical and obtriangular.

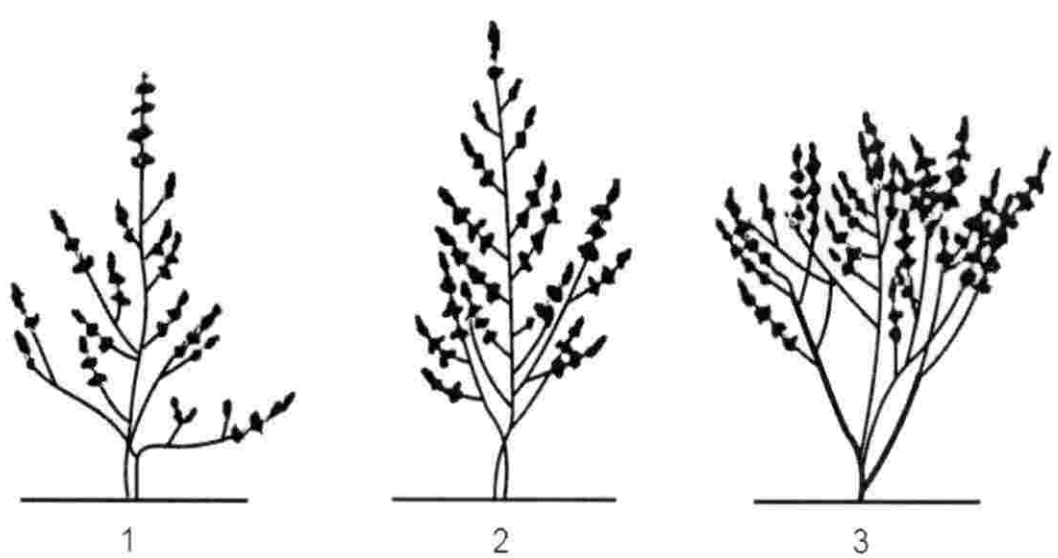

Fig. 7. Shape of inflorescence: (1)Pyramidal, (2)Conical and (3)Obtriangular

3.2.3.5 Inflorescence colour

Colour of inflorescence was noted and grouped as either light green or green.

3.2.4 Fruit characters

Fruits were harvested from the different growing tracts from May, 2015 to September, 2015 coinciding with the ripening stage and were immediately observed for all morphological and biochemical characters in the laboratory of Dept. of Pomology and Floriculture, College of Horticulture, Kerala Agricultural University. All the characters were recorded as average of 20 well ripened fruits.

3.2.4.1 Fruiting season

The fruiting season was recorded as month from start to end of harvesting period in case of each collection.

3.2.4.2 Percentage fruit set

Fruit set was recorded the percentage of flowers that set fruits and mean of ten bunches was calculated

3.2.4.3 Length of fruit bunch

Fruit bunch length was recorded as the length from base of the bunch to tip of the bunch and expressed in centimetre (cm) as mean of length of ten bunches.

3.2.4.4 Number of fruits per bunch

The fruit number was recorded as the number of fruits per cluster/inflorescence and mean of 10 clusters was worked out.

3.2.4.5 Fruit shape

Shape of the fruit was recorded in each collection and grouped into three categories namely globose, ovoid and oblong.

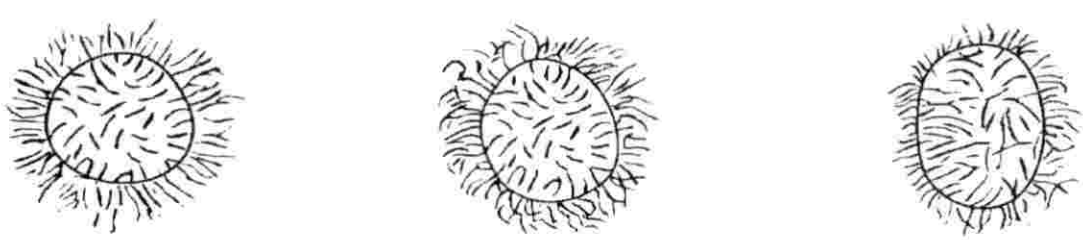

Fig. 8. Fruit shape: (1)Globose, (2)Ovoid and (3)Oblong

3.2.4.6 Fruit length

The length of fruit was measured using Vernier caliper as an average of 20 randomly selected fruits and expressed in centimetre (cm).

3.2.4.7 Fruit diameter

The diameter of the fruit was measured at the widest point of the fruit using Vernier caliper and expressed in centimetre (cm) as the average of 20 fruits.

3.2.4.8 Fruit weight

Twenty mature fruits of variable sizes from each collection were randomly collected to find out the mean weight of fruits. The weight was taken by using a standard electronic balance and expressed in gram (g).

3.2.4.9 Rind colour

Rind colour was observed at the time of fruit maturity and described with the help of Universal Colour Language (UCL) defined by the Inter-society Colour Council, National Bureau of Standards in 1946.

3.2.4.10 Rind thickness (mm)

Rind thickness was measured using Vernier caliper and expressed in millimetre (mm).

3.2.4.11 Rind weight (g)

Weight of the rind was recorded with the help of an electronic balance and expressed in gram (g).

3.2.4.12 Spine length (cm)

Spine length of ten well developed spines selected randomly was measured and expressed as mean length in centimetre (cm).

3.2.4.13 Spine texture

The texture of spine was observed and classified as either soft or stiff.

3.2.4.14 Spine density

The spine density was observed as the number occurring in a 2cm x 2cm area.

3.2.4.15 Spine colour

Spine colour was visually identified and classified into different colour groups namely red, red spine with light green tip, yellow, light green spine with pink base and pink spine with light green tip.

3.2.4.16 Aril weight (g)

The aril of ten mature fruits randomly collected from each collection were taken to find out the mean weight of aril using an electrical balance and expressed in gram (g).

3.2.4.17 Aril colour

Aril colour was visually identified at the fully matured stage and classified into three categories namely white, dull white and creamy white.

3.2.4.18 Aril thickness (mm)

Aril thickness was measured using a Vernier caliper and expressed in millimetre (mm).

3.2.4.19 Aril texture

Aril texture was described at the fully matured stage into soft, firm and crispy.

3.2.4.20 Aril taste

Based on the aril taste the fruits were grouped into different categories such as insipid, acid, acid sweet and sweet.

3.2.4.21 Aril juiciness

Aril juiciness was classified as not juicy, juicy and very juicy types.

3.2.4.22 Attachment of aril to seed

The adherence of aril to seed was observed and classified into poor, medium, good and very good.

3.2.4.23 Aril to fruit ratio

Ratio of aril weight to fruit weight was worked out by weighing each part separately and the same was recorded for all the collections.

3.2.4.24 Shelf life

Number of days the fruit remains in good palatable condition with the natural colour being retained *ie*, start of peel browning under ambient condition.

3.2.5 Seed characters

3.2.5.1 Seed length

Twenty seeds from the mature fruits of each collection were taken to find out the mean length of seed using an electrical balance and expressed in centimetre (cm).

3.2.5.2 Seed width

Twenty seeds from the mature fruits of each collection were taken and width was measured at the widest point from which the mean width was worked out and expressed in centimetre (cm).

3.2.5.3 Seed weight

Twenty seeds from the mature fruits of each collection were taken to find out the mean weight of seed with electrical balance and expressed in gram (g).

3.2.5.4 Seed shape

Shape of seed was observed and classified into four groups namely roundish, obovoid, obovoid elongated and oblong.

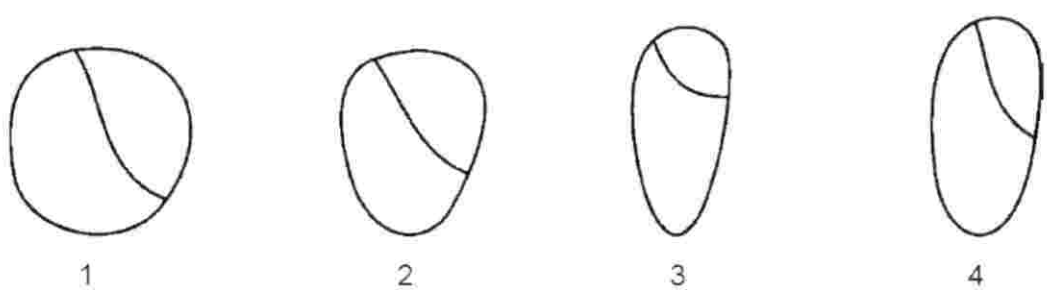

Fig. 8 Seed shape: (1)Roundish, (2)Obovoid, (3)Obovoid elongated and (4)Oblong

3.2.5.5 Seed coat colour

Seed coat colour was observed and classified into five groups namely off-white, creamish, dull brown, brown and dark brown.

3.2.5.6 Seed to fruit ratio

Ratio of seed weight to fruit weight was recorded by weighing each part separately in all collections.

3.2.5.7 Seed to aril ratio

Ratio of seed weight to aril weight was recorded by weighing each part separately in all collections.

3.3 Biochemical analysis

3.3.1 Total soluble solids (TSS)

TSS of fruit aril was recorded directly using a digital hand refractometer having range 0-32°brix and expressed in degree brix (^{0} Brix).

3.3.2 Titratable acidity

The titratable acidity was estimated according to AOAC (1998) by titrating a known weight/volume of the sample against 0.1N NaOH solution using phenolphthalein as an indicator for all the samples. The acidity was calculated and expressed as per cent citric acid.

3.3.3 Reducing sugar

The reducing sugar was determined by adopting the method given by Lane and Eynon (Ranganna, 1997). The rambutan aril was crushed in a grinder and filtered through No.4 Whatman paper. An aliquot of 25 ml filtered juice was then transferred to a 250 ml volumetric flask, mixed with distilled water and neutralized with NaOH. Solution was clarified with neutral lead acetate. The excess lead acetate was removed by adding potassium oxalate and volume was made up to 250 ml.The solution was filtered and an aliquot of the filtrate was titrated against a mixture of Fehling's solution A and B (5 ml each) using methylene blue as indicator and the reducing sugar was expressed as percentage using the following formula.

$$\text{Reducing sugars (\%)} = \frac{0.05 \times \text{Volume made up} \times 100}{\text{Titre value} \times \text{weight of the sample}}$$

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3.3.4 Total sugar

The total sugar was estimated as per the procedure described by Ranganna (1997). 50 ml of the clarified solution (filtrate of reducing sugars) was boiled gently after adding citric acid and water. It was neutralized using NaOH and the volume made up to 250 ml. This made up solution was titrated against a mixture of Fehling's solution A and B. The total sugar was calculated as given below.

$$\text{Total sugars (\%)} = \frac{\text{Titre value} \times 0.1 \times \text{Volume made up} \times 0.064 \times 100}{\text{Volume of the sample} \times \text{Weight of the sample}}$$

3.3.5 Non-reducing sugar

Percentage non reducing sugar was estimated by deducting reducing sugars from total sugars (% total sugars - % reducing sugars).

3.3.6 Total carotenoids

For estimating the total carotenoids (mg/100g) acetone and petroleum ether were used as extracting solvents and absorbance was read at 452 nm (Ranganna, 1997). For this a known weight of fruit juice sample was taken in a separating funnel. Then 10-15 ml of petroleum ether and water containing 5 per cent anhydrous sodium sulphate were added. Extraction of acetone phase was repeated with small volume of petroleum ether until no more colour was extracted. A small amount of anhydrous sodium sulphate was added to absorb the excess water and volume was made up with elutent (3% acetone in petroleum ether). The colour was measured at 452 nm with the elutent as blank using a spectrophotometer. Total carotenoids content was calculated as given below and expressed in mg/100g of material.

$$\text{Total carotenoids (mg/100g)} = \frac{3.857 \times \text{optical density} \times \text{volume made up}}{\text{Weight of the sample}} \times 100$$

3.3.7 Ascorbic acid (mg/100g)

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The estimation of ascorbic acid was carried out by the standard procedure described by AOAC (1998). A known weight of fruit sample was titrated with 2, 6-dichlorophenol indophenol dye, using metaphosphoric acid as stabilizing agent.

A known weight of juice of each collection was taken in 100ml volumetric flask, followed by adding 3 per cent metaphosphoric acid to make up the volume. From this, 10 ml of aliquot was titrated against 2, 6-dichlorophenol indophenol dye. The dye factor was calculated by titrating standard ascorbic acid solution against the dye and ascorbic acid content of sample was calculated using the following formula.

$$\text{Ascorbic acid (mg/100g)} = \frac{\text{Titre value x dye factor x volume made up x 100}}{\text{Weight of sample x aliquot of sample}}$$

3.4 Sensory evaluation

Score card including the quality attributes like appearance, colour, flavour, taste, texture, juiciness, adherence of aril to seed and overall acceptability was prepared for sensory evaluation of the fruits. Each quality attribute was scored by using a 9 point hedonic scale which ranged from dislike extremely (1) to like extremely (9) as suggested by Amerine *et al.* (1965). The score card used is attached as Appendix II.

A series of sensory evaluation was carried out using the 9 point hedonic scale rating for each attribute at laboratory level by a panel of ten judges between the age group of 18-40 years as suggested by Jellinek (1985). A score of 5.5 and above was considered as acceptable. Total score was also calculated separately using the average of each attribute. Hedonic ratings were then converted to rank scores and rank analysis was done by Kendall's coefficient of concordance.

3.5 Major pests and diseases incidence

Observations on pests, diseases and physiological disorders of all the collections were taken from December, 2014 to October, 2015. Pests were reared in the laboratory for identification of their taxonomic position. The percentage pest/disease incidence were found using the formula given by Berger (1980) as under:

$$\text{Per cent disease/pest incidence} = \frac{\text{Number of disease/pest infected tress} \times 100}{\text{Total no. of trees observed}}$$

3.6 Statistical analysis

Statistical analysis was performed by using the tools such as correlation studies, path coefficient analysis, cluster analysis and principal component analysis.

3.6.1 Correlation studies

The association among qualitative characters was studied by using Spearman coefficient (non-parametric) whereas that of quantitative variables was explained by using Pearson coefficient (parametric) which provided the information on the nature and relationship among the various traits.

3.6.2 Path coefficient analysis

In path coefficient analysis the correlation between a particular cause and effect is partitioned into direct and indirect effects of the various causal factors on the effect factor. The principle and techniques suggested by Wright (1921) and Li (1955) were used for the analysis using the formula given by Dewey and Lu (1959).

Scale	Effect
0.00-0.09	Negligible
0.10-0.1	Low
0.20-0.29	Moderate
0.30-1.00	High
More than 1.00	Very high

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3.6.3 Cluster analysis using dendrogram

The qualitative variables related to both the tree and fruit were compared with Jaccard's similarity coefficients and was clustered by the Unweighted Pair Group Average Method (UPGAM) devised by Sneath and Sokal (1973) using NTsys pc 2.02 software. Similarity matrix was computed and the dendrogram was constructed accordingly using the above.

3.6.4 Clustering using principal components

All the 100 collections of rambutan had diverse characters with relatively lesser quantum of similarity. Had all the 100 collections been taken for comparative evaluation, the dimensionality of the problem would have drastically narrowed down the major findings. Hence it was decided to reduce the dimensionality for better analysis and interpretation of the results by grouping the collections in to three major categories namely a) elite selections b) selections for export types and c) selections of promising types for processing/industrial use based on a criteria developed through the measurable and most desirable characteristics as described below.

Clustering was carried out for each category of collections using principal components based on score plot by using the software Minitab 17.

3.6.4.1 Selection for elite types

All the collections were scored based on the most desirable characteristics namely fruit weight, aril taste, aril texture, aril juiciness, attachment of aril to seed, TSS, aril to fruit ratio and seed to fruit ratio. The maximum of point tally that a collection could achieve as regard to this criteria was thus 21. In relation to this, the scores of individual collections were judged and those collection which ranked within the highest $1/3^{rd}$ group were carried forward for further study. The rest of the $2/3^{rd}$ collections possessing scores in the range 4-13were filtered in a step by step manner according to the frequency of the collections such that a representative

sample of two collections each were selected from a particular score using the most relevant characters namely TSS and adherence of aril to seed. Thus the two collections each possessing highest score in case of TSS and aril attachment were also taken for further study. In the event of tie having occurred in the above said traits, the next important criteria (aril to fruit ratio) was taken as the rationale.

The threshold values fixed for each attribute and the scores given are presented as Appendix III.

3.6.4.2 Selection for export trade

With respect to export trade selections, all the collections were scored based on the the quality specifications of export rambutan viz., weight above 30 g, poor adherence of aril to seed, and a minimum total soluble solid content of 16 to 18° Brix (Landrigan *et al.*, 1996; Kader, 2001). Those collections which satisfied all the export specifications were further carried forward in the study. Seven collections which satisfied all the criteria except free seed aril which fell in the category of medium were also taken for further analysis. An exception to the thump rule was made in Col.052 which was distinctly superior with respect to fruit weight and poor adherence but only had a TSS of 15.5° Brix against the base value of 16° Brix.

The threshold values fixed for each attribute and the scores given for each collection are presented in Appendix III.

3.6.4.3 Selection for industrial use

Rambutan collections holding promise for industrial use were filtered by assigning scores based on the processing attributes namely aril weight, juiciness, adherence to seed, TSS, titrable acidity and total sugar content. The maximum of point tally a collection could thus achieve as regard to this criteria was 16. In relation to this, the scores of individual collections were judged and those collections which had a score 10 or above were carried forward for further study. The rest of the collections possessing scores below 10 were filtered in a step by step

manner according to the frequency of the collections such that a representative sample of two collections were selected from a particular score using the most relevant characters namely aril weight and TSS as juicy types had already found its place in the first category. Thus two collections each possessing highest score in aril weight and TSS were also carried further in the study.

The threshold values fixed for each attribute and the scores given for each collection are presented in Appendix III.

Results

4. RESULTS

The results pertaining to "Variability studies in rambutan (*Nephelium lappaceum* L.) " are presented in this chapter based on hundred variable types of rambutan collected from the major rambutan growing tracts of Kerala and presented under the broad subheadings of morphological characterization, biochemical analysis, sensory evaluation and pests and diseases incidence separately as follows.

4.1 Morphological characterization

The various observations on morphological characters *viz.*, tree characters, inflorescence characters and fruit characters recorded as per the standard crop descriptor suggested by IPGRI (2003) were analysed and the results are presented in Tables 1 to 4. The distribution of all the qualitative characters were expressed as percentage frequency and presented in Tables

4.1.1 Tree characters

The data showing tree characters are given in Tables 1 and 2.

4.1.1.1 Tree age

The study included 100 rambutan trees which had reached steady bearing belonging to various age groups. Among these 71 trees came under the age group of 3-10 years, 22 trees in the age group of 11-20 years, 4 trees in the age group of 21-30 and 3 trees fell in the age group of above 30 years.

4.1.1.2 Planting material

The rambutan collections involved 86 trees of seedling origin and 14 budded plants.

4.1.1.3 Trunk surface

All the collections studied were having rough trunk surface.

Table 1a. Qualitative tree and inflorescence characters of rambutan collections (001 to 017) as per IPGRI crop descriptor

Collections	Planting material	Trunk surface	Crown shape	Branching pattern	Young shoot pubescence	Flowering season (month)	Flower composition	Position of inflorescence	Inflorescence shape	Inflorescence colour
Col.001	Seedling	Rough	Pyramidal	Irregular	Absent	end of Jan-mid of March	HFF	Terminal	Obtriangular	Light green
Col.002	Seedling	Rough	Oblong	Irregular	Absent	end of Jan-mid of March	HFF	Terminal	Pyramidal	Light green
Col.003	Seedling	Rough	Pyramidal	Irregular	Absent	end of Jan-mid of March	TM	Terminal	Conical	Light green
Col.004	Seedling	Rough	Spherical	Irregular	Absent	end of Jan-mid of March	HFM&HFF	Terminal	Obtriangular	Light green
Col.005	Seedling	Rough	Spherical	Irregular	Absent	end of Jan-mid of March	HFF	Terminal	Pyramidal	Light green
Col.006	Seedling	Rough	Spherical	Irregular	Absent	end of Jan-mid of March	HFF	Terminal	Obtriangular	Light green
Col.007	Seedling	Rough	Spherical	Irregular	Absent	end of Jan-mid of March	HFFC	Terminal	Pyramidal	Light green
Col.008	Seedling	Rough	Spherical	Irregular	Absent	end of Jan-mid of March	HFF	Terminal	Pyramidal	Light green
Col.009	Seedling	Rough	Oblong	Irregular	Absent	end of Jan-mid of March	HFF	Terminal	Obtriangular	Light green
Col.010	Seedling	Rough	Pyramidal	Irregular	Absent	end of Jan-mid of March	HFF	Terminal	Pyramidal	Light green
Col.011	Seedling	Rough	Oblong	Irregular	Absent	end of Jan-mid of March	TM	Terminal	Obtriangular	Light green
Col.012	Seedling	Rough	Spherical	Irregular	Absent	end of Jan-mid of March	HFF	Terminal	Pyramidal	Light green
Col.013	Seedling	Rough	Semi-circle	Irregular	Absent	end of Jan-mid of March	HFF	Terminal	Conical	Light green
Col.014	Seedling	Rough	Oblong	Irregular	Absent	end of Jan-mid of March	HFF	Terminal	Conical	Light green
Col.015	Seedling	Rough	Semi-circle	Irregular	Absent	end of Jan-mid of March	HFF	Terminal	Pyramidal	Light green
Col.016	Seedling	Rough	Oblong	Irregular	Absent	end of Jan-mid of March	HFF	Terminal	Pyramidal	Light green
Col.017	Buddling	Rough	Spherical	Irregular	Absent	end of Jan-mid of March	HFF	Terminal	Pyramidal	Light green

Table 1b. Qualitative tree and inflorescence characters of rambutan collections (018 to 034) as per IPGRI crop descriptor

Collections	Planting material	Trunk surface	Crown shape	Branching pattern	Young shoot pubescence	Flowering season (month)	Flower composition	Position of inflorescence	Inflorescence shape	Inflorescence colour
Col.018	Seedling	Rough	Oblong	Irregular	Absent	end of Jan-mid of March	HFF	Terminal	Conical	Light green
Col.019	Seedling	Rough	Oblong	Irregular	Absent	end of Feb-end of March	HFF	Terminal	Pyramidal	Light green
Col.020	Seedling	Rough	Semi-circle	Irregular	Absent	end of Feb-end of March	HFF	Terminal	Pyramidal	Light green
Col.021	Buddling	Rough	Spherical	Irregular	Absent	end of Feb-end of March	HFF	Terminal	Pyramidal	Light green
Col.022	Buddling	Rough	Spherical	Irregular	Absent	end of Feb-end of March	HFF	Terminal	Pyramidal	Light green
Col.023	Buddling	Rough	Spherical	Irregular	Absent	end of Feb-end of March	HFF	Terminal	Obtriangular	Light green
Col.024	Buddling	Rough	Spherical	Irregular	Absent	end of Feb-end of March	HFF	Terminal	Pyramidal	Light green
Col.025	Seedling	Rough	Oblong	Irregular	Absent	end of Feb-end of March	HFF	Terminal	Pyramidal	Light green
Col.026	Seedling	Rough	Semi-circle	Irregular	Absent	end of Feb-end of March	HFF	Terminal	Pyramidal	Light green
Col.027	Buddling	Rough	Spherical	Irregular	Absent	end of Feb-end of March	HFF	Terminal	Obtriangular	Light green
Col.028	Buddling	Rough	Spherical	Irregular	Absent	end of Feb-end of March	HFF	Terminal	Pyramidal	Light green
Col.029	Seedling	Rough	Pyramidal	Irregular	Absent	end of Feb-end of March	HFF	Terminal	Pyramidal	Light green
Col.030	Seedling	Rough	Pyramidal	Irregular	Absent	end of Feb-end of March	HFF	Terminal	Pyramidal	Light green
Col.031	Seedling	Rough	Pyramidal	Irregular	Absent	end of Feb-end of March	HFF	Terminal	Pyramidal	Light green
Col.032	Buddling	Rough	Spherical	Irregular	Absent	end of Feb-end of March	HFF	Terminal	Pyramidal	Light green
Col.033	Seedling	Rough	Semi-circle	Irregular	Absent	end of Feb-end of March	HFF	Terminal	Pyramidal	Light green
Col.034	Buddling	Rough	Spherical	Irregular	Absent	end of Feb-end of March	HFF	Terminal	Pyramidal	Light green

Table 1c. Qualitative tree and inflorescence characters of rambutan collections (035 to 051) as per IPGRI crop descriptor

Collections	Planting material	Trunk surface	Crown shape	Branching pattern	Young shoot pubescence	Flowering season (month)	Flower composition	Position of inflorescence	Inflorescence shape	Inflorescence colour
Col.035	Seedling	Rough	Spherical	Irregular	Absent	end of Feb-end of March	HFF	Terminal	Pyramidal	Light green
Col.036	Seedling	Rough	Pyramidal	Irregular	Absent	end of Feb-end of March	HFF	Terminal	Pyramidal	Light green
Col.037	Seedling	Rough	Semi-circle	Irregular	Absent	end of Feb-end of March	HFF	Terminal	Conical	Light green
Col.038	Seedling	Rough	Semi-circle	Irregular	Absent	end of Feb-end of March	HFF	Terminal	Pyramidal	Light green
Col.039	Buddling	Rough	Spherical	Irregular	Absent	end of Feb-end of March	HFF	Terminal	Pyramidal	Light green
Col.040	Buddling	Rough	Spherical	Irregular	Absent	end of Feb-end of March	HFF	Terminal	Pyramidal	Light green
Col.041	Seedling	Rough	Oblong	Irregular	Absent	end of Feb-end of March	HFF	Terminal	Pyramidal	Light green
Col.042	Seedling	Rough	Spherical	Irregular	Absent	end of Feb-end of March	HFF	Terminal	Pyramidal	Light green
Col.043	Seedling	Rough	Oblong	Irregular	Absent	end of Feb-end of March	HFF	Terminal	Pyramidal	Light green
Col.044	Seedling	Rough	Spherical	Irregular	Absent	end of Feb-end of March	HFF	Terminal	Pyramidal	Light green
Col.045	Seedling	Rough	Pyramidal	Irregular	Absent	end of Feb-end of March	HFF	Terminal	Pyramidal	Light green
Col.046	Seedling	Rough	Oblong	Irregular	Absent	end of Feb-end of March	HFF	Terminal	Pyramidal	Light green
Col.047	Seedling	Rough	Oblong	Irregular	Absent	end of Feb-end of March	HFF	Terminal	Obtriangular	Light green
Col.048	Seedling	Rough	Pyramidal	Irregular	Absent	end of Feb-end of March	HFF	Terminal	Pyramidal	Light green
Col.049	Seedling	Rough	Pyramidal	Irregular	Absent	end of Feb-end of March	HFF	Terminal	Pyramidal	Light green
Col.050	Seedling	Rough	Oblong	Irregular	Absent	end of Feb-end of March	HFF	Terminal	Conical	Light green
Col.051	Seedling	Rough	Oblong	Irregular	Absent	end of Feb-end of March	HFF	Terminal	Obtriangular	Light green

Table 1d. Qualitative tree and inflorescence characters of rambutan collections (052 to 068) as per IPGRI crop descriptor

Collections	Planting material	Trunk surface	Crown shape	Branching pattern	Young shoot pubescence	Flowering season (month)	Flower composition	Position of inflorescence	Inflorescence shape	Inflorescence colour
Col.052	Buddling	Rough	Spherical	Irregular	Absent	end of Feb-end of March	HFF	Terminal	Pyramidal	Light green
Col.053	Buddling	Rough	Spherical	Irregular	Absent	end of Feb-end of March	HFF	Terminal	Pyramidal	Light green
Col.054	Seedling	Rough	Oblong	Irregular	Absent	end of Feb-end of March	HFF	Terminal	Pyramidal	Light green
Col.055	Seedling	Rough	Oblong	Irregular	Absent	end of Feb-end of March	HFF	Terminal	Conical	Light green
Col.056	Seedling	Rough	Oblong	Irregular	Absent	end of Feb-end of March	HFF	Terminal	Pyramidal	Light green
Col.057	Seedling	Rough	Oblong	Irregular	Absent	end of Feb-end of March	HFF	Terminal	Pyramidal	Light green
Col.058	Seedling	Rough	Oblong	Irregular	Absent	end of Feb-end of March	HFF	Terminal	Pyramidal	Light green
Col.059	Seedling	Rough	Pyramidal	Irregular	Absent	end of Feb-end of March	HFF	Terminal	Pyramidal	Light green
Col.060	Seedling	Rough	Oblong	Irregular	Absent	end of Feb-end of March	HFF	Terminal	Pyramidal	Light green
Col.061	Seedling	Rough	Pyramidal	Irregular	Absent	mid of March-end of April	HFF	Terminal	Pyramidal	Light green
Col.062	Seedling	Rough	Pyramidal	Irregular	Absent	mid of March-end of April	HFF	Terminal	Obtriangular	Light green
Col.063	Seedling	Rough	Oblong	Irregular	Absent	mid of March-end of April	HFF	Terminal	Pyramidal	Light green
Col.064	Seedling	Rough	Oblong	Irregular	Absent	mid of March-end of April	HFF	Terminal	Pyramidal	Light green
Col.065	Seedling	Rough	Oblong	Irregular	Absent	mid of March-end of April	HFF	Terminal	Pyramidal	Light green
Col.066	Seedling	Rough	Pyramidal	Irregular	Absent	mid of March-end of April	HFF	Terminal	Pyramidal	Light green
Col.067	Seedling	Rough	Pyramidal	Irregular	Absent	mid of March-end of April	HFF	Terminal	Pyramidal	Light green
Col.068	Seedling	Rough	Semi-circle	Irregular	Absent	mid of March-end of April	HFF	Terminal	Conical	Light green

Table 1e. Qualitative tree and inflorescence characters of rambutan collections (069 to 085) as per IPGRI crop descriptor

Collections	Planting material	Trunk surface	Crown shape	Branching pattern	Young shoot pubescence	Flowering season (month)	Flower composition	Position of inflorescence	Inflorescence shape	Inflorescence colour
Col.069	Seedling	Rough	Pyramidal	Irregular	Absent	mid of March-end of April	HFF	Terminal	Pyramidal	Light green
Col.070	Seedling	Rough	Spherical	Irregular	Absent	mid of March-end of April	HFF	Terminal	Obtriangular	Light green
Col.071	Seedling	Rough	Pyramidal	Irregular	Absent	mid of March-end of April	HFF	Terminal	Pyramidal	Light green
Col.072	Seedling	Rough	Semi-circle	Irregular	Absent	mid of March-end of April	HFF	Terminal	Pyramidal	Light green
Col.073	Seedling	Rough	Pyramidal	Irregular	Absent	mid of March-end of April	HFF	Terminal	Pyramidal	Light green
Col.074	Seedling	Rough	Pyramidal	Irregular	Absent	mid of March-end of April	HFF	Terminal	Conical	Light green
Col.075	Seedling	Rough	Pyramidal	Irregular	Absent	mid of March-end of April	HFF	Terminal	Pyramidal	Light green
Col.076	Buddling	Rough	Spherical	Irregular	Absent	mid of March-end of April	HFF	Terminal	Pyramidal	Light green
Col.077	Seedling	Rough	Oblong	Irregular	Absent	mid of March-end of April	HFF	Terminal	Pyramidal	Light green
Col.078	Seedling	Rough	Pyramidal	Irregular	Absent	mid of March-end of April	HFF	Terminal	Conical	Light green
Col.079	Seedling	Rough	Spherical	Irregular	Absent	mid of March-end of April	HFF	Terminal	Pyramidal	Light green
Col.080	Seedling	Rough	Pyramidal	Irregular	Absent	mid of March-end of April	HFF	Terminal	Pyramidal	Light green
Col.081	Seedling	Rough	Semi-circle	Irregular	Absent	mid of March-end of April	HFF	Terminal	Pyramidal	Light green
Col.082	Seedling	Rough	Oblong	Irregular	Absent	mid of March-end of April	HFF	Terminal	Pyramidal	Light green
Col.083	Seedling	Rough	Oblong	Irregular	Absent	mid of March-end of April	HFF	Terminal	Pyramidal	Light green
Col.084	Seedling	Rough	Oblong	Irregular	Absent	mid of March-end of April	HFF	Terminal	Pyramidal	Light green
Col.085	Seedling	Rough	Oblong	Irregular	Absent	mid of March-end of April	HFF	Terminal	Conical	Light green

Table 1f. Qualitative tree and inflorescence characters of rambutan collections (086 to 100) as per IPGRI crop descriptor

Collections	Planting material	Trunk surface	Crown shape	Branching pattern	Young shoot pubescence	Flowering season (month)	Flower composition	Position of inflorescence	Inflorescence shape	Inflorescence colour
Col.086	Seedling	Rough	Oblong	Irregular	Absent	mid of March-end of April	HFF	Terminal	Pyramidal	Light green
Col.087	Seedling	Rough	Pyramidal	Irregular	Absent	mid of March-end of April	HFF	Terminal	Pyramidal	Light green
Col.088	Seedling	Rough	Oblong	Irregular	Absent	mid of March-end of April	HFF	Terminal	Obtriangular	Light green
Col.089	Seedling	Rough	Oblong	Irregular	Absent	mid of March-end of April	HFF	Terminal	Pyramidal	Light green
Col.090	Seedling	Rough	Pyramidal	Irregular	Absent	mid of March-end of April	HFF	Terminal	Pyramidal	Light green
Col.091	Seedling	Rough	Oblong	Irregular	Absent	mid of March-end of April	HFF	Terminal	Obtriangular	Light green
Col.092	Seedling	Rough	Oblong	Irregular	Absent	mid of March-end of April	HFF	Terminal	Pyramidal	Light green
Col.093	Seedling	Rough	Pyramidal	Irregular	Absent	mid of March-end of April	HFF	Terminal	Conical	Light green
Col.094	Seedling	Rough	Oblong	Irregular	Absent	mid of March-end of April	HFF	Terminal	Pyramidal	Light green
Col.095	Seedling	Rough	Semi-circle	Irregular	Absent	mid of March-end of April	HFF	Terminal	Pyramidal	Light green
Col.096	Seedling	Rough	Pyramidal	Irregular	Absent	mid of March-end of April	HFF	Terminal	Conical	Light green
Col.097	Seedling	Rough	Pyramidal	Irregular	Absent	mid of March-end of April	HFF	Terminal	Pyramidal	Light green
Col.098	Seedling	Rough	Oblong	Irregular	Absent	mid of March-end of April	HFF	Terminal	Pyramidal	Light green
Col.099	Seedling	Rough	Pyramidal	Irregular	Absent	mid of March-end of April	HFF	Terminal	Conical	Light green
Col.100	Seedling	Rough	Oblong	Irregular	Absent	end of April-end of May	HFF	Terminal	Pyramidal	Light green

4.1.1.4 Crown shape

Crown shapes like pyramidal, oblong, semi-circle and spherical were observed among the collections. Among the collections 36% fell under the category oblong, 28% in pyramidal, 25% in spherical and 11% of the collections had the crown shape semi-circle. All the budded plants assumed spherical shape.

4.1.1.5 Branching pattern

All the collections studied had an irregular branching pattern.

4.1.1.6 Young shoot pubescence

All the collections were devoid of young shoot pubescence.

4.1.1.7 Leaf colour

Leaf colour of the collections varied from green to dark green. Almost all the collections were having green coloured leaves (90%) followed by a minor group with dark green leaves (10%).

4.1.1.8 Number of leaflets per leaf

Average number of leaflets per leaf ranged from 4.63 to 6.96. The maximum number of leaflets was observed in Col.032 (6.96) and minimum in Col.013 (4.63).

4.1.1.9 Rachis length

Rachis length of the collections ranged from 11.06 cm to 24.75 cm. The highest rachis length of 24.75 cm was recorded in Col.033 and the lowest value of 11.06 cm in Col.027.

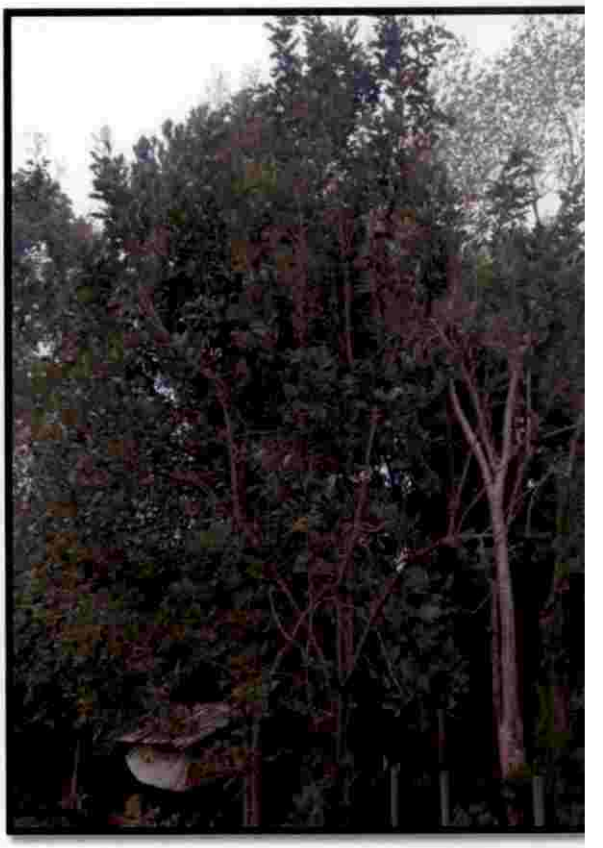
4.1.1.10 Length of petiole

Petiole length of the collections ranged from 5.06 mm to 7.8 mm. The lowest petiole length of 5.06 mm was noted in Col.016 and highest value of 7.8 mm in Col.026.


a


b

Plate 2. Crown shapes in rambutan : c) Semi-circular b) Oblong



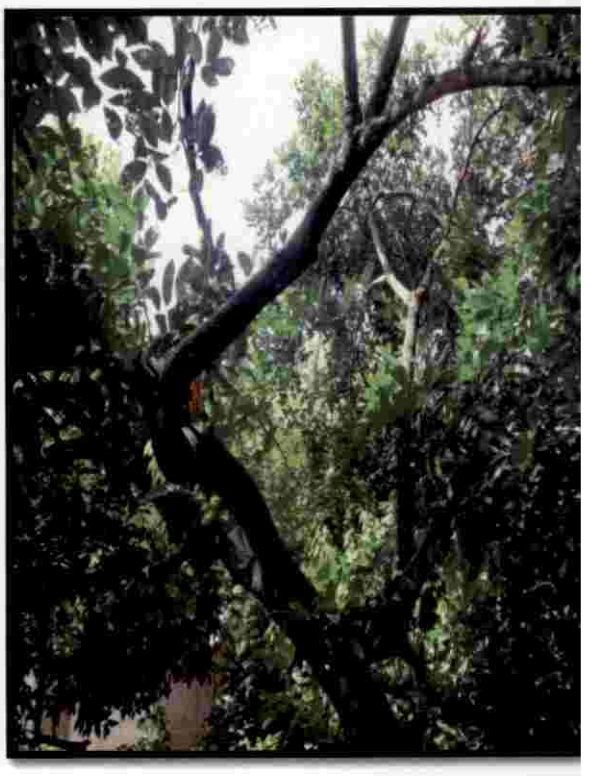


Plate 3. Irregular branching pattern in rambutan

4.1.1.11 Leaflet length

Leaflet length of collections ranged from 9.09 cm to 16.34 cm. Leaflet length was maximum in Col.004 (16.34 cm) and minimum in Col.048 (9.09 cm).

4.1.1.12 Leaflet width

Leaflet width of the collections ranged from 5.06 cm to 8.93 cm. The highest leaflet width was recorded in Col.069 (8.93 cm) and the lowest value of 5.06 cm in Col.074.

4.1.1.13 Leaflet shape

All the collections had an elliptic leaflet shape.

4.1.1.14 Leaflet surface

Leaflet surface was found to be smooth in all the collections.

4.1.2 Inflorescence characters

Inflorescence characters of all the collections are furnished in Table 1a to 1f.

4.1.2.1 Flowering season

Flowering continued for about 35-45 days. Only one flowering season was observed in Kerala. Flowering was earliest in Thrissur (end of January to mid of March) followed by Kottayam and Idukki (end of February to end of March) and Pathanamthitta (mid of March to end of April). Within Pathanamthitta two distinct flowering periods were observed one typical of the plain (end of March to end of April) and of the hilly reach (end of April to end of May) (Table).

4.1.2.2 Flower composition

Inflorescence of most of the collections (97%) consisted of only hermaphrodite flowers functioning as female (HFF). Col.004 produced inflorescence with both HFF and HFM (Hermaphrodite flower functioning as male) and Col.003 and Col.011 were male trees with only true male flowers (TM).

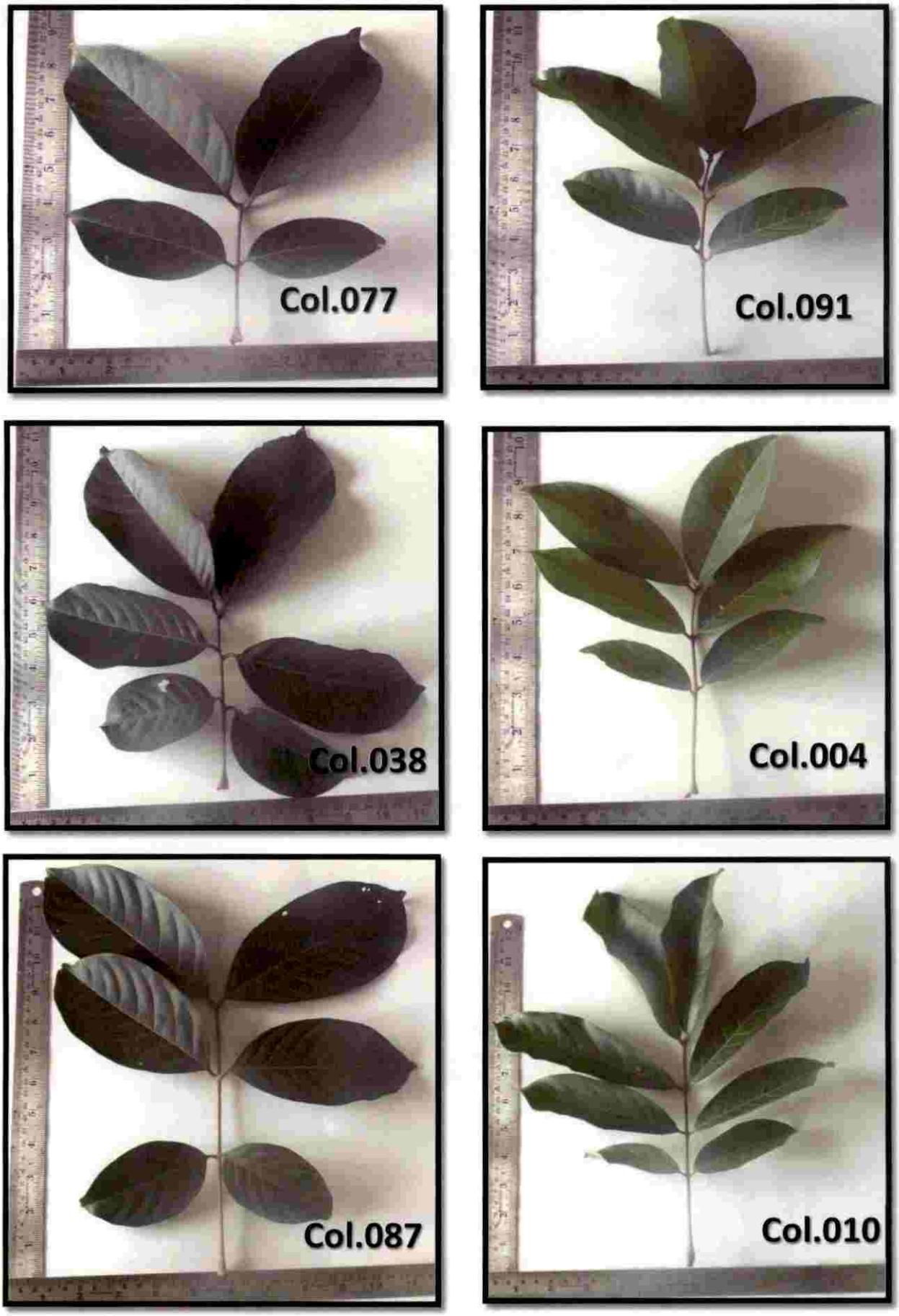


Plate 4. Variability in leaf characters of rambutan

Plate 5. Inflorescence bearing only hermaphroditic female flowers (HF)

Col.004

HF

HM

Plate 6. Inflorescence bearing both HF and hermaphroditic male (HM) flowers

Plate 7. Inflorescence bearing only true male flowers (TM)

Table 2a. Quantitative tree characters of rambutan collections (001 to 043) as per IPGRI crop descriptor

Collections	Age	No.of leaflets per leaf	Rachis length (cm)	Length of petiole (mm)	Leaflet length(cm)	Leaflet width (cm)
Col.001	10	4.92	16.42	7.06	10.07	8.59
Col.002	10	6.04	11.86	7.24	14.35	7.05
Col.003	10	6.4	24.57	5.94	15.05	8.64
Col.004	10	6.08	19.75	6.24	16.34	7.57
Col.005	10	6.28	12.65	7.65	15.45	7.44
Col.006	10	5.48	13.95	7.23	10.76	5.96
Col.007	10	6.28	13.36	6.54	15.09	6.42
Col.008	10	5.92	11.24	6.92	11.13	8.25
Col.009	10	6.65	11.49	6.85	16.08	6.67
Col.010	10	5.72	11.86	5.51	13.65	6.53
Col.011	10	6.17	12.35	5.96	14.09	5.12
Col.012	10	5.43	15.09	5.74	12.21	6.8
Col.013	25	4.63	11.49	5.43	16.05	7.9
Col.014	7	6.85	18.27	5.47	14.5	7.67
Col.015	40	6.4	16.86	5.89	16.34	5.95
Col.016	8	5.48	23.56	5.06	15.45	7.25
Col.017	4	5.43	19.35	5.9	10.76	5.94
Col.018	8	4.93	22.05	5.92	15.09	6.74
Col.019	11	5.92	17.23	5.08	11.13	5.44
Col.020	8	5.65	23.06	5.58	10.87	5.64
Col.021	4	5.04	11.24	5.92	9.87	7.06
Col.022	4	4.63	23.69	7.12	14.65	6.25
Col.023	4	6.28	11.38	7.24	10.16	5.35
Col.024	4	4.75	16.72	6.43	12.35	7.64
Col.025	5	6.17	20.32	5.84	13.65	5.34
Col.026	15	5.92	21.47	7.8	14.22	6.28
Col.027	5	4.76	11.06	7.19	11.07	8.24
Col.028	3	5.38	19.85	5.13	14.05	7.63
Col.029	45	6.28	16.09	6.91	16.13	5.12
Col.030	10	6.08	22.49	6.19	10.84	5.08
Col.031	27	5.48	11.92	6.63	10.75	6.09
Col.032	7	6.96	17.56	7.72	10.06	6.39
Col.033	8	5.34	24.75	6.69	9.89	7.89
Col.034	5	5.86	18.07	5.43	12.13	7.25
Col.035	40	5.09	14.35	5.17	13.88	8.04
Col.036	5	6.08	15.97	7.08	13.78	5.57
Col.037	15	6.4	16.78	5.87	10.76	6.49
Col.038	10	4.75	18.35	5.94	10.16	5.86
Col.039	6	4.67	12.69	5.19	13.85	6.72
Col.040	10	6.17	17.69	7.02	13.65	7.22
Col.041	12	5.08	19.23	5.64	16.09	5.27
Col.042	30	6.28	20.36	7.74	10.26	6.78
Col.043	8	4.63	21.47	6.04	13.95	6.46



Plate 8. Terminal light green inflorescences of rambutan

Pyramidal

Conical

Obtriangular

Plate 9. Shape of inflorescence in rambutan

Table 2b. Quantitative tree characters of rambutan collections (044 to 086) as per IPGRI crop descriptor

Collections	Age	No.of leaflets per leaf	Rachis length (cm)	Length of petiole (mm)	Leaflet length(cm)	Leaflet width (cm)
Col.044	15	5.75	22.89	5.74	10.05	5.72
Col.045	14	5.27	22.43	5.96	10.34	5.34
Col.046	6	5.86	15.79	5.99	14.76	7.21
Col.047	6	6.17	11.49	7.31	10.06	5.92
Col.048	15	4.92	16.42	7.26	9.09	7.08
Col.049	5	5.66	19.87	5.24	12.34	5.09
Col.050	10	6.36	22.56	6.2	13.58	5.63
Col.051	8	6.27	16.55	6.38	10.68	8.14
Col.052	5	5.08	18.35	5.99	11.67	5.95
Col.053	5	6.58	17.75	6.33	15.76	8.34
Col.054	6	4.86	13.76	7.1	10.52	5.97
Col.055	8	6.74	19.24	6.87	13.65	7.96
Col.056	10	5.86	11.49	5.58	16.09	6.96
Col.057	8	5.29	11.97	6.86	10.07	5.72
Col.058	7	5.58	18.32	5.64	14.95	8.35
Col.059	10	6.46	20.91	5.93	15.25	7.67
Col.060	10	6.76	19.04	5.86	10.09	5.98
Col.061	10	5.68	11.06	5.72	14.23	7.49
Col.062	8	6.37	14.93	5.41	10.96	6.12
Col.063	7	5.08	17.59	5.98	15.29	6.94
Col.064	6	6.73	21.09	5.21	12.16	5.93
Col.065	6	4.73	22.82	5.67	16.08	6.72
Col.066	6	5.48	13.86	5.88	15.98	5.83
Col.067	12	4.96	16.57	7.67	10.06	7.29
Col.068	15	6.35	16.46	6.11	15.76	6.97
Col.069	15	5.86	19.6	5.64	14.5	8.93
Col.070	15	6.09	13.65	5.88	13.05	6.05
Col.071	15	6.38	16.76	5.43	14.79	5.27
Col.072	15	6.4	13.24	6.29	10.35	8.67
Col.073	15	5.75	13.59	7.65	13.79	6.44
Col.074	15	5.47	20.07	5.59	10.75	5.06
Col.075	15	5.27	20.02	6.28	16.04	6.32
Col.076	5	6.18	17.63	6.71	15.95	7.76
Col.077	10	4.92	19.45	7.16	11.56	5.27
Col.078	8	5.86	17.86	6.29	16.09	7.68
Col.079	15	6.78	12.05	6.75	10.13	6.45
Col.080	15	6.48	15.79	6.69	15.68	6.72
Col.081	20	6.08	21.09	6.73	12.38	5.94
Col.082	7	6.48	15.73	7.15	13.16	6.73
Col.083	6	4.96	13.89	7.33	14.36	5.82
Col.084	8	6.46	24.05	5.42	10.75	6.08
Col.085	8	5.86	23.55	7.05	14.35	7.49
Col.086	10	4.92	13.79	5.86	12.09	5.97

per IPGRI crop descriptor

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Collections	Age	No.of leaflets per leaf	Rachis length (cm)	Length of petiole (mm)	Leaflet length(cm)	Leaflet width (cm)
Col.087	7	6.28	16.05	5.57	10.77	6.89
Col.088	6	5.08	19.06	5.95	13.25	7.55
Col.089	7	5.28	19.46	5.45	15.56	5.64
Col.090	7	5.38	21.49	6.27	10.38	6.34
Col.091	7	6.08	20.07	5.78	10.75	8.64
Col.092	7	5.92	12.92	5.95	12.36	6.92
Col.093	10	5.65	19.39	5.85	16.09	5.92
Col.094	10	6.34	21.43	7.18	12.43	5.21
Col.095	25	6.65	15.36	5.83	12.57	5.68
Col.096	15	6.18	22.35	6.75	11.45	7.09
Col.097	15	4.92	21.09	6.75	15.68	6.89
Col.098	8	6.08	15.79	5.42	13.25	5.94
Col.099	15	4.96	22.89	7.33	12.38	5.82
Col.100	8	5.08	22.36	5.95	10.13	6.73

4.1.2.3 Position of inflorescence

Inflorescences were born at the shoot tips (terminal) in all the collections.

4.1.2.4 Shape of inflorescence

Three types of inflorescence were found in rambutan during the study namely pyramidal, conical and obtriangular. Majority of the collections (73%) were with pyramidal type inflorescence followed by conical (14%) and obtriangular type (13%).

4.1.2.5 Inflorescence colour

All the collections produced light green coloured inflorescences.

4.1.3 Fruit characters

The data pertaining to fruit characters of 98 rambutan collections are listed in Table 3 and 4. Distribution of qualitative traits related to fruit among the collections were also found out and presented in Table as percentage frequency.

4.1.3.1 Fruiting season

Fruiting and harvesting were a reflection of the flowering period. Flowering to fruit maturity took about 90-120 days. Plants came to harvest in mid of May to end of June in Trichur, in June to mid of July in Kottayam and Idukki, in end of July- mid of August in plain of Pathanamthitta and in August - September in hills of Pathanamthitta.

4.1.3.2 Percentage fruit set

Percentage fruit set ranged from 12% to 35% with the highest fruit set being recorded in Col.099 (35%) and the lowest of 12% in Col.033, Col.071 and Col.074 respectively.

4.1.3.3 Length of fruit bunch

Length of fruit bunch varied from 20 cm to 48 cm with the maximum fruit bunch length in Col.059 (48 cm) and minimum length in Col.066 (20 cm).

Plate 10. Rambutan trees in harvesting stage – field view

4.1.3.4 Number of fruits per bunch

The number of fruits per bunch ranged from 12 to 38. The highest number of fruits per bunch was recorded in Col.004 and lowest in Col.091.

4.1.3.5 Fruit shape

The collections were grouped in to three categories namely oblong, globose and ovoid on the basis of fruit shape. Among the 98 collections, 57.14% of the collections came under the shape oblong, 29.59% with the shape globose and 13.27 % with the shape ovoid.

4.1.3.6 Fruit length

Fruit length varied between 3.5 cm and 7.5 cm with the highest value in Col.052 and the lowest value in Col.012.

4.1.3.7 Fruit diameter

Fruit diameter ranged from 2 cm to 4.2 cm. The highest fruit diameter was observed in Col.047 and the lowest in Col.041

4.1.3.8 Fruit weight

Among the collections, the highest fruit weight of 61.5 g was recorded in Col.052 and the lowest fruit weight of 12 g in Col.012 and Col.013 respectively.

4.1.3.9 Rind colour

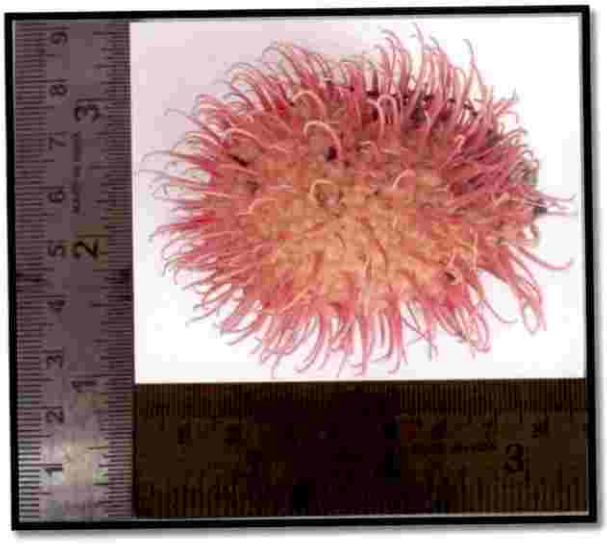
Rind colour of the collections fell under 8 groups namely light greenish yellow, pale yellow, strong yellowish pink, strong reddish orange, strong red, vivid red, dark red and deep purplish red. Among the collections, 31.63 % of the collections exhibited strong reddish orange colour followed by strong red (17.35%), strong yellowish pink (14.29%), vivid red (12.24%), pale yellow (11.22%), light greenish yellow (5.1%), deep purplish red (5.1%) and dark red (3.06%).

Col.013

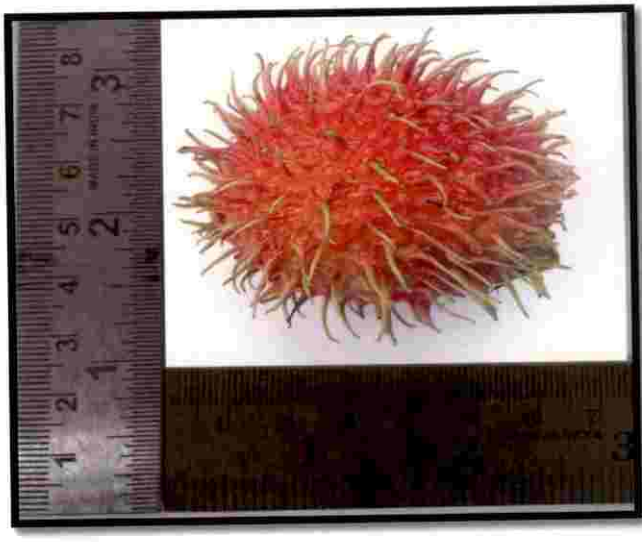
Col.015

Col.016

Col.067

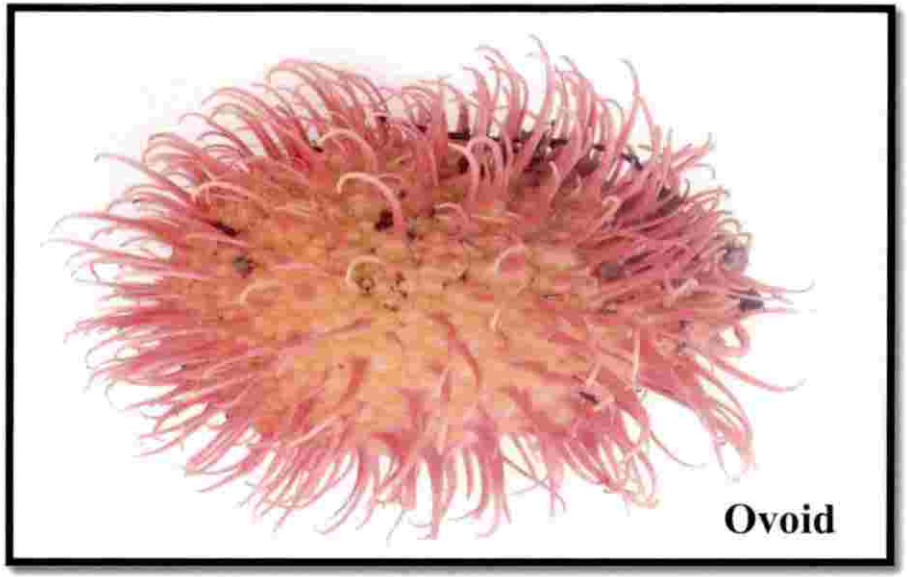


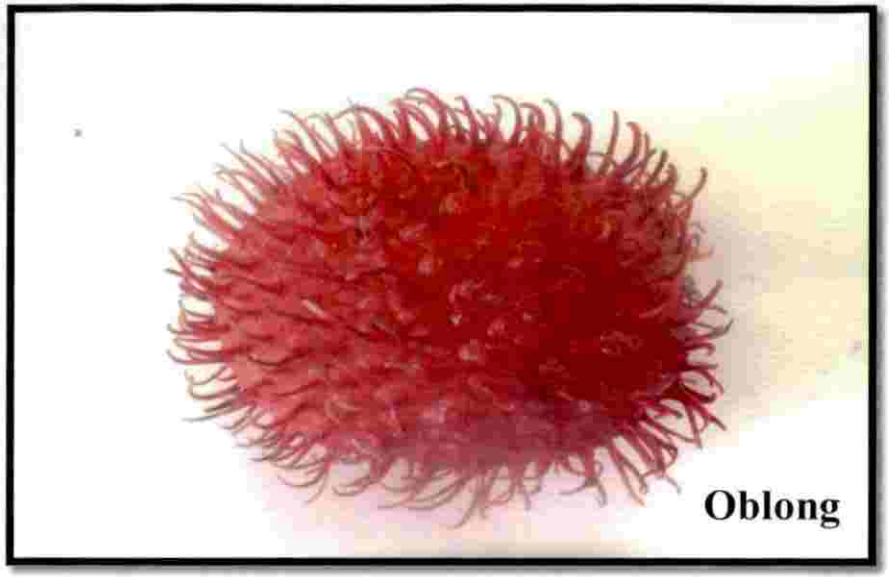
Col.022



Col.052

Plate 11. Variability in fruit size of rambutan collections





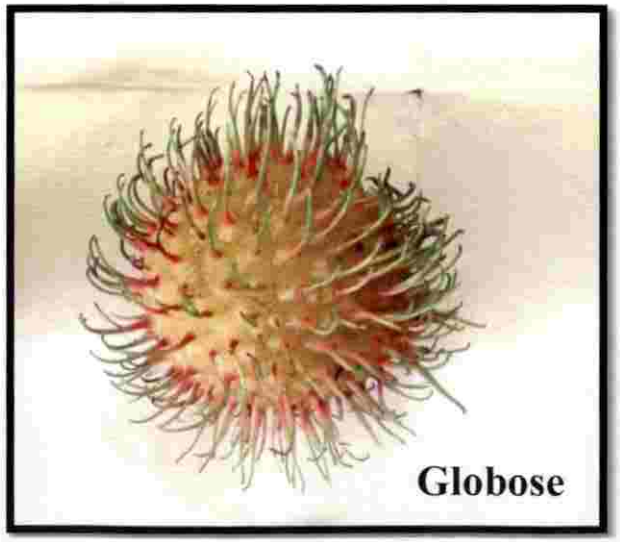


Plate 12. Fruit shapes in rambutan

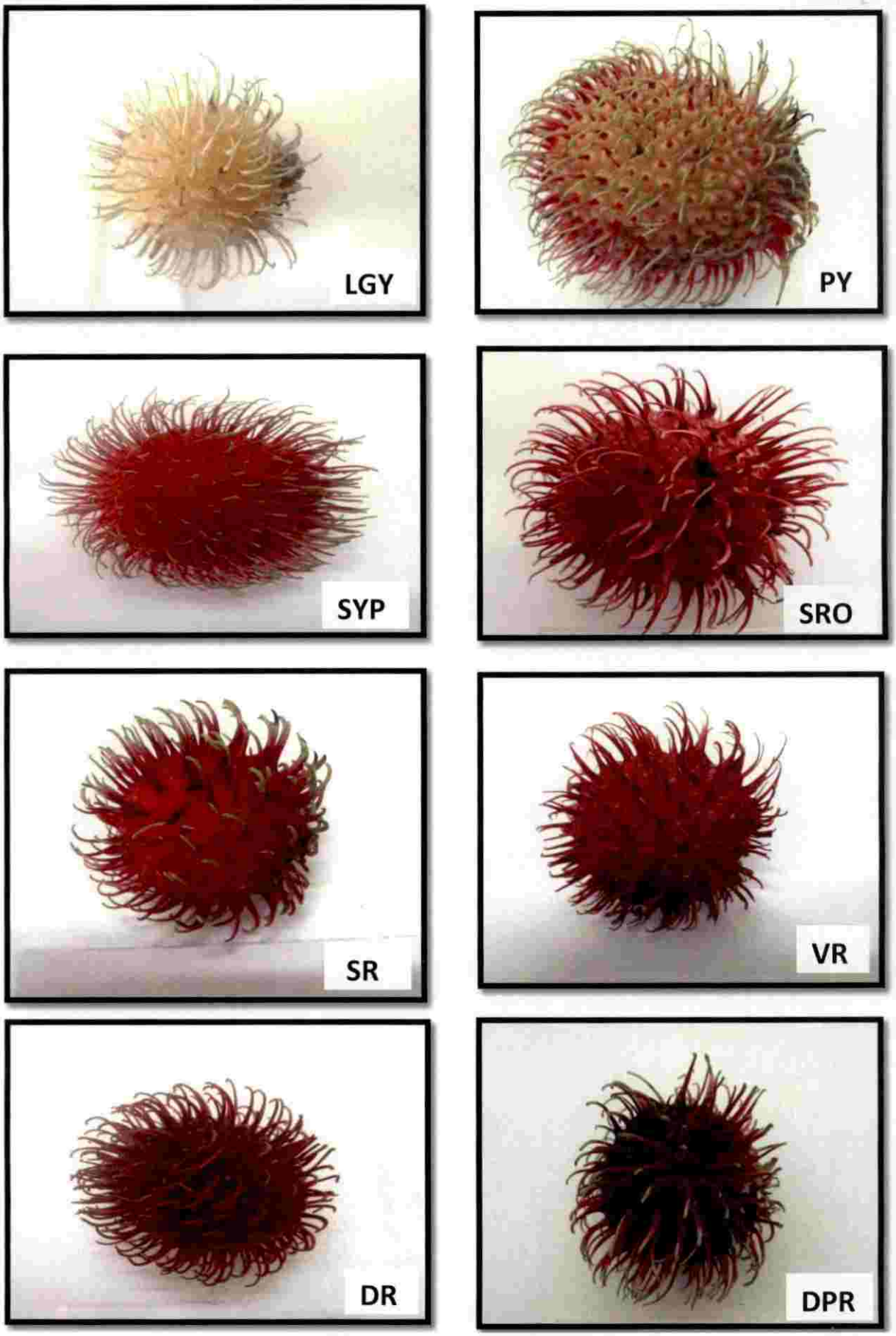


Plate 13. Rind colour of rambutan collections

LGY – Light Greenish Yellow PY – Pale Yellow SYP – Strong Yellowish Pink

SRO- Strong Reddish Orange SR – Strong Red VR – Vivid Red DR – Dark Red DPR – Deep Purplish Red

Table 3a. Qualitative fruit characters of rambutan collections (001 to 020) as per IPGRI crop descriptor

Collections	Fruit shape	Rind colour	Spine texture	Spine colour	Aril colour	Aril taste	Aril texture	Aril juiciness	Attachment of aril to seed	Seed shape	Seed coat colour
Col.001	Oblong	SRO (40C)	Soft	Red with light green tip	White	Acid sweet	Soft	Not juicy	Very good	Obovoid elongated	Creamish
Col.002	Oblong	SYP (37A)	Stiff	Red with light green tip	White	Sweet	Soft	Juicy	Very good	Oblong	Creamish
Col.004	Ovoid	SRO(40C)	Soft	Red with light green tip	Creamy white	Acid sweet	Soft	Juicy	Very good	Oblong	Creamish
Col.005	Oblong	SRO(40C)	Soft	Red with light green tip	Creamy white	Acid sweet	Soft	Juicy	Very good	Obovoid elongated	Creamish
Col.006	Oblong	SRO (40C)	Stiff	Red with light green tip	Creamy white	Acid sweet	Soft	Juicy	Very good	Obovoid	Creamish
Col.007	Oblong	SR(45D)	Stiff	Red with light green tip	White	Acid sweet	Soft	Juicy	Very good	Obovoid	Creamish
Col.008	Ovoid	SRO (40C)	Soft	Red with light green tip	Creamy white	Acid	Soft	Not juicy	Very good	Obovoid	Creamish
Col.009	Oblong	SRO (40C)	Soft	Red with light green tip	White	Sweet	Soft	Very juicy	Very good	Oblong	Creamish
Col.010	Oblong	SRO (40C)	Stiff	Red with light green tip	White	Sweet	Soft	Juicy	Very good	Irregular	Creamish
Col.012	Globose	SRO (40C)	Stiff	Red with light green tip	Creamy white	Sweet	Soft	Juicy	Very good	Obovoid	Creamish
Col.013	Oblong	LGY (3D)	Stiff	Light green	White	Acid	Soft	Not juicy	Very good	Oblong	Creamish
Col.014	Ovoid	SR (45D)	Soft	Red with light green tip	Creamy white	Acid sweet	Firm	Juicy	Very good	Obovoid elongated	Creamish
Col.015	Globose	SR (45D)	Soft	Red with light green tip	Creamy white	Sweet	Soft	Very juicy	Very good	Oblong	Creamish
Col.016	Oblong	SR (45D)	Soft	Red with light green tip	Creamy white	Sweet	Firm	Juicy	Very good	Obovoid elongated	Creamish
Col.017	Globose	PY (12D)	Soft	Red with light green tip	Creamy white	Acid	Soft	Juicy	Very good	Obovoid elongated	Creamish
Col.018	Oblong	DPR (61A)	Soft	Red with light green tip	Creamy white	Sweet	Soft	Very juicy	Good	obovoid	Creamish
Col.019	Oblong	SRO(40C)	Soft	Red with light green tip	Dull white	Sweet	Crispy	Juicy	Medium	Obovoid elongated	Creamish
Col.020	Oblong	SRO(40C)	Stiff	Red with light green tip	Creamy white	Acid sweet	Soft	Very juicy	Very good	Obovoid elongated	Creamish

Table 3b. Qualitative fruit characters of rambutan collections (021 to 039) as per IPGRI crop descriptor

Collections	Fruit shape	Rind colour	Spine texture	Spine colour	Aril colour	Aril taste	Aril texture	Aril juiciness	Attachment of aril to seed	Seed shape	Seed coat colour
Col.021	Ovoid	SRO(40C)	Soft	Red with light green tip	Dull white	Sweet	Crispy	Juicy	Poor	Obovoid elongated	Creamish
Col.022	Ovoid	SRO(40C)	Soft	Red with light green tip	Dull white	Sweet	Crispy	Juicy	Poor	Obovoid	Creamish
Col.023	Globose	PY (12D)	Soft	Light green with pink base	Dull white	Sweet	Crispy	Juicy	Poor	Roundish	Creamish
Col.024	Oblong	SR (45D)	Soft	Red with light green tip	Dull white	Sweet	Crispy	Not juicy	Poor	Oblong	Creamish
Col.025	Globose	PY (12D)	Soft	Yellow	White	Acid sweet	Soft	Juicy	Very good	Obovoid	Creamish
Col.026	Oblong	SYP (37A)	Soft	Red with light green tip	White	Acid sweet	Soft	Very juicy	Very good	Obovoid	Creamish
Col.027	Ovoid	PY (12D)	Soft	Red with light green tip	Dull white	Sweet	Crispy	Juicy	Medium	Obovoid elongated	Creamish
Col.028	Globose	SYP (37A)	Soft	Red with light green tip	Dull white	Sweet	Crispy	Juicy	Very good	Roundish	Creamish
Col.029	Oblong	PY (12D)	Soft	Light green	White	Sweet	Soft	Juicy	Very good	Obovoid	Creamish
Col.030	Globose	SRO (40C)	Soft	Red with light green tip	White	Acid sweet	Soft	Not juicy	Very good	Obovoid	Creamish
Col.031	Oblong	SR (45D)	Soft	Red with light green tip	White	Acid sweet	Soft	Juicy	Very good	Oblong	Creamish
Col.032	Ovoid	SR (45D)	Soft	Red	White	Sweet	Soft	Juicy	Very good	Oblong	Creamish
Col.033	Globose	SR (45D)	Soft	Red with light green tip	White	Sweet	Crispy	Juicy	Poor	Obovoid	Creamish
Col.034	Oblong	SYP (37A)	Soft	Red with light green tip	Dull white	Sweet	Crispy	Not juicy	Poor	Obovoid	Creamish
Col.035	Oblong	PY (12D)	Soft	Light green	White	Acid sweet	Soft	Juicy	Very good	Oblong	Creamish
Col.036	Globose	SR (45D)	Soft	Red with light green tip	Dull white	Sweet	Soft	Not juicy	Very good	Roundish	Creamish
Col.037	Oblong	SR (45D)	Soft	Red with light green tip	Dull white	Acid sweet	Soft	Not juicy	Medium	Roundish	Creamish
Col.038	Oblong	SYP (37A)	Soft	Red with light green tip	White	Acid	Firm	Not juicy	Very good	Obovoid	Creamish
Col.039	Ovoid	VR (46B)	Soft	Red with light green tip	Dull white	Sweet	Crispy	Not juicy	Good	Obovoid elongated	Creamish

Table 3c. Qualitative fruit characters of rambutan collections (040 to 057) as per IPGRI crop descriptor

Collections	Fruit shape	Rind colour	Spine texture	Spine colour	Aril colour	Aril taste	Aril texture	Aril juiciness	Attachment of aril to seed	Seed shape	Seed coat colour
Col.040	Globose	PY (12D)	Soft	Light green with pink base	Dull white	Sweet	Crispy	Not juicy	Medium	Oblong	Creamish
Col.041	Globose	VR (46B)	Soft	Red	Dull white	Acid sweet	Soft	Not juicy	Very good	Oblong	Creamish
Col.042	Globose	PY (12D)	Soft	Light green with pink base	Dull white	Sweet	Crispy	Juicy	Poor	Obovoid	Creamish
Col.043	Ovoid	PY (12D)	Soft	Light green	Dull white	Sweet	Soft	Not juicy	Very good	Obovoid elongated	Creamish
Col.044	Oblong	SYP (37A)	Soft	Red with light green tip	White	Acid sweet	Soft	Juicy	Very good	Obovoid	Creamish
Col.045	Oblong	LGY (3D)	Soft	Yellow	White	Acid sweet	Soft	Not juicy	Very good	Oblong	Creamish
Col.046	Oblong	SYP (37A)	Soft	Red with light green tip	White	Sweet	Soft	Juicy	Medium	Obovoid	Creamish
Col.047	Oblong	SYP (37A)	Soft	Red with light green tip	White	Sweet	Soft	Juicy	Very good	Obovoid	Creamish
Col.048	Oblong	LGY (3D)	Soft	Pink with light green tip	White	Acid sweet	Soft	Not juicy	Medium	Obovoid	Creamish
Col.049	Globose	SRO (40C)	Soft	Red with light green tip	White	Acid sweet	Soft	Not juicy	Very good	Roundish	Creamish
Col.050	Ovoid	SRO (40C)	Soft	Red with light green tip	White	Sweet	Soft	Not juicy	Very good	Obovoid	Creamish
Col.051	Globose	LGY (3D)	Stiff	Light green with pink base	White	Sweet	Soft	Not juicy	Very good	Oblong	Creamish
Col.052	Oblong	SR (45D)	Soft	Red with light green tip	Creamy white	Sweet	Crispy	Not juicy	Poor	Obovoid	Creamish
Col.053	Oblong	SR (45D)	Soft	Red with light green tip	Creamy white	Sweet	Crispy	Not juicy	Poor	Obovoid elongated	Creamish
Col.054	Oblong	DR (59A)	Soft	Red with light green tip	Dull white	Sweet	Crispy	Not juicy	Very good	Obovoid	Creamish
Col.055	Globose	DR (59A)	Soft	Red with light green tip	Dull white	Sweet	Crispy	Juicy	Poor	Obovoid	Creamish
Col.056	Oblong	SRO (40C)	Soft	Red with light green tip	Dull white	Acid sweet	Soft	Juicy	Very good	Obovoid	Creamish
Col.057	Globose	SRO (40C)	Soft	Red with light green tip	Dull white	Acid sweet	Soft	Not juicy	Very good	Obovoid elongated	Creamish

Table 3d. Qualitative fruit characters of rambutan collections (058 to 075) as per IPGRI crop descriptor

Collections	Fruit shape	Rind colour	Spine texture	Spine colour	Aril colour	Aril taste	Aril texture	Aril juiciness	Attachment of aril to seed	Seed shape	Seed coat colour
Col.058	Globose	SRO (40C)	Stiff	Red with light green tip	Dull white	Sweet	Soft	Juicy	Very good	Oblong	Creamish
Col.059	Oblong	DPR (61A)	Soft	Red with light green tip	Dull white	Acid sweet	Soft	Juicy	Very good	Obovoid	Creamish
Col.060	Globose	DPR (61A)	Soft	Red	Dull white	Sweet	Soft	Not juicy	Very good	Roundish	Creamish
Col.061	Oblong	DPR (61A)	Soft	Red	Dull white	Sweet	Soft	Very juicy	Medium	Obovoid elongated	Creamish
Col.062	Oblong	SYP (37A)	Soft	Red with light green tip	Dull white	Acid sweet	Soft	Juicy	Very good	Obovoid elongated	Creamish
Col.063	Ovoid	DPR (61A)	Soft	Red	Dull white	Sweet	Crispy	Juicy	Poor	Obovoid	Creamish
Col.064	Oblong	VR (46B)	Soft	Red with light green tip	Dull white	Acid sweet	Firm	Very juicy	Very good	Oblong	Creamish
Col.065	Globose	VR (46B)	Soft	Red	Dull white	Sweet	Crispy	Juicy	Medium	Oblong	Creamish
Col.066	Oblong	SYP (37A)	Soft	Red with light green tip	Dull white	Acid sweet	Soft	Juicy	Very good	Oblong	Creamish
Col.067	Oblong	SYP (37A)	Soft	Red with light green tip	Dull white	Acid sweet	Soft	Juicy	Very good	Oblong	Creamish
Col.068	Globose	PY (12D)	Stiff	Red with light green tip	Dull white	Acid sweet	Crispy	Not juicy	Poor	Oblong	Creamish
Col.069	Globose	SR (45D)	Stiff	Red with light green tip	Dull white	Acid sweet	Crispy	Not juicy	Poor	Roundish	Creamish
Col.070	Oblong	SR (45D)	Stiff	Red with light green tip	Dull white	Insipid	Crispy	Not juicy	Poor	Obovoid elongated	Creamish
Col.071	Globose	SR (45D)	Stiff	Red with light green tip	Dull white	Sweet	Crispy	Juicy	Poor	Roundish	Creamish
Col.072	Globose	SRO (40C)	Soft	Red with light green tip	Dull white	Sweet	Crispy	Juicy	Poor	Obovoid elongated	Creamish
Col.073	Oblong	SRO (40C)	Soft	Red with light green tip	Dull white	Sweet	Crispy	Juicy	Poor	Obovoid elongated	Creamish
Col.074	Oblong	SRO (40C)	Soft	Red with light green tip	Dull white	Sweet	Crispy	Not juicy	Poor	Obovoid elongated	Creamish
Col.075	Oblong	SR (45D)	Stiff	Red with light green tip	Dull white	Sweet	Crispy	Not juicy	Poor	Obovoid	Creamish

Table 3e. Qualitative fruit characters of rambutan collections (076 to 093) as per IPGRI crop descriptor

Collections	Fruit shape	Rind colour	Spine texture	Spine colour	Aril colour	Aril taste	Aril texture	Aril juiciness	Attachment of aril to seed	Seed shape	Seed coat colour
Col.076	Ovoid	PY (12D)	Stiff	Yellow	Dull white	Sweet	Crispy	Not juicy	Medium	Obovoid elongated	Creamish
Col.077	Oblong	SRO (40C)	Soft	Red with light green tip	Dull white	Sweet	Crispy	Not juicy	Medium	Obovoid elongated	Creamish
Col.078	Oblong	VR (46B)	Soft	Red with light green tip	Dull white	Sweet	Crispy	Not juicy	Medium	Obovoid elongated	Creamish
Col.079	Oblong	VR (46B)	Soft	Red with light green tip	White	Sweet	Soft	Not juicy	Very good	Obovoid	Creamish
Col.080	Oblong	SYP (37A)	Soft	Red with light green tip	Creamy white	Sweet	Crispy	Not juicy	Medium	Oblong	Creamish
Col.081	Oblong	SRO (40C)	Soft	Red with light green tip	Dull white	Acid sweet	Soft	Not juicy	Very good	Obovoid	Creamish
Col.082	Ovoid	VR (46B)	Soft	Red with light green tip	Dull white	Acid	Soft	Not juicy	Medium	Obovoid elongated	Creamish
Col.083	Oblong	SRO (40C)	Soft	Red with light green tip	Dull white	Sweet	Crispy	Not juicy	Medium	Oblong	Creamish
Col.084	Oblong	SRO (40C)	Soft	Red with light green tip	Dull white	Acid sweet	Soft	Very juicy	Very good	Oblong	Creamish
Col.085	Oblong	VR (46B)	Soft	Red with light green tip	Dull white	Sweet	Crispy	Juicy	Very good	Obovoid	Creamish
Col.086	Oblong	VR (46B)	Soft	Red with light green tip	Dull white	Sweet	Crispy	Juicy	Very good	Oblong	Creamish
Col.087	Globose	VR (46B)	Soft	Red with light green tip	Dull white	Sweet	Crispy	Not juicy	Good	Irregular	Creamish
Col.088	Oblong	SRO (40C)	Soft	Red with light green tip	White	Acid sweet	Soft	Juicy	Very good	Oblong	Creamish
Col.089	Oblong	SRO (40C)	Soft	Red with light green tip	White	Acid sweet	Soft	Not juicy	Very good	Oblong	Creamish
Col.090	Oblong	VR (46B)	Soft	Red with light green tip	Dull white	Sweet	Soft	Juicy	Very good	Oblong	Creamish
Col.091	Oblong	SYP (37A)	Soft	Red with light green tip	Dull white	Sweet	Soft	Juicy	Very good	Obovoid	Creamish
Col.092	Globose	DR (59A)	Soft	Red with light green tip	Dull white	Acid sweet	Crispy	Not juicy	Very good	Obovoid	Creamish
Col.093	Oblong	SRO (40C)	Soft	Red with light green tip	Dull white	Sweet	Crispy	Juicy	Very good	Obovoid elongated	Creamish

Table 3f. Qualitative fruit characters of rambutan collections (094 to 100) as per IPGRI crop descriptor

Collections	Fruit shape	Rind colour	Spine texture	Spine colour	Aril colour	Aril taste	Aril texture	Aril juiciness	Attachment of aril to seed	Seed shape	Seed coat colour
Col.094	Globose	LGY (3D)	Soft	Yellow	Dull white	Insipid	Crispy	Juicy	Medium	Obovoid	Creamish
Col.095	Globose	SYP (37A)	Soft	Red with light green tip	White	Acid	Soft	Not juicy	Very good	Obovoid	Creamish
Col.096	Oblong	SR (45D)	Stiff	Red with light green tip	Dull white	Sweet	Crispy	Not juicy	Medium	Obovoid	Creamish
Col.097	Globose	SRO (40C)	Stiff	Red with light green tip	Dull white	Sweet	Firm	Not juicy	Very good	Roundish	Creamish
Col.098	Oblong	SRO (40C)	Soft	Red with light green tip	Dull white	Sweet	Soft	Juicy	Very good	Obovoid	Creamish
Col.099	Globose	SRO (40C)	Soft	Red	White	Sweet	Soft	Juicy	Very good	Roundish	Creamish
Col.100	Oblong	VR (46B)	Soft	Red with light green tip	Dull white	Sweet	Crispy	Not juicy	Very good	Oblong	Creamish

4.1.3.10 Rind thickness

Rind thickness varied between 2 mm and 7 mm with the highest value in Col.037 and lowest value in Col.046.

4.1.3.11 Rind weight

Rind weight ranged from 4.87 g to 33.75 g. Col.052 showed maximum rind weight while Col.012 showed the minimum value.

4.1.3.12 Spine length

Spine length varied between 6 mm and 22 mm. The maximum spine length was noticed in Col.034 and minimum in Col.006.

4.1.3.13 Spine texture

Most of the collections (82.65%) possessed soft textured spines whereas 17.35% of the collections exhibited stiff spines.

4.1.3.14 Spine density

The density of spine in 2m x 2m area varied between 12 and 45 with the highest density in Col.030 and the lowest in Col.052.

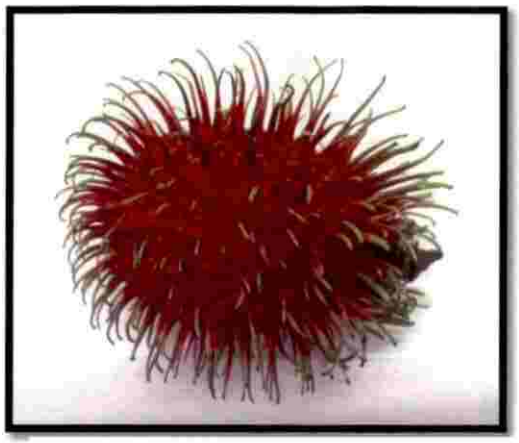
4.1.3.15 Spine colour

Spine colour varied widely among the collections. The predominant spine colour observed was red with light green tip (79.59%) followed by red (7.14%), yellow (4.08%), light green (4.08), light green with pink base (4.08%) and pink with light green tip (1.02%).

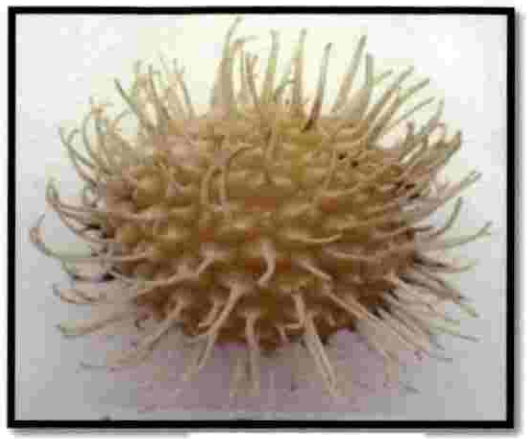
4.1.3.16 Aril weight

Aril weight varied from 2.2 g to 21 g. Among the collections, highest aril weight was found in Col.052 while Col.008 recorded the lowest aril weight.

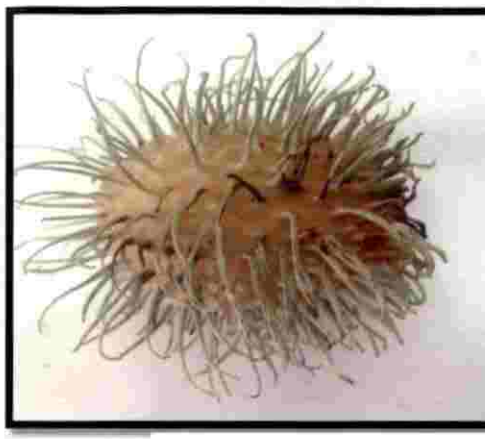
Red



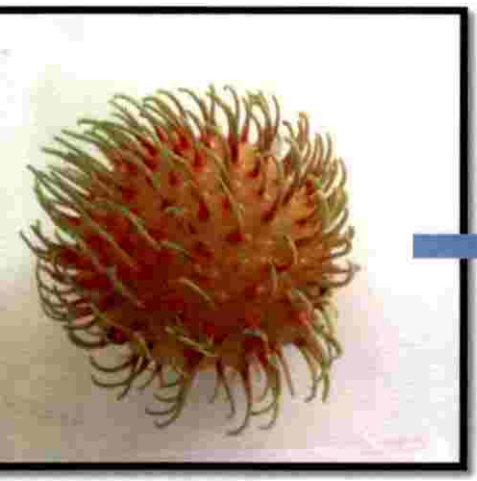
Red with light green tip



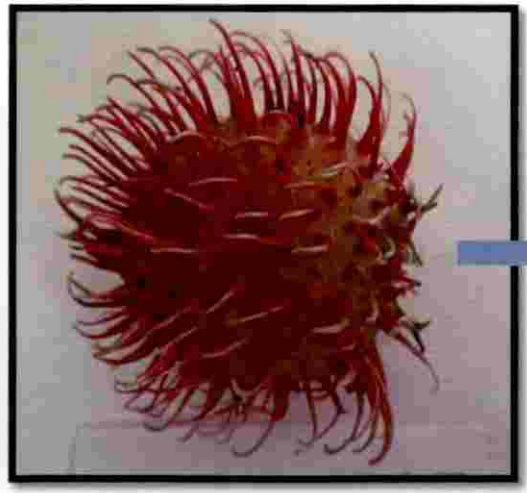
Yellow



Light green



Light green with pink base



Pink with light green tip

Plate 14. Spine colour of rambutan collections

Dense

Medium

Sparse

Plate 15. Spine density of rambutan collections

4.1.3.17 Aril colour

Three types of aril colour were found among the collections namely white, creamy white and dull white. Dull white aril was observed in 57.14% of the collections followed by white (28.57%) and creamy white (14.29%).

4.1.3.18 Aril thickness

Aril thickness varied from 3 mm to 10 mm. Col.061, Col.072 and Col.096 had the maximum aril thickness while Col.008 showed the lowest aril thickness.

4.1.3.19 Aril texture

Regarding the aril texture, 55.1% of the collections had soft aril, 39.8% of the collections had crispy aril and 5.1% of the collections were with firm texture.

4.1.3.20 Aril taste

The collections varied in aril taste from insipid to sweet. Among the collections, 59.18% produced fruits which were sweet types, 32.65% acid sweet types, 6.12% were of acidic aril and 2.04% with insipid taste.

4.1.3.21 Aril juiciness

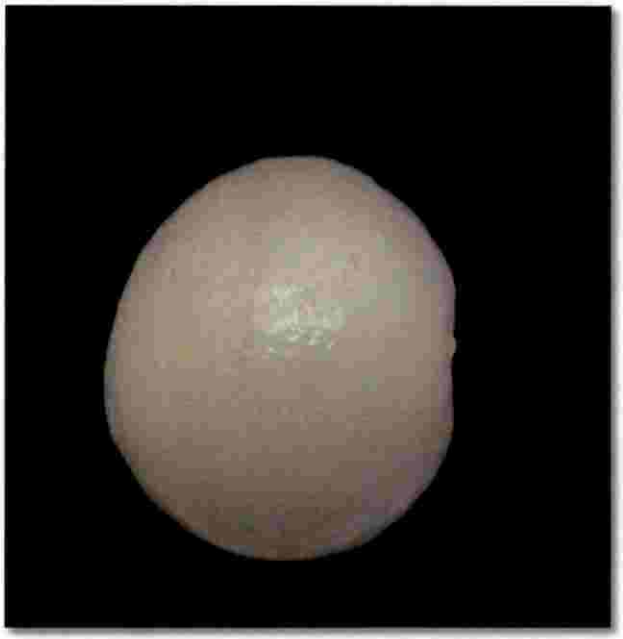
With regard to aril juiciness, 8.16% of the collections produced fruits which could be characterized as very juicy types, 47.99% were juicy type and 43.88% were non-juicy type.

4.1.3.22 Attachment of aril to seed

Free seed aril was observed only in 19.39% of the collections (poor attachment), while the attachment was medium in 16.33% of the collections. Adherence of aril to seed was very good (very strong) in 61.22% of the collections and good in 3.06 % of the collections.

4.1.3.23 Seed length

Seed length ranged from 2 cm to 4 cm. The maximum seed length recorded was in Col.027 and the lowest in Col.015.

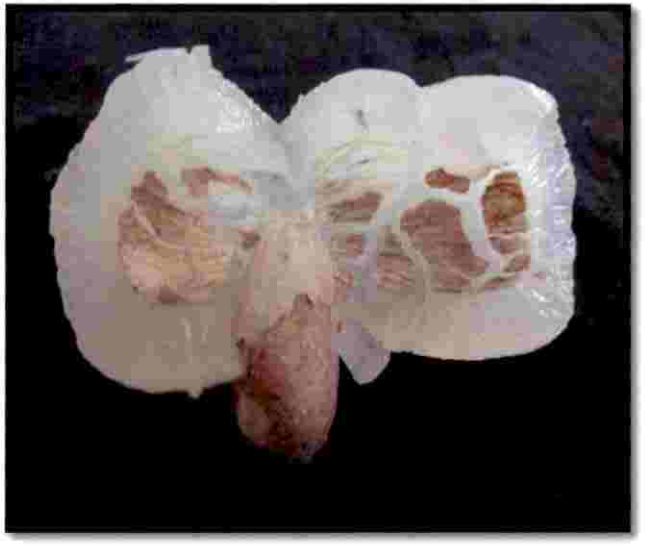


White

Creamy white

Dull white

Plate 16. Aril colour in rambutan collections



Poor (Free stone aril)

Medium

Good

Very Good

4.1.3.24 Seed width

Seed width varied from 1 cm to 2.2 cm with the highest value of 2.2 cm being observed in five collections (Col.008, Col.023, Col.081, Col.094 and Col.098) and the lowest value in Col.016.

4.1.3.25 Seed weight

The maximum seed weight of 4.3 g was recorded in Col.023 whereas the minimum seed weight of 1.45 g was observed in Col.072.

4.1.3.26 Seed shape

Different seed shapes were observed among the collections *viz.*, roundish, obovoid, obovoid elongated, oblong and irregular. Of these obovoid seed shape accounted for 35.71% of the collections, oblong shaped seeds in 27.55% of the collections, 24.49% of the collections with obovoid elongated seeds, 10.20% of the collections were roundish and 2.04% of the collections were irregular shaped.

4.1.3.27 Seed coat colour

With regard to seed coat colour, all the collections were invariably creamish.

4.1.3.28 Aril to fruit ratio

The largest edible portion (aril to fruit ratio) was recorded in Col.072 (0.52), whereas the lowest aril to fruit ratio (0.15) was in Col.008.

4.1.3.29 Seed to fruit ratio

Regarding the seed to fruit ratio, Col.020, Col.021 and Col.072 recorded the lowest value of 0.05 and the highest value of 0.26 was recorded in Col.008.

4.1.3.30 Seed to aril ratio

Seed to aril ratio ranged from 0.09 to 1.76. The maximum ratio was found in Col.008 and the minimum ratio in Col.072.

Roundish

Oblong

Obovoid

Obovoid elongated

Irregular

16

Table 4a. Quantitative fruit characters of rambutan collections (001-028) as per IPGRI crop descriptor

Collections	% fruit set	Length of fruit bunch (cm)	No. of fruits per bunch	Fruit length (cm)	Fruit diameter (cm)	Fruit weight (g)	Rind thick-ness (mm)	Rind weight (g)	Spine length (mm)	Spine density	Aril weight (g)	Aril thick-ness (mm)	Seed length (cm)	Seed width (cm)	Seed weight (g)	Aril to fruit ratio	Seed to fruit ratio	Seed to aril ratio	Shelf life (days)
Col.001	27	25	32	5.5	3.2	28	5	17	11	32	7	5	3	1.6	1.79	0.25	0.06	0.26	3
Col.002	18	28	25	4.5	3.1	25.4	5	12.67	0.7	20	8	7	2.8	1.8	2.78	0.31	0.11	0.35	4
Col.004	25	32	38	6	3.2	25	4	13.38	12	15	7	5	2.5	1.6	2.26	0.28	0.09	0.32	4
Col.005	18	30	18	5.5	2.7	23.6	4	11.2	13	32	7.2	6	3	1.8	3	0.31	0.13	0.42	4
Col.006	20	23	13	4.5	2.6	19.6	4	9.5	6	17	7.2	6	2.6	1.8	2.76	0.37	0.14	0.38	4
Col.007	22	42	20	5.5	2.9	30	5	17.39	8	19	7.5	6	2.6	1.8	2.82	0.25	0.09	0.38	4
Col.008	29	35	18	5	2.5	15	3	6.73	7	19	2.2	3	3.1	2.2	3.87	0.15	0.26	1.76	4
Col.009	28	40	30	4	2.5	15	3	6.73	7	23	5.2	5	2.2	1.4	1.53	0.35	0.10	0.29	3
Col.010	19	26	28	5	2	24	4	14.12	7	24	7.1	5	3	1.5	2	0.30	0.08	0.28	4
Col.012	28	23	15	3.5	2.5	12	3	4.87	7	15	4.17	4	2.2	1.2	1.83	0.35	0.15	0.44	4
Col.013	20	28	23	4	2.4	12	4	5.58	6	27	3.1	4	2.1	1.6	2.19	0.26	0.18	0.71	3
Col.014	30	30	21	6	3.2	34	4	12	16	15	9.5	6	3	1.5	2.76	0.28	0.08	0.29	3
Col.015	18	35	23	4	2.4	14.5	3	6	10	23	5.4	5	2	1.2	1.84	0.37	0.13	0.34	4
Col.016	32	28	32	6	3	26.5	4	12.5	15	18	9.5	6	3	1	2.19	0.36	0.08	0.22	4
Col.017	20	26	34	4.5	3	19	3	8.4	8	25	7.2	7	2.6	1.2	1.74	0.38	0.09	0.24	4
Col.018	18	23	17	5.5	3	28	3	13	14	25	10	6	3	1.8	2.52	0.36	0.09	0.25	4
Col.019	18	31	15	6	3.7	40.5	4	20	12	22	15.47	7	3.5	1.5	2.57	0.38	0.06	0.17	4
Col.020	19	38	23	6	3.4	40.2	5	21.6	9	19	11	8	2.8	1.1	1.9	0.27	0.05	0.17	4
Col.021	20	22	27	7	3.7	52	5	27.65	13	26	19	7	3.3	1.5	2.72	0.37	0.05	0.14	4
Col.022	25	41	31	6	4	45	4	21.8	12	21	18	6	3.5	1.8	3.25	0.40	0.07	0.18	4
Col.023	28	36	24	5	4.2	45.5	5	19.2	13	17	18.5	7	3	2.2	4.3	0.41	0.09	0.23	4
Col.024	28	41	28	5	3.4	28.7	5	14.6	12	17	8.96	4	3	1.8	3.37	0.31	0.12	0.38	4
Col.025	16	23	27	5	3.7	30.6	4	12.26	14	23	13	7	3	1.7	3	0.42	0.10	0.23	4
Col.026	28	40	33	5.5	2.8	25.6	3	14.03	12	30	6.7	5	2.7	1.9	2.26	0.26	0.09	0.34	4
Col.027	20	28	31	6.6	4	47.5	6	25.36	11	26	16.7	9	4	1.8	3	0.35	0.06	0.18	4
Col.028	15	30	22	5	3.6	36.6	4	15.5	16	35	16.7	9	2.6	1.9	3.25	0.46	0.09	0.19	4

Table 4b. Quantitative fruit characters of rambutan collections (029-054) as per IPGRI crop descriptor

Collections	% fruit set	Length of fruit bunch (cm)	No. of fruits per bunch	Fruit length (cm)	Fruit diameter (cm)	Fruit weight (g)	Rind thick-ness (mm)	Rind weight (g)	Spine length (mm)	Spine density	Aril weight (g)	Aril thick-ness (mm)	Seed length (cm)	Seed width (cm)	Seed weight (g)	Aril to fruit ratio	Seed to fruit ratio	Seed to aril ratio	Shelf life (days)
Col.029	18	35	28	4	2.3	12.5	3	6.14	10	32	3.2	4	2.2	1.3	1.86	0.26	0.15	0.58	4
Col.030	15	38	13	4	2.3	20	4	10.2	10	45	5	4	2.6	1.8	2.5	0.25	0.13	0.50	4
Col.031	18	26	17	5	3.1	27.4	4	14	13	25	9.5	6	3	1.7	2.57	0.35	0.09	0.27	4
Col.032	25	23	32	4.5	2.9	21.6	4	9.65	9	28	8.14	5	2.7	1.5	2.38	0.38	0.11	0.29	4
Col.033	12	26	13	5	3.3	32.2	4	14.4	13	25	13.5	8	2.5	1.8	2.64	0.42	0.08	0.20	4
Col.034	18	38	20	5.5	3.6	33.5	5	18.4	22	29	10.5	7	3.2	2.1	3.2	0.31	0.10	0.30	4
Col.035	20	30	18	4.5	3.1	20	4	8.98	10	21	5	5	2.7	1.7	2	0.25	0.10	0.40	4
Col.036	29	35	33	4	3.2	20.28	5	9.73	8	28	5.7	5	2.5	2	2.74	0.28	0.14	0.48	4
Col.037	20	32	25	5	3	23.08	7	15.25	10	24	10.2	9	2.3	1.8	2.29	0.44	0.10	0.22	4
Col.038	18	23	23	4.5	3.1	26.8	5	13.92	8	25	8.5	6	2.6	1.8	2.29	0.32	0.09	0.27	4
Col.039	22	26	32	5.5	3.4	42	4	15	18	32	16	8	3.2	1.6	2.86	0.38	0.07	0.18	4
Col.040	28	32	18	4.2	3.2	28	3	12	13	32	11.5	9	2.7	2.1	3.67	0.41	0.13	0.32	4
Col.041	28	26	30	4	3.1	20	3	7	18	44	6	6	2.4	1.6	2.23	0.30	0.11	0.37	4
Col.042	30	35	25	5	3.2	22.5	3	8.64	12	25	9.6	6	2.3	2	2.86	0.43	0.13	0.30	4
Col.043	20	22	18	6	3.3	32.59	4	15.02	16	27	12	7	3.5	1.6	3.63	0.37	0.11	0.30	4
Col.044	22	42	15	5	2.7	25.41	4	15.18	9	23	5.5	4	2.5	1.5	2.28	0.22	0.09	0.41	4
Col.045	27	45	30	5	3.4	29.5	4	13.64	13	23	10	7	3.1	1.9	3.78	0.34	0.13	0.38	3
Col.046	18	25	25	4.5	3.3	25.36	2	9.85	14	23	10.5	7	2.7	1.7	2.9	0.41	0.11	0.28	4
Col.047	20	30	18	4.4	3.1	22.72	3	10.53	14	25	8.3	6	2.7	1.7	2.4	0.37	0.11	0.29	4
Col.048	15	22	18	4.2	3	17.6	3	7.93	12	29	6.5	5	2.7	1.7	2.08	0.37	0.12	0.32	4
Col.049	15	25	13	4	3.3	19.25	4	8.45	14	40	7.6	6	2.3	1.8	2.19	0.39	0.11	0.29	3
Col.050	30	32	24	4.5	3	22.67	5	12.52	17	40	6.5	6	2.8	1.8	2.5	0.29	0.11	0.38	4
Col.051	22	38	23	4	2.7	16	4	7.44	11	38	5	7	2.5	1.8	2.31	0.31	0.14	0.46	4
Col.052	20	40	25	7.5	4	61.5	6	33.75	13	12	21	9	3.5	2	4.24	0.34	0.07	0.20	4
Col.053	30	26	33	6.5	3.7	45	5	22.97	14	19	16.2	8	3.6	1.8	3.38	0.36	0.08	0.21	4
Col.054	18	48	25	5	3.8	35	4	16.7	12	25	11.2	6	3.2	2	4	0.32	0.11	0.36	3

Table 4c. Quantitative fruit characters of rambutan collections (055-080) as per IPGRI crop descriptor

Collections	% fruit set	Length of fruit bunch (cm)	No. of fruits per bunch	Fruit length (cm)	Fruit diameter (cm)	Fruit weight (g)	Rind thick-ness (mm)	Rind weight (g)	Spine length (mm)	Spine density	Aril weight (g)	Aril thick-ness (mm)	Seed length (cm)	Seed width (cm)	Seed weight (g)	Aril to fruit ratio	Seed to fruit ratio	Seed to aril ratio	Shelf life (days)
Col.055	20	26	25	5	3.8	44	4	19.5	11	22	19.2	9	3	2	3.1	0.44	0.07	0.16	3
Col.056	30	28	33	5.5	3.3	39.3	4	18.22	13	40	15.5	9	2.8	2.1	3.44	0.39	0.09	0.22	4
Col.057	18	35	30	5	3.5	37.3	4	14.35	14	32	14.5	9	3.2	2.1	3.64	0.39	0.10	0.25	4
Col.058	32	30	15	4.3	3.2	24.5	3	10.79	9	12	10.5	8	2.6	1.8	2.98	0.43	0.12	0.28	4
Col.059	27	48	20	5	3.6	31.8	3	13.92	14	18	15	8	3.1	2.1	2.98	0.47	0.09	0.20	4
Col.060	18	45	24	4.5	3.4	24.6	3	11.8	12	30	8.5	6	2.7	2.1	3.42	0.35	0.14	0.40	4
Col.061	25	42	30	5	3	32.23	4	11.1	13	32	12	10	3	1.7	2.72	0.37	0.08	0.23	4
Col.062	18	40	17	5.5	2.8	28.76	4	13.83	17	24	10	6	3	1.8	2.91	0.35	0.10	0.29	3
Col.063	20	41	23	5.6	3.2	42.18	4	15.5	19	16	14.4	8	3.1	1.6	3.7	0.34	0.09	0.26	4
Col.064	22	38	18	5.5	3.6	34.88	4	14.45	21	30	11	6	2.7	1.8	2.71	0.32	0.08	0.25	4
Col.065	22	35	20	4.5	3.9	30.62	4	14.5	13	21	14.5	8	2.8	2	3.83	0.47	0.13	0.26	3
Col.066	28	20	25	5	3.5	30.81	4	13	15	26	7.2	7	2.6	2	3.45	0.23	0.11	0.48	4
Col.067	28	28	30	4.5	3.1	22.67	4	10.22	9	35	9.6	6	2.5	1.8	2.9	0.42	0.13	0.30	4
Col.068	28	23	32	4.5	3.7	32.5	5	14.36	10	30	12.6	5	2.4	1.7	2.6	0.39	0.08	0.21	3
Col.069	20	25	28	5	3.5	34.8	4	15.43	12	30	14.1	6	2.6	1.9	3.02	0.41	0.09	0.21	3
Col.070	25	35	15	5.5	3.4	30.2	4	13.74	13	37	11.4	6	2.6	1.6	2.22	0.38	0.07	0.19	3
Col.071	12	26	16	4.5	3.5	27.7	4	11.15	17	40	11.5	7	2.5	1.8	2.2	0.42	0.08	0.19	4
Col.072	28	38	20	4.5	3.7	30.35	3	9.91	11	25	15.6	10	2.3	1.6	1.45	0.51	0.05	0.09	4
Col.073	26	30	22	4.5	3.5	29.5	3	9.17	16	26	14.3	7	3	1.8	2.91	0.48	0.10	0.20	4
Col.074	12	40	18	5	3.2	30.7	4	11.6	17	27	14	7	2.5	1.7	2.21	0.46	0.07	0.16	4
Col.075	25	22	16	4.5	3.3	24.4	4	9.72	12	36	9.8	6	2.5	1.9	2.53	0.40	0.10	0.26	4
Col.076	22	42	32	6	3.4	37	6	21.5	15	30	11	8	3.2	1.7	3.13	0.30	0.08	0.28	3
Col.077	15	38	13	4.5	3.1	20	3	9	14	42	5.54	5	2.8	1.8	3.23	0.28	0.16	0.58	4
Col.078	25	30	20	4.5	2.9	17.5	3	7.76	14	33	5.62	4	2.8	1.6	2.27	0.32	0.13	0.40	4
Col.079	26	24	28	5	3.2	28.1	5	13.1	10	22	10.3	7	3	1.9	2.75	0.37	0.10	0.27	4
Col.080	25	26	30	4.2	3	20.17	4	9.11	11	25	6.2	5	3	2	3.5	0.31	0.17	0.56	3

Table 4d. Quantitative fruit characters of rambutan collections (081-100) as per IPGRI crop descriptor

Collections	% fruit set	Length of fruit bunch (cm)	No. of fruits per bunch	Fruit length (cm)	Fruit diameter (cm)	Fruit weight (g)	Rind thick-ness (mm)	Rind weight (g)	Spine length (mm)	Spine density	Aril weight (g)	Aril thick-ness (mm)	Seed length (cm)	Seed width (cm)	Seed weight (g)	Aril to fruit ratio	Seed to fruit ratio	Seed to aril ratio	Shelf life (days)
Col.081	28	35	32	5	3.6	32.56	4	12.4	13	32	15	8	3	2.2	3.57	0.46	0.11	0.24	4
Col.082	26	28	18	4.6	3	29.5	3	12.5	10	23	10	6	3	1.8	3.09	0.34	0.10	0.31	4
Col.083	20	28	25	5.6	3.3	42.3	3	14.2	12	30	11	7	3.2	1.8	3.92	0.26	0.09	0.36	4
Col.084	28	28	15	4.3	3.6	22.18	3	18.4	11	33	16	5	2.6	1.8	2.92	0.36	0.13	0.37	4
Col.085	18	32	14	4.4	3.4	40.2	5	9	14	35	8.5	5	3.2	2	3.47	0.21	0.09	0.41	3
Col.086	32	32	25	4	3	43	5	25	18	39	15.5	8	3.2	1.8	3.5	0.36	0.08	0.23	4
Col.087	27	22	25	3.9	3.7	16.53	4	21	13	26	5	4	2.3	1.2	3.1	0.30	0.19	0.62	4
Col.088	15	42	21	5.5	3.3	19.5	4	5	9	22	7	6	2.6	1.8	3.6	0.36	0.18	0.51	3
Col.089	20	25	18	5.2	3.4	21.09	5	7	7	28	7	5	2.5	1.8	3.4	0.33	0.16	0.49	3
Col.090	20	35	18	5.2	3.1	17.24	3	7.2	10	24	5.5	5	2.7	1.8	2.86	0.32	0.17	0.52	4
Col.091	16	30	12	5.3	3.5	22.23	4	7	13	32	8.1	6	2.6	1.6	1.94	0.36	0.09	0.24	4
Col.092	20	26	20	5.2	4	15.12	5	5.3	16	36	4	5	2.5	1.9	3.5	0.26	0.23	0.88	4
Col.093	27	42	15	4.5	3.6	31	3	12	15	25	10	6	2.5	1.7	3.8	0.32	0.12	0.38	4
Col.094	28	32	18	4.1	3.4	24.1	3	11	14	29	8	6	3	2.2	3.7	0.33	0.15	0.46	4
Col.095	19	25	35	4	2.9	24	4	9.8	14	20	7.9	6	2.6	2	3.05	0.33	0.13	0.39	3
Col.096	25	22	33	5.5	4	38.6	5	19	14	23	15	10	2.6	1.7	2.8	0.39	0.07	0.19	4
Col.097	20	35	30	4.5	3.4	28	4	11.85	15	25	11.5	9	2.6	1.9	2.9	0.41	0.10	0.25	4
Col.098	30	35	28	4.5	3	26.7	4	12	14	27	11	7	3.1	2.2	3.85	0.41	0.14	0.35	4
Col.099	35	30	20	4	3	18	3	7.51	13	32	5	6	2.1	1.7	2.25	0.28	0.13	0.45	4
Col.100	30	28	25	4.5	3.2	26.2	4	11.6	10	23	13	6	2.6	1.8	3.1	0.38	0.12	0.31	3

4.1.3.31 Shelf life

Shelf life of all the collections varied from 3 to 4 days under ambient conditions. Majority of the collections (79.59%) had a shelf life of 4 days.

4.2 Biochemical analysis

Results pertaining to biochemical analysis are furnished in Tables 5a to 5c.

4.2.1 Total soluble solids

Wide variability were observed among the collections with regard to the total soluble solids (TSS), which ranged from 10 to 27.5 °Brix. The highest value of 27.5 °Brix was recorded in Col.061 and the lowest value of 10 °Brix was recorded in Col.010.

4.2.3 Titratable acidity

Titratable acidity ranged from 0.12 to 1.4%. Col.008, Col.020, Col.044 and Col.082 recorded the highest value of 1.4%, whereas Col.094 had the lowest value of 0.12%.

4.2.4 Total sugar

Total sugar content ranged from 10.06 to 18.41% among the collections. Col.061 recorded the highest value of 18.41%, while Col.010 and Col.070 recorded the lowest value of 10.06%.

4.2.5 Reducing sugar

Reducing sugar content varied from 2.08 to 5.98%. The highest value of 5.98% was observed in Col.015 and the lowest value of 2.08% was in Col.070.

4.2.6 Non-reducing sugar

Non-reducing sugar varied from 7.26 to 12.45% with the highest value being recorded in Col.061 and the lowest value in Col.013.

Cracking of rind

Plate 19. Shelf life of rambutan fruits under ambient conditions

Table 5a. Biochemical characters of rambutan collections (001 to 045) as per IPGRI crop descriptor

Collections	TSS (° Brix)	Titrable acidity(%)	Total sugar (%)	Reducing sugar (%)	Non-reducing sugar(%)	Total carotenoids (mg/100g)	Ascorbic acid (mg/100g)
Col.001	19	1.08	13.44	4.86	8.58	0.019	18.18
Col.002	24	0.7	17.22	5.65	11.57	0.021	27.27
Col.004	21.5	0.83	14.76	5.12	9.64	0.026	27.27
Col.005	20	0.7	15.55	5.43	10.12	0.015	27.77
Col.006	21	0.51	14.74	5.12	9.62	0.034	22.22
Col.007	22	0.89	16.02	5.12	10.9	0.019	27.43
Col.008	15	1.4	11.36	3.79	7.57	0.016	18.18
Col.009	19	0.32	13.52	4.8	8.72	0.013	30.16
Col.010	11	0.32	10.06	2.76	7.3	0.016	27.43
Col.012	19	0.25	13.56	4.56	9	0.031	30.16
Col.013	13	1.08	11.02	3.76	7.26	0.019	27.28
Col.014	20	0.83	14.88	5.31	9.57	0.019	27.77
Col.015	26	0.7	17.74	5.98	11.76	0.025	45.45
Col.016	22	0.7	16.04	5.43	10.61	0.032	27.22
Col.017	16	1.02	11.65	4.23	7.42	0.017	22.22
Col.018	20	0.38	14.76	5.14	9.62	0.019	30.16
Col.019	22	0.25	16.09	5.52	10.57	0.022	27.43
Col.020	19.5	1.4	15.12	4.61	10.51	0.036	30.16
Col.021	21	0.83	15.32	5.36	9.96	0.025	27.43
Col.022	21	0.32	14.89	5.24	9.65	0.014	27.28
Col.023	22	0.7	15.45	5.43	10.02	0.029	27.28
Col.024	16	0.51	12.02	4.14	7.88	0.021	18.18
Col.025	19	0.57	13.06	4.63	8.43	0.033	30.16
Col.026	17	0.51	12.94	3.79	9.15	0.026	32.26
Col.027	23	0.38	17.04	5.6	11.44	0.021	27.43
Col.028	22	0.32	17.32	5.41	11.91	0.031	18.18
Col.029	18	0.57	13.25	4.56	8.69	0.019	22.22
Col.030	15.5	1.08	11.45	3.13	8.32	0.025	35.23
Col.031	21	0.89	14.87	5.32	9.55	0.022	27.28
Col.032	21	0.25	14.06	5.21	8.85	0.027	27.43
Col.033	22	0.32	15.04	5.43	9.61	0.017	30.16
Col.034	15.5	0.38	12.09	2.91	9.18	0.035	32.26
Col.035	19	0.51	13.23	4.61	8.62	0.036	22.22
Col.036	17	0.83	13.15	3.94	9.21	0.015	27.43
Col.037	16.5	0.7	11.36	3.42	7.94	0.024	32.26
Col.038	12	1.08	10.95	2.56	8.39	0.019	18.18
Col.039	16	0.7	12.09	3.28	8.81	0.029	35.23
Col.040	21	0.25	14.74	5.32	9.42	0.013	35.23
Col.041	20	1.08	14.88	5.44	9.44	0.013	18.18
Col.042	24	0.64	17.22	5.68	11.54	0.012	26.27
Col.043	16	0.89	11.45	3.67	7.78	0.031	32.26
Col.044	15.5	1.4	11.65	3.58	8.07	0.019	27.28
Col.045	18.8	0.83	13.33	4.68	8.65	0.019	27.43

Table 5b. Biochemical characters of rambutan collections (046 to 088) as per IPGRI crop descriptor

Collections	TSS (° Brix)	Titrable acidity(%)	Total sugar (%)	Reducing sugar (%)	Non-reducing sugar(%)	Total carotenoids (mg/100g)	Ascorbic acid (mg/100g)
Col.046	19.6	0.38	13.63	4.92	8.71	0.021	30.16
Col.047	17.5	0.7	12.81	4.03	8.78	0.026	32.26
Col.048	19	0.51	13.2	4.65	8.55	0.017	35.23
Col.049	22	0.89	16.5	5.43	11.07	0.024	32.26
Col.050	23	0.7	17.03	5.65	11.38	0.023	27.43
Col.051	22	0.51	17.6	5.64	11.96	0.027	22.22
Col.052	15.5	0.51	13.57	3.12	10.45	0.016	28.32
Col.053	15.5	0.51	13.06	3.09	9.97	0.025	32.26
Col.054	22	1.02	16.5	5.45	11.05	0.016	27.28
Col.055	22.2	0.7	17.6	5.51	12.09	0.017	32.26
Col.056	20	0.83	14.88	4.95	9.93	0.023	34.59
Col.057	21	0.7	14.74	4.84	9.9	0.029	22.22
Col.058	21	0.83	14.5	4.76	9.74	0.029	32.26
Col.059	22	0.7	16.04	5.43	10.61	0.013	34.59
Col.060	21	0.64	14.89	5.39	9.5	0.012	27.43
Col.061	27.5	0.64	18.41	5.96	12.45	0.024	34.59
Col.062	22	1.08	16.45	5.49	10.96	0.031	26.27
Col.063	18	0.25	13.23	4.72	8.51	0.023	27.43
Col.064	18.5	0.38	13.67	4.75	8.92	0.030	22.22
Col.065	18	0.89	12.95	4.82	8.13	0.021	35.23
Col.066	17.5	1.02	13.86	3.97	9.89	0.014	26.27
Col.067	20	0.57	15.55	5.03	10.52	0.035	30.16
Col.068	17	1.08	13.22	3.97	9.25	0.012	28.32
Col.069	17	0.51	13.09	4.06	9.03	0.017	32.26
Col.070	10	0.19	10.06	2.08	7.98	0.027	22.22
Col.071	17	0.7	12.65	3.65	9	0.015	27.27
Col.072	22.5	0.7	16.04	5.56	10.48	0.026	18.18
Col.073	20	0.7	15.23	5.48	9.75	0.015	27.77
Col.074	18	1.08	13.23	4.56	8.67	0.024	34.59
Col.075	20	0.38	14.65	4.61	10.04	0.019	28.32
Col.076	21	0.51	14.65	5.39	9.26	0.019	35.23
Col.077	15	0.38	11.65	3.94	7.71	0.021	32.26
Col.078	18	0.38	12.36	4.76	7.6	0.033	32.26
Col.079	18	1.02	13.25	4.83	8.42	0.032	22.22
Col.080	16	0.7	12.68	3.98	8.7	0.011	28.32
Col.081	19	0.83	13.64	4.56	9.08	0.023	27.43
Col.082	13	1.4	10.95	2.76	8.19	0.018	26.27
Col.083	20	0.7	14.88	4.56	10.32	0.027	30.16
Col.084	21	0.7	14.75	5.12	9.63	0.020	32.26
Col.085	19	0.64	13.65	4.53	9.12	0.016	28.32
Col.086	21	0.51	15.32	5.52	9.8	0.020	28.32
Col.087	18	0.57	13.95	4.71	9.24	0.025	34.59
Col.088	20	0.76	14.32	5.16	9.16	0.021	35.23

Table 5c. Biochemical characters of rambutan collections (089to 0100) as per IPGRI crop descriptor

Collections	TSS (° Brix)	Titrable acidity(%)	Total sugar (%)	Reducing sugar (%)	Non-reducing sugar(%)	Total carotenoids (mg/100g)	Ascorbic acid (mg/100g)
Col.089	17	0.89	12.65	4.32	8.33	0.036	34.59
Col.090	21	0.7	14.65	5.16	9.49	0.035	41.44
Col.091	22	0.51	16.24	5.43	10.81	0.024	32.26
Col.092	19.5	0.51	14.25	5.09	9.16	0.027	30.16
Col.093	17	0.76	12.56	4.15	8.41	0.013	28.32
Col.094	14	0.12	11.25	2.46	8.79	0.027	27.77
Col.095	12	0.7	10.54	2.34	8.2	0.024	22.22
Col.096	24	0.7	17.32	5.78	11.54	0.017	28.17
Col.097	20.5	0.57	15.34	5.32	10.02	0.032	35.23
Col.098	23.5	0.7	17.24	5.67	11.57	0.034	41.06
Col.099	24	1.08	17.65	5.93	11.72	0.011	27.43
Col.100	18	0.44	13.62	4.63	8.99	0.022	22.22

100

4.2.7 Total carotenoids

All the collections recorded very low or a meagre content of total carotenoids which ranged from 0.011 to 0.036 mg/100g. Col.020, Col.035 and Col.089 recorded the highest value of 0.036 mg/100g whereas Col.080 and Col.099 recorded the lowest value of 0.011 mg/100g.

4.2.8 Ascorbic acid

Ascorbic acid content varied widely among the collections and ranged from 18.18 to 45.45 mg/100g. The highest content of 45.45 mg/100g was recorded in Col.015, whereas Col.001, Col.008, Col.038 and Col.041 recorded the lowest content of 18.18 mg/100g.

4.3 Sensory evaluation

All the collections were scored for different attributes like appearance, colour, flavour, taste, texture, aril juiciness, adherence of aril to seed and overall acceptability on a 9 point hedonic scale which ranged from dislike extremely (1) to like extremely (9). Hedonic ratings were then converted to rank scores and rank analysis was done by Kendall's coefficient of concordance and total score was tabulated from the mean value of each attribute (Table 6a to 6d)

Among the 98 collections studied, Col.018 (92.63) recorded highest rank for appearance followed by eight collections (Col.015, Col.016, Col.023, Col.033, Col.057, Col.061, Col.066 and Col.096) with a mean rank of 87.13. Col.016, Col.021 and Col.096 recorded highest rank of 86 with regard to colour followed by Col.086 (82.9) and Col.015 (77.7). The highest rank in case of flavour was recorded in Col.021 (87.5) followed by Col.023 (85.5) and Col.005 (83.2). With regard to taste, the highest rank obtained was 91.2 in Col.015, Col.42 and Col.061 which was followed by Col.016 and Col.021 with a mean rank of 85.3 and Col.018 and Col.055 with a mean rank of 85.2. Col.084 (84.9) recorded the highest rank with respect to texture followed by Col.021 and Col.061 with a mean rank of 81.3 and Col.045 with a mean rank of 79.1. With regard to aril juiciness Col.084 (89.6) was most accepted by the panellists followed by Col.026 (89.4) and Col.018 (89.2)

Table 6a. Mean rank scores of sensory evaluation of rambutan collections

Appearance		Colour		Flavour		Aril Taste		Aril Texture		Aril Juiciness		Adherence of aril to seed		Overall acceptability	
Collections	Rank mean	Collections	Rank mean	Collections	Rank mean	Collections	Rank mean	Collections	Rank mean	Collections	Rank mean	Collections	Rank mean	Collections	Rank mean
Col.018	92.63	Col.016	86	Col.021	87.5	Col.015	91.2	Col.084	84.9	Col.084	89.6	Col.087	90.6	Col.021	87.7
Col.015	87.13	Col.021	86	Col.023	85.5	Col.042	91.2	Col.021	81.3	Col.026	89.4	Col.055	90.4	Col.023	87.7
Col.016	87.13	Col.096	86	Col.005	83.2	Col.061	91.2	Col.061	81.3	Col.018	89.2	Col.021	88.8	Col.042	87.7
Col.023	87.13	Col.086	82.9	Col.090	83.1	Col.016	85.3	Col.045	79.1	Col.015	88.7	Col.023	88.8	Col.019	80.7
Col.033	87.13	Col.015	77.7	Col.063	80.1	Col.021	85.3	Col.002	76	Col.020	88.7	Col.042	88.8	Col.033	79.1
Col.057	87.13	Col.057	73.8	Col.061	77.4	Col.018	85.2	Col.095	75.7	Col.061	88.7	Col.071	88.8	Col.059	75.6
Col.061	87.13	Col.063	73.1	Col.046	76.8	Col.055	85.2	Col.046	74	Col.009	85.1	Col.073	88.8	Col.022	73.7
Col.066	87.13	Col.052	72.1	Col.042	74.9	Col.098	85.1	Col.066	72	Col.064	82.7	Col.069	88.7	Col.032	73.7
Col.096	87.13	Col.061	72.1	Col.091	74.8	Col.032	80.9	Col.099	70.9	Col.063	81.2	Col.068	88.2	Col.058	73.7
Col.059	80.75	Col.018	70	Col.004	74.7	Col.099	80.9	Col.020	70.8	Col.006	79.9	Col.034	87.7	Col.064	73.7
Col.042	76.38	Col.054	68.2	Col.047	74.7	Col.027	80.7	Col.075	70.4	Col.085	79	Col.075	86.3	Col.073	73.7
Col.071	76.38	Col.005	67.9	Col.074	74.7	Col.023	78.9	Col.047	68.4	Col.098	78.5	Col.033	86.1	Col.018	73.4
Col.060	76.25	Col.071	67.9	Col.010	74.6	Col.096	78.9	Col.062	68.4	Col.004	77.6	Col.070	85.7	Col.052	73.2
Col.025	74.13	Col.023	67.4	Col.064	74	Col.033	74.2	Col.036	68	Col.047	77.1	Col.074	84.6	Col.053	73.2
Col.056	74.13	Col.053	67.4	Col.086	74	Col.090	72.2	Col.093	67.7	Col.056	76.7	Col.072	84.1	Col.061	73.2
Col.063	73	Col.060	66.3	Col.009	71.3	Col.091	70.2	Col.083	67.6	Col.072	76.7	Col.022	81.8	Col.039	72.7
Col.019	71.5	Col.041	64.4	Col.077	71.3	Col.020	70.1	Col.067	66.2	Col.059	75.9	Col.052	81	Col.040	70.7
Col.034	70.63	Col.043	62.5	Col.006	70	Col.050	69.8	Col.077	63.1	Col.017	74	Col.053	81	Col.065	70.7
Col.051	70.63	Col.065	62.2	Col.017	69.3	Col. 002	69.7	Col.074	63	Col.090	72.3	Col.061	81	Col.027	69.7
Col.040	70.5	Col.032	62.1	Col.072	69.3	Col.051	68.1	Col.059	62.6	Col.046	72.2	Col.039	79.2	Col.035	69.3
Col.043	69.5	Col.055	61.9	Col.089	68.3	Col.073	67.2	Col.022	61.4	Col.094	72.2	Col.082	78.6	Col.056	69
Col.017	68.38	Col.064	61.8	Col.015	68.2	Col.028	67.1	Col.073	61	Col.067	71.6	Col.040	76.6	Col.072	69
Col.031	65.13	Col.031	60.6	Col.031	68.1	Col.058	65.9	Col.031	60.4	Col.016	70.3	Col.016	72.3	Col.083	69
Col.045	65.13	Col.051	59.7	Col.035	68.1	Col.014	65.7	Col.032	60.4	Col.021	70.3	Col.020	72.3	Col.028	65.6
Col.049	65.13	Col.056	59.7	Col.016	67.8	Col.022	65.5	Col.039	60.4	Col.019	69.5	Col.096	72.3	Col.075	65.3
Col.097	65.13	Col.036	59	Col.020	67.8	Col.035	65.5	Col.058	60.4	Col.093	69.5	Col.076	72	Col.031	64.9

Table 6b. Mean rank scores of sensory evaluation of rambutan collections

Appearance		Colour		Flavour		Aril Taste		Aril Texture		Aril Juiciness		Adherence of aril to seed		Overall acceptability	
Collections	Rank mean	Collections	Rank mean	Collections	Rank mean	Collections	Rank mean	Collections	Rank mean	Collections	Rank mean	Collections	Rank mean	Collections	Rank mean
Col.099	65.13	**Col.097**	57.3	**Col.041**	67.7	**Col.040**	65.5	**Col.065**	60.4	**Col.055**	67	**Col.083**	72	**Col.057**	64.9
Col.028	64.75	**Col.098**	57.3	**Col.084**	67.3	**Col.064**	61.3	**Col.071**	60.4	**Col.058**	67	**Col.063**	71.5	**Col.050**	63.7
Col.014	63.88	**Col.040**	56.7	**Col.085**	63.6	**Col.060**	61.1	**Col.085**	60.4	**Col.066**	67	**Col.094**	70.2	**Col.055**	63.7
Col.079	63.88	**Col.027**	56.4	**Col.088**	63.6	**Col.041**	60.9	**Col.090**	60.4	**Col.086**	67	**Col.024**	69.8	**Col.071**	62.7
Col.081	63.88	**Col.039**	56.4	**Col.014**	63.5	**Col.019**	60.8	**Col.078**	57.4	**Col.031**	66.6	**Col.046**	69.7	**Col.086**	61.2
Col.089	63.88	**Col.079**	56.4	**Col.007**	62.9	**Col.029**	60.8	**Col.086**	57	**Col.044**	64.1	**Col.077**	68.9	**Col.060**	59.7
Col.092	63.13	**Col.045**	55.7	**Col.030**	62.9	**Col.045**	60.5	**Col.076**	55.7	**Col.035**	64	**Col.080**	68.3	**Col.074**	59.7
Col.009	59.63	**Col.084**	55.7	**Col.098**	62.9	**Col.004**	59.4	**Col.051**	55.3	**Col.099**	63.9	**Col.027**	68.2	**Col.034**	57.6
Col.074	59.63	**Col.069**	55.1	**Col.026**	62.7	**Col.075**	59.2	**Col.064**	55.3	**Col.071**	59.4	**Col.065**	68.2	**Col.007**	57.2
Col.098	58.38	**Col.020**	54.7	**Col.048**	62.7	**Col.065**	59	**Col.098**	55.3	**Col.032**	58.9	**Col.078**	68.2	**Col.015**	57.1
Col.036	57.38	**Col.028**	54.7	**Col.045**	62.6	**Col.054**	56.4	**Col.041**	55.1	**Col.033**	58.8	**Col.048**	67.8	**Col.024**	56.9
Col.058	57.38	**Col.033**	54.7	**Col.099**	62.6	**Col.049**	56.2	**Col.092**	55.1	**Col.065**	58.8	**Col.019**	65.1	**Col.010**	56.2
Col.065	57.38	**Col.029**	54.5	**Col. 002**	62.3	**Col.083**	56.2	**Col.029**	55	**Col.073**	58	**Col.018**	51.6	**Col.046**	55.3
Col.005	56.38	**Col.059**	54	**Col.071**	61.9	**Col.006**	56	**Col.004**	54.6	**Col.014**	57.6	**Col.037**	41.8	**Col.099**	54.3
Col.069	53	**Col.019**	53.5	**Col.040**	61.6	**Col.072**	56	**Col.035**	54.6	**Col.029**	57.6	**Col.044**	41	**Col.051**	53.9
Col.094	53	**Col.044**	53.5	**Col.018**	58.1	**Col.067**	54.8	**Col.037**	54.6	**Col.023**	54.7	**Col.035**	40.5	**Col.062**	53.5
Col.022	52	**Col.004**	53.1	**Col.032**	58.1	**Col.046**	54.7	**Col.040**	54.6	**Col.042**	54.7	**Col.041**	40.5	**Col.067**	53.5
Col.004	51.63	**Col.007**	52.9	**Col.034**	58.1	**Col.086**	54.6	**Col.072**	54.6	**Col.010**	54.3	**Col.045**	40.5	**Col.005**	52.8
Col.021	51	**Col.062**	50.2	**Col.029**	57.2	**Col.005**	53.8	**Col.018**	51.3	**Col.012**	54.3	**Col.007**	40.4	**Col.066**	52.8
Col.048	51	**Col.072**	50.2	**Col.096**	56.9	**Col.007**	53.8	**Col.060**	51.3	**Col.025**	54.3	**Col.091**	40.1	**Col.091**	52.8
Col.073	50.63	**Col.093**	50.2	**Col.033**	56.5	**Col.025**	52.9	**Col.069**	50.3	**Col.091**	54.3	**Col.098**	40.1	**Col.016**	52.6
Col.091	50	**Col.038**	49.6	**Col.050**	56.5	**Col.031**	49.9	**Col.088**	50.3	**Col.007**	54	**Col.031**	37.8	**Col.020**	52.6
Col.035	49.75	**Col.049**	49.6	**Col.095**	56.5	**Col.048**	49.9	**Col.048**	49.8	**Col.027**	54	**Col.062**	37.8	**Col.096**	52.6
Col.012	49.63	**Col.066**	49.6	**Col.022**	56.3	**Col.071**	49.5	**Col.082**	49.8	**Col.062**	53.7	**Col.099**	37.8	**Col.048**	52.5
Col.083	49.63	**Col.085**	49.6	**Col. 001**	55.9	**Col.093**	49.5	**Col.070**	49.7	**Col. 002**	53.6	**Col.025**	37.4	**Col.078**	52.5
Col.075	49.38	**Col.081**	49.3	**Col.056**	55.9	**Col.092**	48. 3	**Col.050**	49.6	**Col.022**	53.4	**Col.056**	37.2	**Col.054**	48.3

Table 6c. Mean rank scores of sensory evaluation of rambutan collections

Appearance		Colour		Flavour		Aril Taste		Aril Texture		Aril Juiciness		Adherence of aril to seed		Overall acceptability	
Collections	Rank mean	Collections	Rank mean	Collections	Rank mean	Collections	Rank mean	Collections	Rank mean	Collections	Rank mean	Collections	Rank mean	Collections	Rank mean
Col.054	45.25	Col.091	49.3	Col.059	55.9	Col.062	48.1	Col.007	49.4	Col.088	53.4	Col.086	37.2	Col.014	47.6
Col.032	44.25	Col.035	48.6	Col.066	55.8	Col.087	48.1	Col.038	48.5	Col.005	52.5	Col.009	36.7	Col.029	47.6
Col.050	44.25	Col.078	48	Col.055	50.1	Col.078	45.2	Col.087	48	Col.028	49	Col.054	36.7	Col.043	47.5
Col.077	43.88	Col.030	47.7	Col.075	50.1	Col.034	45	Col.009	47.9	Col.037	43.7	Col.097	36.7	Col.063	47.5
Col.041	43.25	Col.048	47.7	Col.076	50.1	Col.063	45	Col.033	47.3	Col.079	43.7	Col.010	36.6	Col.026	47.4
Col.084	43.25	Col.017	46.7	Col.019	45	Col.089	45	Col.034	47	Col. 001	41	Col.092	36.4	Col.017	47.3
Col.085	43.25	Col.022	46.7	Col.067	43.5	Col.077	43.4	Col.006	44.7	Col.008	39.2	Col.008	35.9	Col.098	47.2
Col.007	42.88	Col.025	45.9	Col.025	33.9	Col. 001	43.2	Col.017	44.7	Col.092	39.2	Col.081	35.3	Col.006	46.2
Col.027	42.88	Col.075	45.2	Col.028	33.7	Col.059	43.2	Col.094	44.7	Col.045	38.6	Col.060	35.1	Col.077	46.2
Col.038	42.88	Col. 001	42.7	Col.038	32.8	Col.085	43.2	Col. 001	44	Col.057	38.6	Col.049	35	Col. 001	43.8
Col.044	42.25	Col.046	42.5	Col.081	32	Col.009	41.8	Col.026	44	Col.081	38.6	Col.059	35	Col.025	42.7
Col.053	42.25	Col.083	41.6	Col.080	31.3	Col.010	41.8	Col.049	44	Col.030	36.4	Col.047	33.6	Col.036	42.7
Col.078	42.25	Col.100	40.9	Col.024	30.9	Col.024	41.8	Col.091	44	Col.080	35.4	Col.093	32.4	Col.049	42.7
Col.064	37.5	Col.067	38.1	Col.070	30.6	Col.036	41.8	Col.081	43.8	Col.097	35.4	Col.012	32.2	Col.087	42.7
Col.055	37.13	Col.073	38.1	Col.044	29.7	Col.056	41.8	Col.019	43.1	Col.040	35.2	Col.028	31.9	Col.076	42.4
Col.067	37.13	Col.092	37.9	Col.058	29.7	Col.066	41.8	Col.043	43	Col.083	35	Col.029	31.9	Col.068	41.8
Col.072	37.13	Col.006	37.3	Col.060	29.7	Col.052	39.1	Col.097	42.2	Col.089	35	Col.030	31.5	Col.079	41.8
Col.024	35.5	Col.014	37.3	Col.012	27.8	Col.053	39.1	Col.025	42.1	Col.043	31.3	Col. 001	31	Col. 002	41.5
Col.039	35.5	Col.090	37.3	Col.062	27.2	Col.039	38.9	Col.044	41.4	Col.036	30.9	Col.017	31	Col.041	41.5
Col.047	35.5	Col.070	36.7	Col.065	27.2	Col.026	38.7	Col.063	40.8	Col.054	30.5	Col.043	30.4	Col.045	41.5
Col.086	35.5	Col.050	36.6	Col.068	27.2	Col.047	38.7	Col.023	38	Col.076	30.5	Col.085	30.4	Col.047	41.5
Col.090	34.13	Col.089	35.9	Col.073	27.2	Col.074	38.7	Col.005	37.4	Col.095	30.5	Col.013	29.9	Col.085	41.5
Col.029	30.75	Col.042	35.7	Col.094	27.2	Col.076	38.7	Col.010	37.4	Col.082	30.3	Col.050	28.4	Col.097	41.5
Col.062	30.75	Col.076	35	Col.043	26.7	Col.097	38.7	Col.089	37.4	Col.087	30.3	Col. 002	28	Col.004	41
Col.076	29.75	Col.047	34.5	Col.079	26.7	Col.079	37.3	Col.012	36.7	Col.060	29.9	Col.084	27.8	Col.092	40.3
Col.088	29.75	Col.099	33.5	Col.093	26.7	Col.088	34.2	Col.028	36.5	Col.038	28.1	Col.067	27.7	Col.081	37.3

Table 6d. Mean rank scores of sensory evaluation of rambutan collections

Appearance		Colour		Flavour		Aril Taste		Aril Texture		Aril Juiciness		Adherence of aril to seed		Overall acceptability	
Collections	Rank mean	Collections	Rank mean	Collections	Rank mean	Collections	Rank mean	Collections	Rank mean	Collections	Rank mean	Collections	Rank mean	Collections	Rank mean
Col.030	28.75	Col.034	32.9	Col.036	26.6	Col.100	32.3	Col.015	32.7	Col.039	27.3	Col.036	27.2	Col.089	37.2
Col.052	28.75	Col.082	32.9	Col.057	26.6	Col.068	32.2	Col.016	32.7	Col.024	27.1	Col.051	26.6	Col.084	36.1
Col.093	28.75	Col.088	32.9	Col.027	25.6	Col.057	32	Col.052	32.7	Col.096	22.6	Col.005	26.2	Col.093	31.4
Col.080	27.75	Col.095	32.9	Col.087	25.6	Col.070	28	Col.024	32.3	Col.034	20.4	Col.032	26.2	Col.012	30.9
Col. 001	25	Col.008	31	Col.092	25.6	Col.043	26.6	Col.030	32.3	Col.041	19.4	Col.079	24.2	Col.090	30.7
Col.020	24.5	Col.010	30.3	Col.082	25.5	Col.069	22.1	Col.068	31.3	Col.069	17.2	Col.004	23.7	Col.100	28.2
Col.046	23	Col.087	30.2	Col.037	23.2	Col.081	21.3	Col.080	30.7	Col.052	15.1	Col.026	23.4	Col.009	18.1
Col.026	20	Col. 002	29.5	Col.008	23	Col.044	21.1	Col.100	30.1	Col.074	15	Col.090	23.1	Col.037	17.4
Col.006	19.38	Col.013	29.5	Col.039	23	Col.080	15.8	Col.014	27.4	Col.100	15	Col.095	22.9	Col.088	17.4
Col.070	19.38	Col.037	29.5	Col.054	23	Col.094	10.3	Col.056	26	Col.070	14.5	Col.014	22.8	Col.044	11.6
Col.100	18.88	Col.009	29.4	Col.078	23	Col.017	10	Col.013	25.3	Col.078	14.1	Col.100	22.5	Col.030	11.2
Col.037	18.25	Col.026	29.4	Col.097	23	Col.095	8.9	Col.054	25	Col.048	14	Col.038	21.6	Col.094	10.8
Col.008	16.88	Col.058	29.4	Col.069	22.5	Col.030	8.6	Col.055	25	Col.049	14	Col.057	21.2	Col.080	9.8
Col.095	16.75	Col.068	28.8	Col.051	20.8	Col.037	7.9	Col.057	25	Col.068	12.7	Col.089	21.1	Col.013	9.5
Col.010	13.75	Col.012	28.6	Col.100	20.8	Col.013	7.4	Col.079	25	Col.075	12.7	Col.058	20.8	Col.038	8.8
Col.068	12	Col.024	28.6	Col.053	17.1	Col.082	7.4	Col.027	21.1	Col.053	11.7	Col.066	19.7	Col.069	8.8
Col.013	10.13	Col.080	28.6	Col.052	17	Col.008	7.2	Col.042	20.2	Col.077	11.2	Col.015	18	Col.070	8.7
Col.087	7.75	Col.094	28	Col.049	16.8	Col.012	6.6	Col.008	17.7	Col.051	11	Col.064	17	Col.082	5.7
Col.082	7.63	Col.077	27.9	Col.083	16.1	Col.084	5.7	Col.053	13.6	Col.050	9.8	Col.006	16.9	Col.008	4.8
Col. 002	7.5	Col.074	23.7	Col.013	11.2	Col.038	5.1	Col.096	13.6	Col.013	6.4	Col.088	14.3	Col.095	4.7
Kendall's Coefficient	0.135	0.026		0.007		0.012		0.031		0.004		0.062		0.005	

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respectively. Regarding the adherence of aril to seed, Col.087 recorded the highest rank of 90.6 followed by Col.055 (90.4) and five collections (Col.021, Col.023, Col.042, Col.71 and Col.073) with a mean rank of 88.8. In overall acceptability the highest rank of 87.7 was recorded in Col.021, Col.023 and Col.042 followed by Col.019 (80.7) and Col.033 (79.1).

The highest total score (sum of mean value of each attribute) was recorded in Col.061 (60.2) followed by Col.021 (59.4), Col.023 (58) and Col.042 (56) and the lowest total score was recorded in Col.013 (35.2). They were most preferred/accepted by panellists because of their better fruit weight, taste, juiciness and easy detachment of aril from seed. The mean value of each attribute and total score of each collection are given in Appendix IV.

4.4 Major pests and diseases incidence

Observations on major pests and diseases incidence including the causal agent, nature of damage, symptoms etc were taken and recorded the percentage incidence of all these problems (Table 7 and Fig. 9)

4.4.1 Pests incidence

a. Leaf folder (*Thalassodes quadraria*: Geometridae)

Larvae are brownish loopers which fold the new vegetative flush and feed from within. Adults are small greenish moths.

b. Mealy Bug (*Planococcus citri* : Pseudococcidae)

This pest was observed in all the rambutan growing tracts of Kerala. It found both on inflorescence as well as immature and ripe fruits. Both nymphs and adults suck sap from the flowers and fruits. Honey dew secretion of this causes sooty mould. Infested parts became black covered with sooty mould. The affected flowers and fruits fell off. Premature fruit fall seriously hindered the yield.

c. Fruit borer (*Conogethes (Dichocrocis) punctiferalis*: Pyraustidae)

It was observed in rambutan during fruiting season (May-August). Larvae bore into both immature and mature fruits, feeding on the seeds, the aril and rendering them empty and unmarketable. Oozing out of excreta and frass at the mouth of the bore hole is very conspicuous which affects the marketability of even uninfested fruits of the same flower. Adult is a pale, yellowish moth with black spots on both the wings.

d. Fruit webber (*Eublemma anguilifera*: Noctuidae)

Larvae spin webs, sheltered under them and feed on fruits. Pupation takes place in cocoons near at or near the base of the fruit or in nearby branches. The infested fruits may become weak and dry up. It is observed in all the fruits infested with fruit borer (*Conogethes punctiferalis*).

Besides these, other pests of minor importance like fruit fly (*Bactrocera dorsalis*), armored scale of unknown species, lobster caterpillar (*Neostauropus alternus*) *etc* have also been observed during the study.

Among the problems observed, fruit borer (*Conogethes punctiferalis*) and fruit webber (*Eublemma anguilifera*) caused considerable yield loss in major rambutan growing tracts of Kerala.

4.4.2 Disease incidence

a. Fruit rot or Anthracnose (*Colletotrichum gloeosporioides*)

Anthracnose was observed in both harvested and ripened fruit in the field. Anthracnose is an important postharvest disease of rambutan worldwide particularly in high rainfall regions. Symptoms appear as circular, dark brown to black lesions on the fruit rind and fruit becomes unmarketable (O'Hare, 1995).

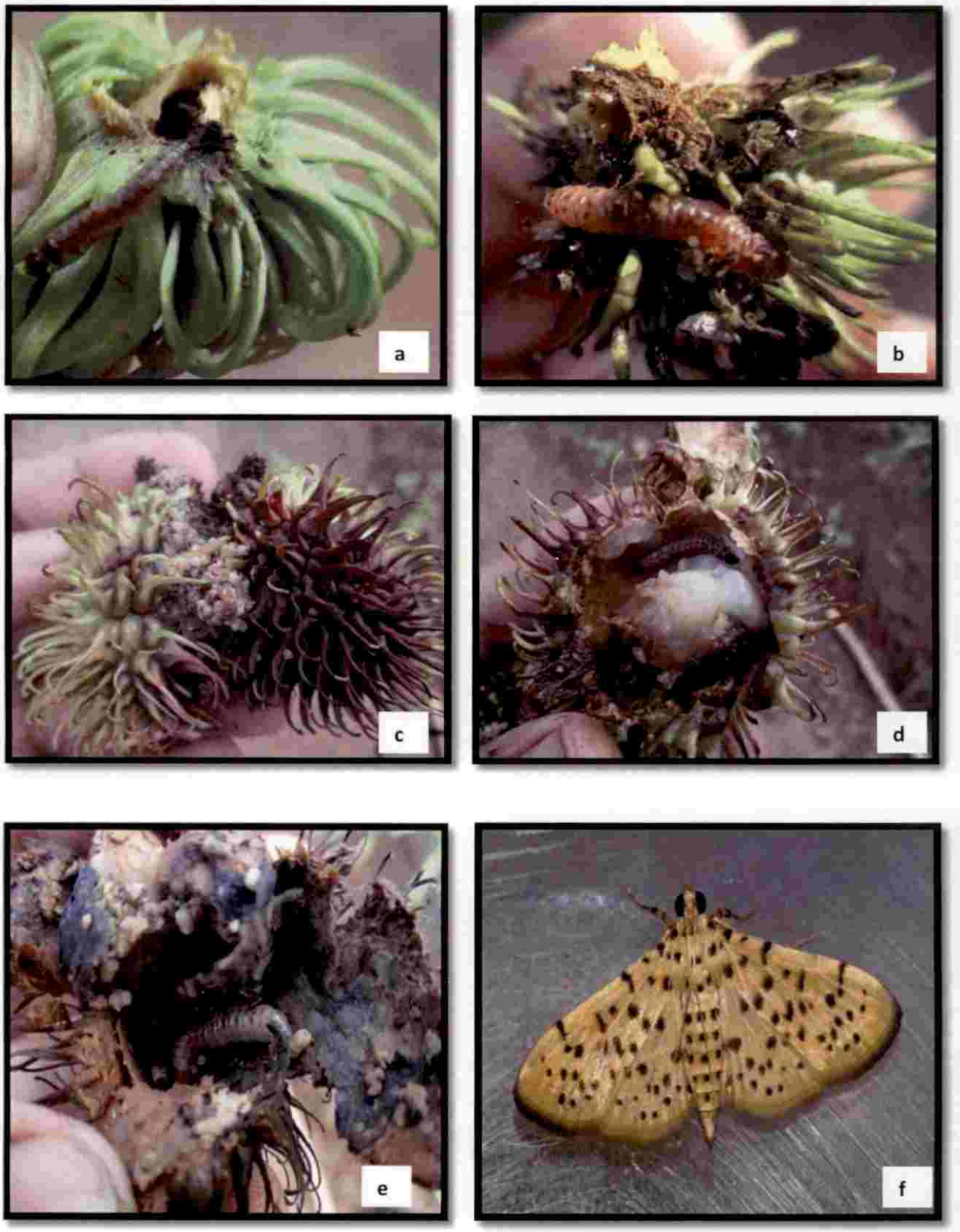


Plate 20. Fruit borer (*Conogethes punctiferalis*) attack in rambutan

a,b) Larva bores in to immature fruit c) Attack on mature fruit d) Larva feeds on seed and aril e)Empty fru
f) Adult

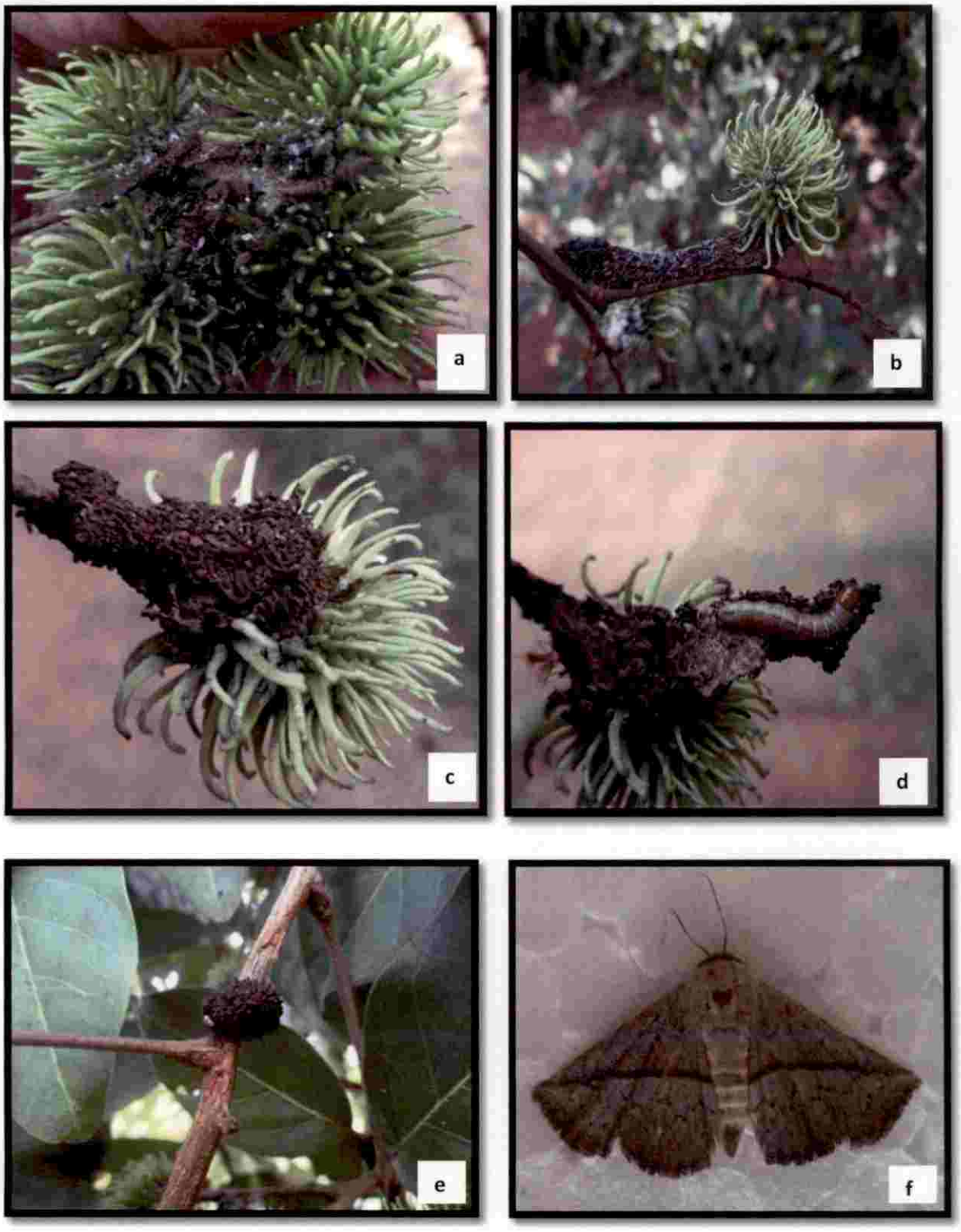


Plate 21. Fruit webber (*Eublemma anguilifera*) attack in rambutan

a) Webbing b,c&d) Pupation in the base of fruit e)Cocoon in nearby branches f)Adult

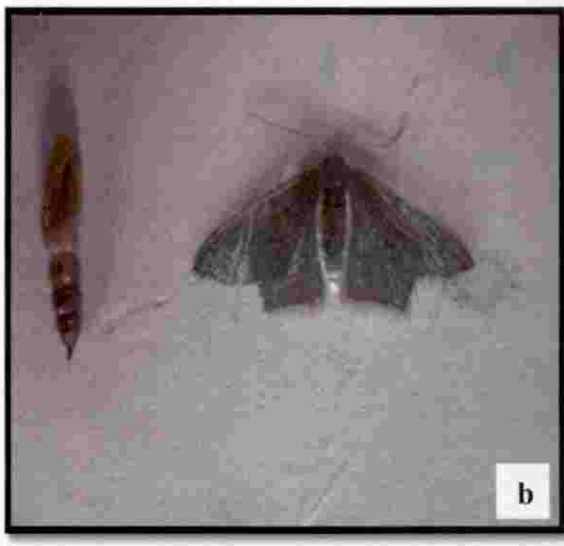
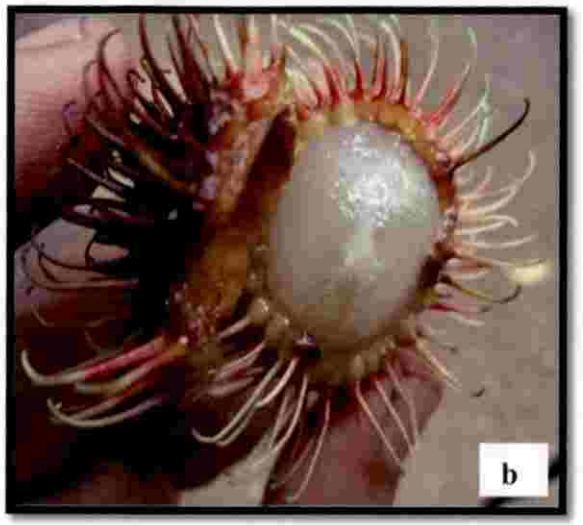


Plate 22. Rambutan pests of minor importance

a)Leaf folder(*Thalassodes quadraria*) b) Adult of *Thalassodes quadraria*
c) Mealy bug (*Planococcus citri*) attack on inflorescence
d)Mealy bug (*Planococcus citri*) attack on fruit
e) Lobster caterpillar (*Neostauropus alternus*) f) Armored scale



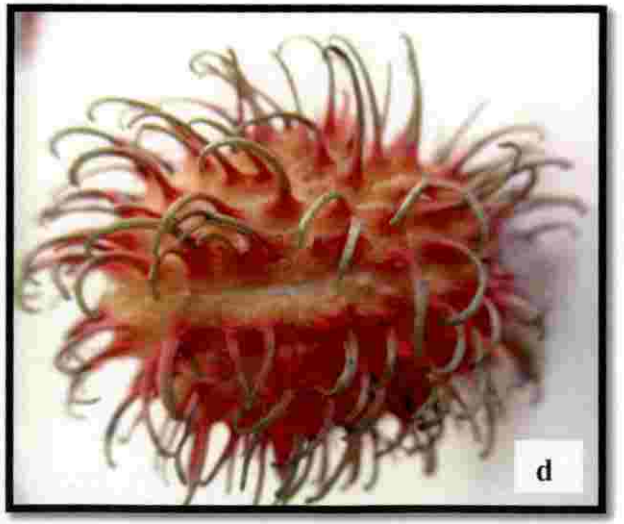


Plate 23. Diseases and physiological disorders in rambutan

a,b&c) Fruit rot (*Colletotrichum gloeosporioides*) d)Fruit splitting

Table 7. Per cent incidence of pests and diseases observed in rambutan collections

Problems	Percentage incidence
Leaf folder (*Thalassodes quadraria*)	86.73
Mealy bug (*Planococcus citri*)	76.53
Fruit borer (*Conogethes punctiferalis*)	66.32
Fruit webber (*Eublemma anguilifera*)	66.32
Fruit rot (*Colletotrichum gloeosporiodes*)	92.85
Fruit splitting	15.30

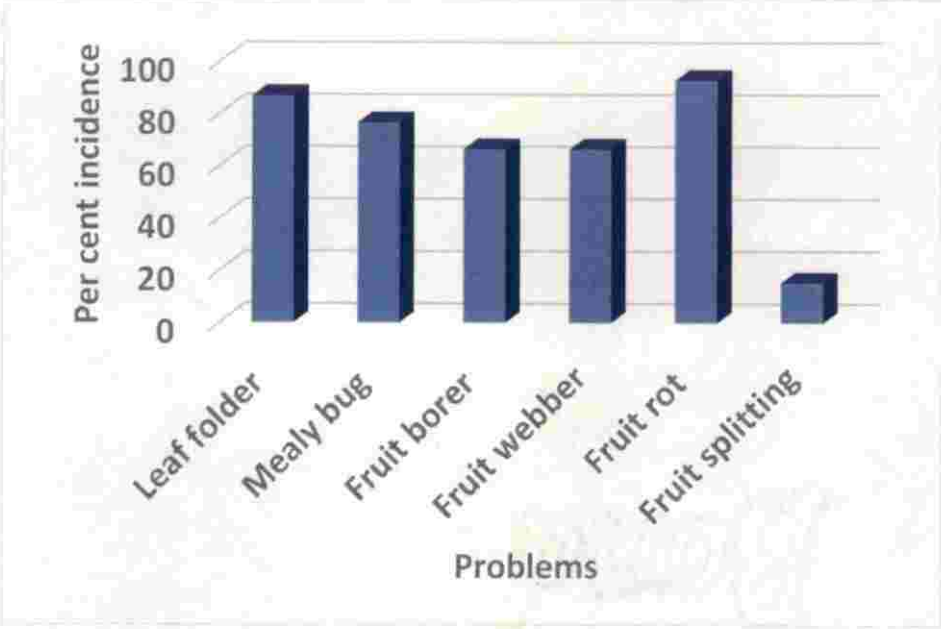


Fig. 9. Per cent incidence of pests and diseases observed in rambutan collections

4.4.3 Physiological disorders

a. Fruit splitting or Fruit cracking

Fruit splitting was observed in few collections (15.30% incidence) during our study. There are many factors that influence fruit cracking such as genetic, morphological environmental and physiological factors (Khadivi-Khub, 2015).

4.5 Phenological growth stages of rambutan based on BBCH scale

Phenological growth stages of rambutan were characterized according to the BBCH (Biologische Bundesansalt Bundessortenamt und Chemische industrie) scale. The BBCH scale described for rambutan in this work used 7 of the 10 principal growth stages (PGS) starting with vegetative bud development (PGS-0) followed by leaf development (PGS-1), shoot development (PGS-3), inflorescence emergence (PGS-5), flowering (PGS-6), fruit development (PGS-7) and ending with fruit maturity (PGS-8). Secondary growth stages were also described (Table 8).

Phenological growth stages of rambutan were recorded from Wayanad district of Kerala in addition to the above mentioned major rambutan growing tracts of Kerala. The timeline showing the phenology (flushing, flowering and harvesting) of rambutan in different locations is presented in Fig. 10.

4.6 Correlation studies

The association of various characters was studied by using correlation analysis which provides information on the nature and relationship among various traits so that it serves an effective tool for the exploitation of a particular trait towards crop improvement.

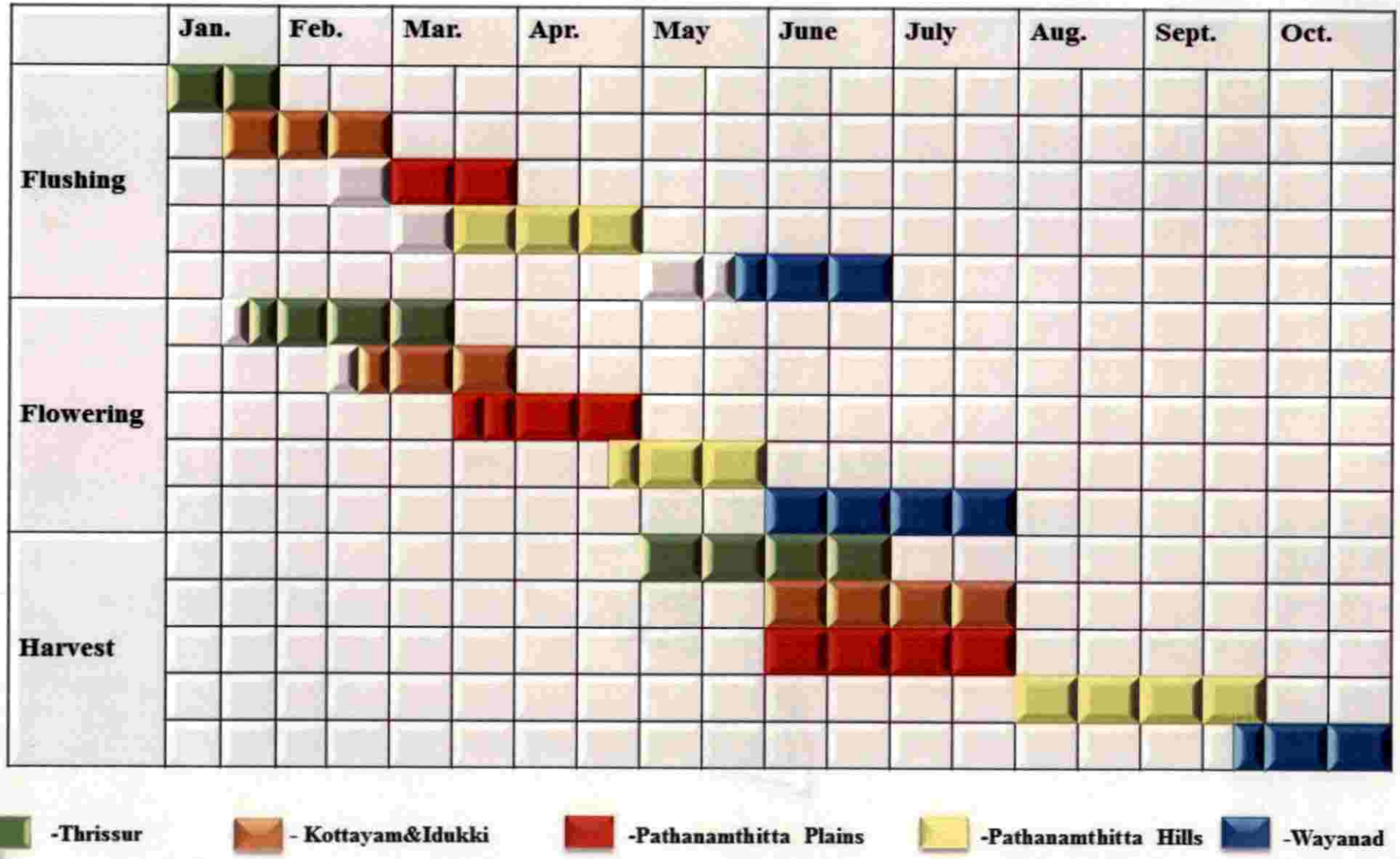


Fig. 10. Time line showing the phenology of rambutan in different locations of Kerala

Plate 24. Main phenological growth stages of rambutan according to BBCH scale (PGS- 0, 1, 3, 5 and 6)

Plate 25. Main phenological growth stages of rambutan according to BBCH scale (PGS- 7 and 8)

a&b) Two viable fruits on the same peduncle c)Three undersized fruits on the same peduncle

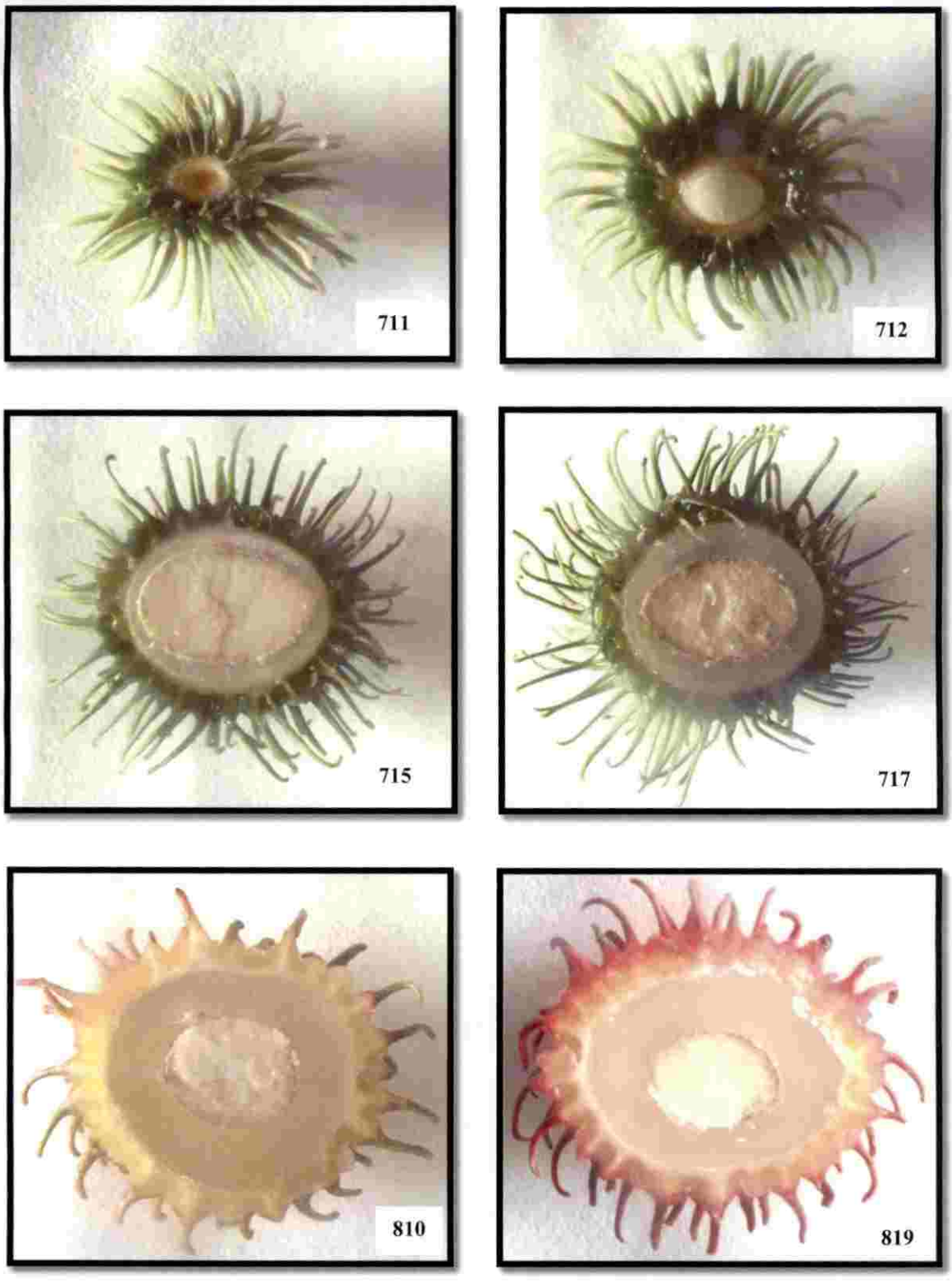


Plate 26. Rambutan fruit development (CS)

Table 8. Description of the phenological growth stages of rambutan according to BBCH scale.

BBCH code	Description
PGS- 0 : Vegetative bud development	
011	Beginning of bud swell
017	Beginning of bud break
019	End of bud break
PGS- 1 : Leaf development	
110	First leaves separated
111	First leaves unfolded
119	All leaves unfolded: all leaflets fully expanded
PGS- 3 : Shoot development	
310	Beginning of shoot extension
311	10% of final shoot length
313	30% of final shoot length
317	70% of final shoot length
319	90% or more of final shoot length
PGS- 5 : Inflorescence emergence	
510	Reproductive buds dormant
511	Beginning of reproductive bud swell
512	Panicle axes begin to elongate
513	Beginning of panicle development
515	50% of final inflorescence length
519	End of inflorescence extension
PGS- 6 : Flowering	
610	First flowers open
615	50% flowers open
617	70% flowers open
619	90% flowers open
PGS- 7 : Fruit development	
710	No ovary growth still visible
711	Initial ovary growth. First physiological fruit abscission
712	20% of final fruit size. Beginning of ovary growth
713	30% of final fruit size
715	50% of final fruit size. Seed is covered by aril
717	70% of final fruit size. Aril becomes fleshy
719	90% or more of final fruit size
PGS- 7 : Fruit maturity	
810	Skin colour changes from green to yellow
819	Physiological and harvest maturity.

4.6.1 Correlation among qualitative characters

The association among 14 qualitative characters *viz.*, leaf colour, crown shape, flower composition, inflorescence shape, fruit shape, rind colour, spine texture, spine colour, aril colour, aril taste, aril texture, aril juiciness, adherence of aril to seed and seed shape was measured both at 0.05 and 0.01 level by Spearman correlation coefficient (non-parametric) (Table 9)

Correlation matrix formed with qualitative traits revealed high significant positive genotypic correlation between aril taste and aril texture (0.411) and aril taste and aril colour (0.314) which was significant at 1 per cent level. In addition, significant negative genotypic correlations were observed between aril texture and adherence of aril to seed (-0.713), rind colour and spine colour (-0.401) and aril taste and adherence of aril to seed (-0.318) at 0.01 level and between aril colour and adherence of aril (-0.227) to seed at 0.05 level.

4.6.2 Correlation among quantitative characters

Pearson correlation coefficient (parametric) was used to study the association among the 31 quantitative characters *viz.*, age of the tree, number of leaflets per leaf, rachis length, petiole length, leaflet length, leaflet width, percentage fruit set, length of fruit bunch, number of fruits per bunch, fruit length, fruit diameter, fruit weight, rind thickness, rind weight, spine length, spine density, aril weight, aril thickness, seed length, seed width, seed weight, aril to fruit ratio, seed to fruit ratio, seed to aril ratio, total soluble solids, titratable acidity, total sugar, reducing sugar, non-reducing sugar, total carotenoids and ascorbic acid (Table 10a to 10c).

Significant positive correlations were observed between rachis length and spine length (0.200), petiole length and seed width (0.261), leaflet width and fruit length (0.202) and percentage fruit set and number of fruits per bunch (0.331).

Table 9. Correlations among qualitative traits of rambutan

	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14
R1	1													
R2	-0.052	1												
R3	-0.034	0.137	1											
R4	0.006	-0.055	**.202***	1										
R5	0.127	-0.062	-0.054	0.098	1									
R6	-0.029	-0.075	0.123	0.011	0.191	1								
R7	-0.065	0.14	-0.047	0.104	-0.045	-0.056	1							
R8	0.098	0.133	-0.015	0.033	-0.01	**-.401****	0.118	1						
R9	-0.019	0.131	0.17	-0.03	-0.09	0.027	0.015	-0.152	1					
R10	0.186	-0.094	-0.103	-0.006	-0.036	0.002	-0.019	-0.135	0.108	1				
R11	**.231***	0.109	-0.09	-0.031	-0.14	-0.17	0.017	0.029	**.314****	**.411****	1			
R12	-0.186	-0.069	0.07	0.058	0.114	0.111	-0.085	-0.129	0.079	0.074	**-.207***	1		
R13	-0.031	**-.228***	0.078	0.006	0.12	**.220***	-0.056	-0.03	**-.227***	**-.318****	**-.713****	0.17	1	
R14	0.098	-0.109	0.126	-0.017	.234*	0.046	0	0.027	0.02	-0.027	-0.035	0.084	0.115	1

*. Correlation is significant at the 0.05 level **. Correlation is significant at the 0.01 level

R1-Leaf colour R2-Crown shape R3-Flower composition R4-Inflorescence shape R5-Fruit shape R6-Rind colour R7-Spine texture R8-Spine colour R9-Aril colour R10-Aril taste R11-Aril texture R12-Aril juiciness R13-Adherence of aril to seed R14-Seed shape

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Table 10a. Correlations among quantitative traits of rambutan

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16
X1	1															
X2	0.118	1														
X3	-0.083	-0.064	1													
X4	0.056	0.049	-0.141	1												
X5	0.117	0.035	0.01	-0.164	1											
X6	-0.092	-0.012	-0.133	0.026	0.131	1										
X7	-0.045	0.144	-0.006	0.143	0.155	0.131	1									
X8	-0.009	0.062	0.118	0.034	-0.027	-0.102	0.011	1								
X9	0.019	0.031	-0.155	0.146	0.175	0.096	**.331(**)**	-0.038	1							
X10	**-.317(**)**	-0.146	0.015	-0.092	-0.01	**.202(*)**	-0.104	0.115	0.193	1						
X11	**-.376(**)**	-0.077	0.162	-0.055	-0.085	0.077	0.022	0.014	0.096	**.420(**)**	1					
X12	**-.359(**)**	-0.149	-0.008	-0.04	-0.014	0.065	-0.018	0.113	**.213(*)**	**.694(**)**	**.636(**)**	1				
X13	-0.19	-0.046	-0.103	-0.093	-0.109	0.081	-0.082	-0.029	**.254(*)**	**.436(**)**	**.303(**)**	**.435(**)**	1			
X14	**-.330(**)**	-0.102	-0.008	-0.083	-0.135	0.039	0.048	0.075	**.250(*)**	**.651(**)**	**.523(**)**	**.837(**)**	**.541(**)**	1		
X15	-0.166	-0.011	**.200(*)**	**-.255(*)**	0.104	-0.111	-0.024	0.104	-0.036	**.222(*)**	**.387(**)**	**.366(**)**	-0.007	**.222(*)**	1	
X16	0.039	-0.026	0.05	0.021	-0.004	**-.210(*)**	-0.116	-0.098	-0.106	**-.305(**)**	-0.079	-0.179	-0.061	-0.198	**.293(**)**	1

* Correlation is significant at the 0.05 level ** Correlation is significant at the 0.01 level

X1- Age X2-No. of leaflets per leaf X3-Rachis length X4-Petiole length X5-Leaflet length X6-Leaflet width X7-Percentage fruit set X8-Length of fruit bunch X9-No. of fruits per bunch X10-Fruit length X11-Fruit diameter X12-Fruit weight X13-Rind thickness X14-Rind weight X15-Spine length X16-Spine density X17-Aril weight X18-Aril thickness X19-Seed length X20-Seed width X21-Seed weight X22-Aril to fruit ratio X23-Seed to fruit ratio X24-Seed to aril ratio X25-Shelf life X26-TSS X27-Acidity X28-Total Sugar X29-Reducing Sugar X30-Non reducing sugar X31-Total carotenoids X32-Vit. C

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Table 10b. Correlations among quantitative traits of rambutan

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16
X17	**-.297(**)**	-0.082	0.053	-0.091	-0.066	0.083	0.014	0.043	0.172	**.504(**)**	**.690(**)**	**.864(**)**	**.264(**)**	**.717(**)**	**.341(**)**	-0.15
X18	**-.214(*)**	-0.037	-0.029	-0.065	-0.006	0.14	-0.025	0.07	**.207(*)**	**.333(**)**	**.487(**)**	**.627(**)**	**.253(*)**	**.457(**)**	**.303(**)**	-0.061
X19	**-.405(**)**	-0.185	-0.11	0.098	-0.06	0.106	-0.013	0.099	0.168	**.639(**)**	**.377(**)**	**.699(**)**	**.300(**)**	**.611(**)**	**.281(**)**	-0.174
X20	-0.151	0.069	-0.029	**.261(**)**	-0.052	-0.022	0.063	0.195	-0.032	-0.024	**.312(**)**	**.215(*)**	0.097	0.075	0.162	0.137
X21	**-.355(**)**	-0.123	-0.008	0.117	0.049	-0.079	0.113	**.211(*)**	0.041	**.232(*)**	**.468(**)**	**.449(**)**	0.15	**.327(**)**	**.255(*)**	-0.111
X22	-0.049	0.052	0.081	-0.066	-0.068	0.061	-0.028	-0.076	0.041	-0.024	**.382(**)**	**.237(*)**	-0.098	0.101	0.17	-0.065
X23	0.12	0.03	-0.068	0.106	0	-0.057	0.076	0	-0.192	**-.460(**)**	**-.301(**)**	**-.681(**)**	**-.277(**)**	**-.567(**)**	**-.245(*)**	0.076
X24	0.099	0.015	-0.153	0.115	-0.002	0.027	0.088	0.045	-0.171	**-.259(*)**	**-.348(**)**	**-.521(**)**	-0.177	**-.415(**)**	**-.253(*)**	0.039
X25	0.005	-0.027	-0.034	0.111	-0.146	-0.128	0.037	-0.052	-0.074	0.039	-0.042	0.01	-0.155	0.078	0.092	0.016
X26	0.003	0.071	0.049	0.119	-0.035	0.16	0.082	0.128	0.036	0.048	0.178	0.092	-0.04	0.026	0.061	-0.008
X27	0.063	-0.039	-0.018	-0.071	-0.093	-0.152	0.059	0.038	0.028	-0.017	-0.119	-0.076	0.071	-0.053	-0.195	-0.057
X28	-0.028	0.08	0.02	0.105	-0.02	0.171	0.099	0.115	0.057	0.096	**.214(*)**	0.17	0.019	0.112	0.081	0.026
X29	-0.008	0.009	0.032	0.115	-0.023	0.192	0.083	0.103	0.026	0.005	0.143	0.012	-0.09	-0.04	0.055	0.009
X30	-0.038	0.121	0.008	0.083	-0.015	0.129	0.096	0.106	0.072	0.15	**.235(*)**	**.262(**)**	0.097	**.208(*)**	0.088	0.035
X31	-0.077	-0.064	-0.034	**-.246(*)**	-0.158	-0.019	-0.112	-0.091	-0.075	0.123	-0.017	-0.033	0.114	-0.031	0.071	-0.067
X32	-0.05	0.042	0.171	-0.094	**.214(*)**	-0.032	-0.13	0.083	-0.11	0.005	0.015	-0.028	-0.082	-0.007	0.081	0.037

* Correlation is significant at the 0.05 level ** Correlation is significant at the 0.01 level

X1- Age X2-No. of leaflets per leaf X3-Rachis length X4-Petiole length X5-Leaflet length X6-Leaflet width X7-Percentage fruit set X8-Length of fruit bunch X9-No. of fruits per bunch X10-Fruit length X11-Fruit diameter X12-Fruit weight X13-Rind thickness X14-Rind weight X15-Spine length X16-Spine density X17-Aril weight X18-Aril thickness X19-Seed length X20-Seed width X21-Seed weight X22-Aril to fruit ratio X23-Seed to fruit ratio X24-Seed to aril ratio X25-Shelf life X26-TSS X27-Acidity X28-Total Sugar X29-Reducing Sugar X30-Non reducing sugar X31-Total carotenoids X32-Vit. C

Table 10c. Correlations among quantitative traits of rambutan

	X17	X18	X19	X20	X21	X22	X23	X24	X25	X26	X27	X28	X29	X30	X31	X32
X17	1															
X18	.728(**)	1														
X19	.530(**)	.323(**)	1													
X20	.250(*)	.237(*)	.267(**)	1												
X21	.378(**)	.240(*)	.513(**)	.667(**)	1											
X22	.638(**)	.592(**)	-0.004	0.127	0.025	1										
X23	-.628(**)	-.527(**)	-.327(**)	.200(*)	.257(*)	-.332(**)	1									
X24	-.630(**)	-.570(**)	-0.166	0.152	0.193	-.622(**)	.851(**)	1								
X25	0.039	0.141	0.048	-0.064	-0.085	0.049	-0.047	-0.019	1							
X26	0.194	.346(**)	-0.011	-0.019	-0.029	.271(**)	-0.151	-.225(*)	0.16	1						
X27	-0.174	-0.121	-0.117	-0.027	-0.044	-.266(**)	0.066	.233(*)	-0.132	-0.084	1					
X28	.247(*)	.390(**)	0.02	0.022	0.001	.254(*)	-0.187	-.243(*)	0.114	.946(**)	-0.067	1				
X29	0.129	.239(*)	-0.041	-0.08	-0.044	.244(*)	-0.064	-0.145	0.076	.937(**)	-0.066	.885(**)	1			
X30	.298(**)	.444(**)	0.062	0.095	0.033	.224(*)	-.250(*)	-.279(**)	0.125	.812(**)	-0.057	.937(**)	.667(**)	1		
X31	-0.009	0.057	0.055	-0.145	-0.054	0.074	0.012	-0.082	0.182	0.044	-0.121	0.005	-0.015	0.02	1	
X32	0.05	0.088	-0.016	-0.003	0.121	0.196	0.11	-0.1	0.006	.219(*)	-0.104	0.15	0.135	0.139	0.147	1

* Correlation is significant at the 0.05 level ** Correlation is significant at the 0.01 level

X1- Age X2-No. of leaflets per leaf X3-Rachis length X4-Petiole length X5-Leaflet length X6-Leaflet width X7-Percentage fruit set X8-Length of fruit bunch X9-No. of fruits per bunch X10-Fruit length X11-Fruit diameter X12-Fruit weight X13-Rind thickness X14-Rind weight X15-Spine length X16-Spine density X17-Aril weight X18-Aril thickness X19-Seed length X20-Seed width X21-Seed weight X22-Aril to fruit ratio X23-Seed to fruit ratio X24-Seed to aril ratio X25-Shelf life X26-TSS X27-Acidity X28-Total Sugar X29-Reducing Sugar X30-Non reducing sugar X31-Total carotenoids X32-Vit. C

Fruit weight expressed high significant positive correlations with aril weight (0.864), rind weight (0.837), seed length (0.699), fruit length (0.694), fruit diameter (0.636), aril thickness (0.627), seed weight (0.449) and rind thickness (0.435). The characters having significant negative correlation with fruit weight were seed to fruit ratio (-0.681) and seed to aril ratio (-0.521) and age of the tree (-0.359).

Aril weight exhibited significant positive correlations with fruit weight (0.864), aril thickness (0.728), aril to fruit ratio (0.638) and seed length (0.530). On the other hand, it was negatively correlated with seed to aril ratio (-0.630), seed to fruit ratio (-0.628) and age of the tree (-0.297).

Spine length showed significant positive correlation with aril weight (0.341), aril thickness (0.303), seed length (0.281), seed weight (0.252) and rind weight (0.222) whereas it had significant negative correlation with petiole length (-0.255

Very high significant positive correlations were observed between total soluble solids and total sugar (0.946), reducing sugar (0.937) and non-reducing sugar (0.812).

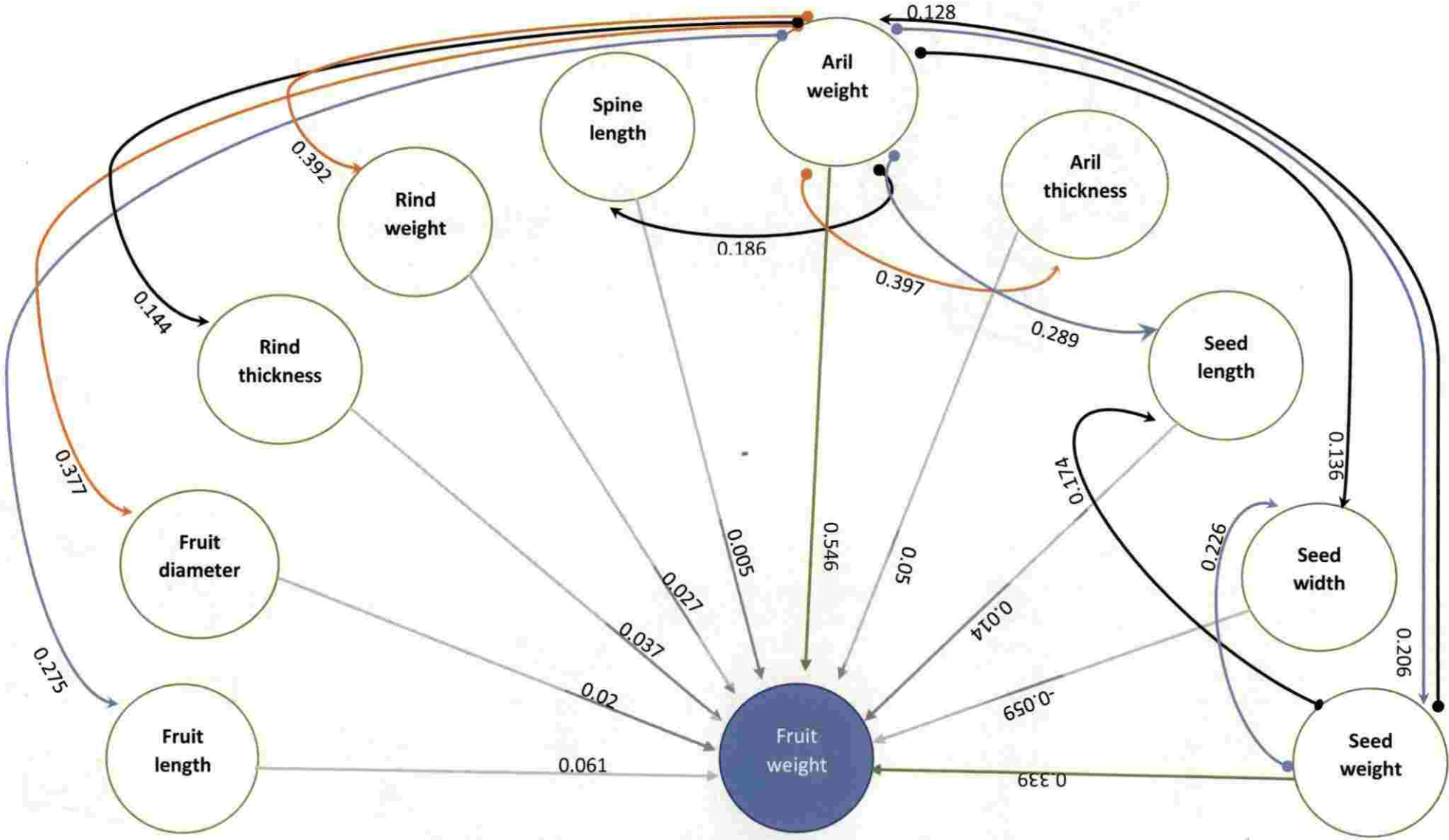
4.7 Path coefficient analysis

Path coefficient analysis was used to study the direct and indirect effect of component characters and fruit weight by partitioning the correlation between fruit weight and component characters into direct and indirect effects. The results of path coefficient analysis is furnished in Table 11 and the path diagram showing direct and indirect effects are presented in Fig. 11.

4.7.1 Direct effects

The highest positive direct genotypic effect on fruit weight was exhibited by aril weight (0.546) and its correlation with fruit weight was also positive (0.864).

Seed weight exhibited high and positive direct effect on fruit weight (0.339) and its correlation with fruit weight was also positive (0.449). The negative direct



Residual Effect = 0.02953

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Fig. 11. Path diagram showing direct and indirect effects on fruit weight of rambutan

Table 11. Path coefficient analysis of various characters on the fruit weight of rambutan

Character	Percentage fruit set	Number of fruits per bunch	Fruit length	Fruit diameter	Rind thickness	Rind weight	Spine length	Aril weight	Aril thickness	Seed length	Seed width	Seed weight
Percentage fruit set	**-0.033**	-0.010	0.003	-0.000	0.002	-0.002	0.000	-0.000	0.000	0.000	-0.002	-0.004
Number of fruits per bunch	0.002	**0.007**	0.001	0.000	0.001	0.002	-0.000	0.001	0.001	0.001	-0.000	0.000
Fruit length	-0.006	0.011	**0.061**	0.025	0.027	0.039	0.014	0.031	0.020	0.039	-0.001	0.014
Fruit diameter	0.000	0.001	0.009	**0.020**	0.006	0.011	0.008	0.014	0.009	0.007	0.006	0.010
Rind thickness	-0.003	0.009	0.016	0.011	**0.037**	0.019	-0.000	0.009	0.009	0.011	0.004	0.005
Rind weight	0.001	0.007	0.017	0.014	0.015	**0.027**	0.006	0.019	0.012	0.016	0.002	0.009
Spine length	-0.000	-0.000	0.001	0.002	-0.000	0.001	**0.005**	0.002	0.002	0.001	0.000	0.001
Aril weight	0.008	0.094	0.275	0.377	0.144	0.392	0.186	**0.546**	0.397	0.289	0.136	0.206
Aril thickness	-0.001	0.010	0.016	0.024	0.013	0.023	0.015	0.036	**0.05**	0.016	0.011	0.012
Seed length	-0.000	0.002	0.009	0.005	0.004	0.009	0.004	0.008	0.005	**0.014**	0.004	0.007
Seed width	-0.003	0.002	0.001	-0.018	-0.006	-0.004	-0.009	-0.015	-0.014	-0.016	**-0.059**	-0.034
Seed weight	0.038	0.014	0.079	0.159	0.051	0.111	0.086	0.128	0.081	0.174	0.226	**0.339**

Residual effect,h = 0.02953

effects of percentage fruit set (-0.033) and seed width (-0.059) on fruit weight were negligible.

In addition, number of fruits per bunch (0.007), fruit length (0.061), fruit diameter (0.02), rind thickness (0.037), rind weight (0.027), spine length (0.005), aril thickness (0.05) and seed length (0.014) showed negligible positive and direct effects on fruit weight.

4.7.2 Indirect effects

Aril weight showed moderate positive and indirect effect on fruit weight (0.275) through the negligible and positive direct effect of fruit length (0.061) and expressed high positive and indirect effect on fruit weight (0.377) through the negligible positive and direct effect of fruit diameter (0.020).

Aril weight (0.144) exhibited low positive and indirect effect on fruit weight through the negligible positive and direct effect of rind thickness (0.037).

Aril weight expressed high positive and indirect effect on fruit weight (0.392) through the negligible positive and direct effect of rind weight (0.027).

The indirect effect of seed weight (0.111) through the negligible positive and direct effect of rind weight (0.027) was low and positive.

Also aril weight (0.186) exhibited low positive and indirect effect on fruit weight through the negligible positive and direct effect of spine length (0.005).

4.8 Principal component analysis (PCA)

Principal component analysis is essentially a data reduction technique wherein the original variables are subjected to a linear transformation, resulting in principal components and the number of PCs to be retained are based on Kaiser's criterion (Eigenvalue >1) (Kaiser, 1958).

The principal component analysis was performed based on the six tree morphological characters and twenty six fruit characters of rambutan separately.

The cumulative variance, factor scores and contribution of variation of each of the character is presented in Table 12 and 13.

4.8.1 PCA of tree characters

The results of principal component analysis based on six tree characters of rambutan are presented in Table 12.

The scree plot in response to principal components (Fig. 12) revealed that the first three principal components were having Eigen value > 1 which accounted for 58.8% of the total variation. The first factor (PCI), which explained 21.4% of the total variation, was correlated with length of petiole, leaflet length and rachis length. The second factor (PC2) accounted for 20.1% of the total variance, and was associated with tree age, number of leaflets per leaf and leaflet length. The third factor (PC3) which explained 17.3% of the total variance and featured leaflet width.

4.8.1.1 Loading plot of tree characters based on first two principal components

The loading plot showing the relation among various tree characters based on first two principal components are presented in Fig. 13. The correlation between any two variables is approximated by the cosine of the angle between their vectors.

The loading plot revealed positive correlation between rachis length and leaflet width; leaflet width and leaflet length; tree age and number of leaflets per leaf as indicated by the small acute angles between their vectors (r=cos0=+1).

It was observed a near zero correlation between leaflet width and number of leaflets per leaf as indicated by mutually near perpendicular vectors (r=cos90=0) and a negative correlation between leaflet width and length of petiole as indicated by the approximate angle of 180° between their vectors (r=cos180= -1). Some discrepancies of the plot predictions and original data were expected since the first principal components explained 41.5% of the total divergence.

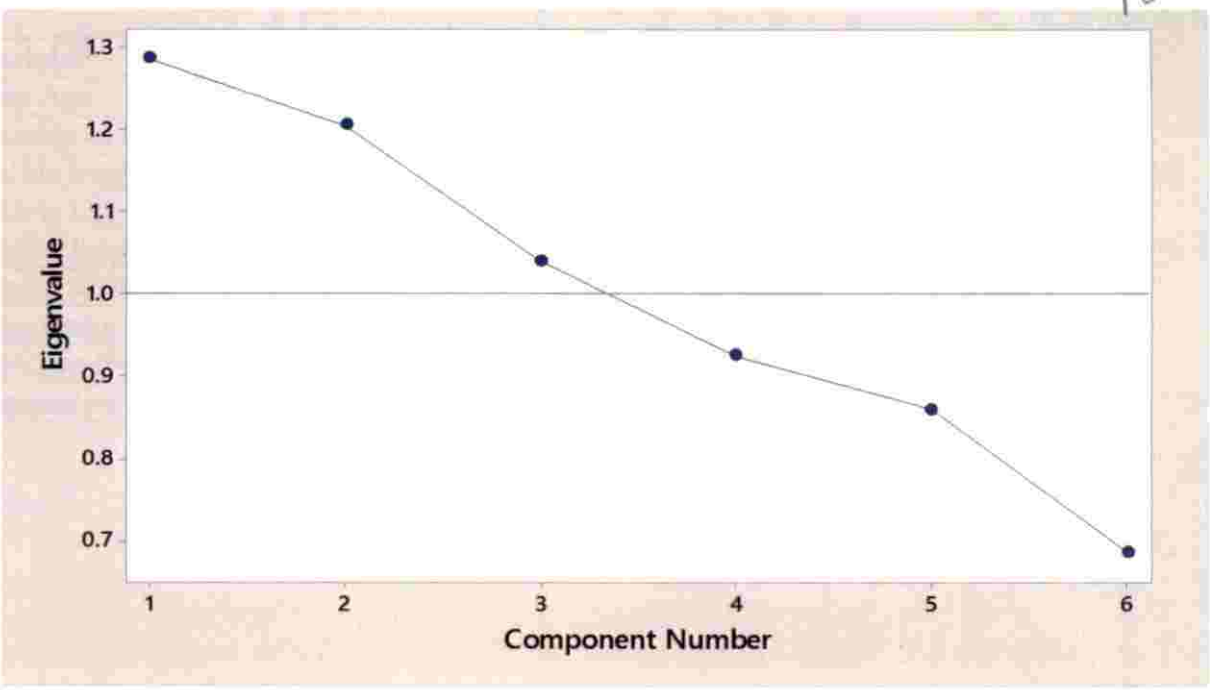

Fig. 12. Scree plot showing the eigen values based on tree characters

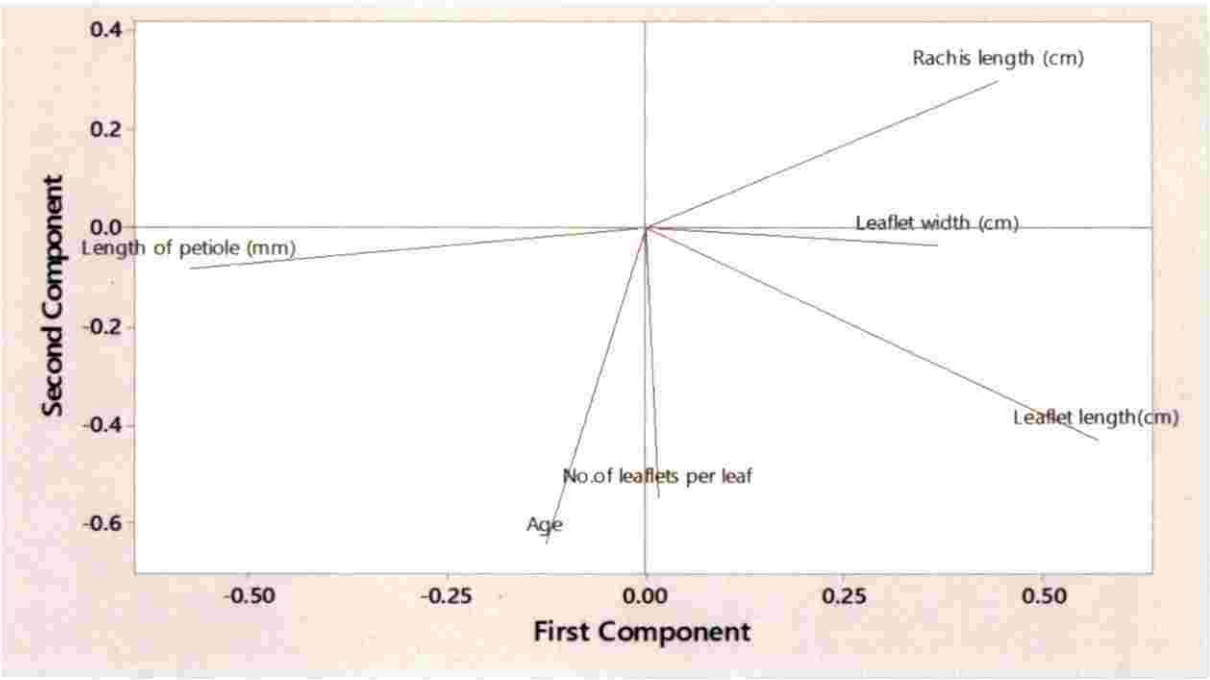

Fig. 13. Loading plot of tree characters based on first two principal components

Table 12. Eigen values, factor loadings and contribution of variations by tree characters in rambutan

Variable	PC1	PC2	PC3
Tree Age	-0.128	-0.646	0.297
Number of leaflets per leaf	0.016	-0.549	-0.087
Rachis length	0.443	0.299	0.199
Petiole length	-0.575	-0.086	-0.466
Leaflet length	0.567	-0.429	-0.038
Leaflet width	0.367	-0.035	-0.804
Eigen value	1.29	1.21	1.04
Variance (%)	21.4	20.1	17.3
Cumulative variance (%)	21.4	41.5	58.8

4.8.2 PCA of fruit characters

The results of principal component analysis based on twenty six fruit characters of rambutan are presented in Table 13 and the scree plot showing the significant principal components (Eigen value > 1) are furnished in Fig. 14.

The first eight principal components of data accounted for 75.3% of the total divergence among the collections Eigen value > 1. The first principal component (PC1) explained 25.6% of the total divergence and was determined by aril weight, fruit weight and aril thickness. The second component (PC2) contributed 14% of the total variance and was correlated with titratable acidity, total soluble solids, reducing sugar and total sugar. The third component (PC3) explained 9% of the total divergence and was composed of characters such as seed weight, seed width, seed to fruit ratio and seed to aril ratio. The fourth component (PC4) which accounted for 7.4% of the total variance, was contributed by characters such as aril to fruit ratio, spine length and titratable acidity. The fifth component (PC5) contributed 5.7% of the total divergence and was correlated with characters such as total carotenoids, percentage fruit set, number of fruits per bunch and fruit length. The sixth component (PC6) accounted for 4.8% of the total variation and was associated with spine density, length of fruit bunch and total carotenoids. The seventh component (PC7) contributed 4.6% of the total variation, which was determined by characters such as shelf life, spine length, percentage fruit set and spine density. The eighth component (PC8) described 4.1% of the total divergence, which was mainly contributed by length of fruit bunch and rind thickness.

4.8.2.1 Loading plot of fruit characters based on first two principal components

The loading plot showing the relation among various fruit characters based on first two principal components are presented in Fig. 15.

Strong positive associations were observed between reducing sugar, total soluble solids, total sugar and non-reducing sugar ; seed to fruit ratio and seed to aril ratio ; aril thickness and aril to fruit ratio; fruit weight, fruit diameter, rind

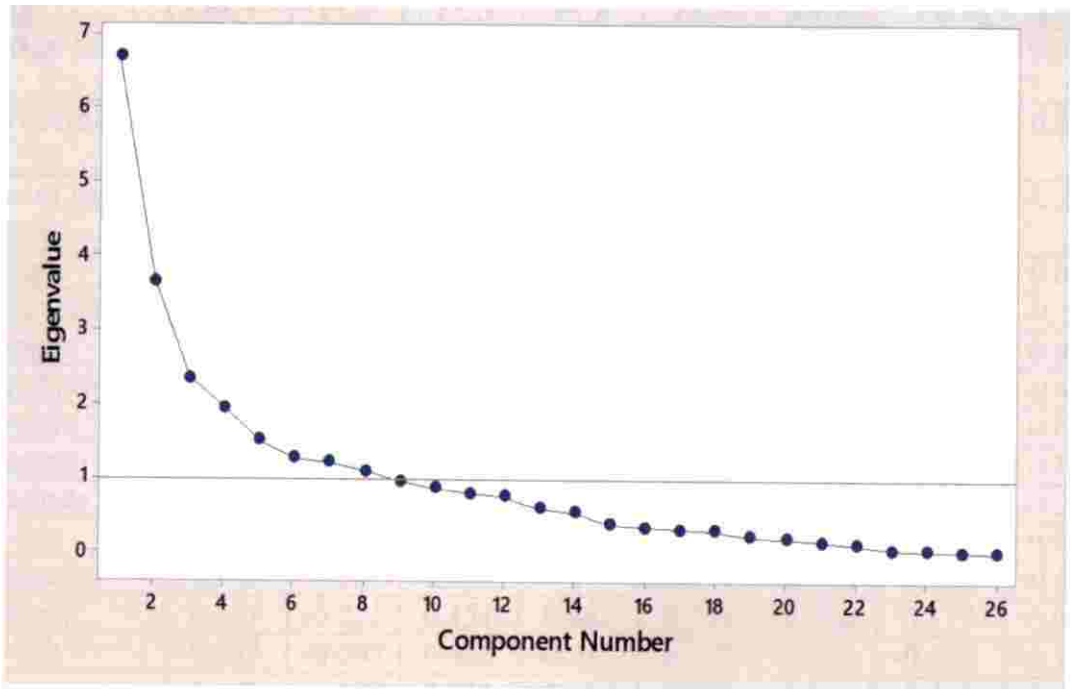

Fig. 14. Scree plot showing the eigen values based on fruit characters

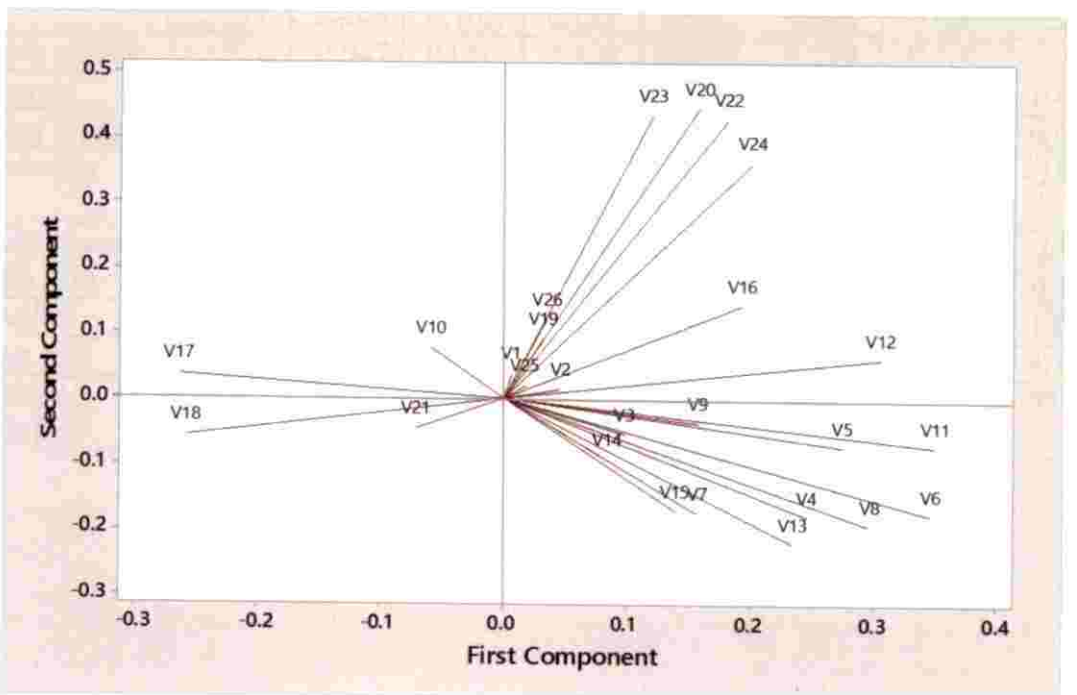

Fig. 15. Loading plot of fruit characters based on first two principal components

V1-percentage fruit set, V2-length of fruit bunch, V3-number of fruits per bunch, V4-fruit length, V5-fruit diameter, V6-fruit weight, V7-rind thickness, V8-rind weight, V9-spine length, V10-spine density, V11-aril weight, V12-aril thickness, V13-seed length V14-seed width, V15-seed weight, V16-aril to fruit ratio, V17-seed to fruit ratio, V18-seed to aril ratio, V19-shelf life, V20-TSS, V21-titrable acidity, V22-total sugar, V23-reducing sugar, V24-non-reducing sugar, V25-total carotenoids, V26-ascorbic acid

Table 13. Eigen values, factor loadings and contribution of variations by fruit characters in rambutan

Variable	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8
Percentage fruit set	0.005	0.038	0.136	0.214	-0.417	-0.345	0.353	0.052
Length of fruit bunch	0.045	0.016	0.237	0.064	0.105	0.097	-0.209	0.592
Number of fruits per bunch	0.098	-0.055	-0.054	0.298	-0.347	-0.169	0.183	-0.218
Fruit length	0.246	-0.180	-0.029	0.232	0.313	-0.004	0.006	0.067
Fruit diameter	0.275	-0.073	0.137	-0.119	-0.088	0.009	-0.040	-0.141
Fruit weight	0.346	-0.178	0.010	0.053	0.022	0.068	0.011	0.083
Rind thickness	0.158	-0.175	-0.027	0.264	0.102	0.202	-0.082	-0.484
Rind weight	0.297	-0.194	-0.028	0.171	0.070	0.027	0.061	0.015
Spine length	0.158	-0.038	0.074	-0.320	0.084	0.257	0.354	0.129
Spine density	-0.060	0.077	0.034	-0.289	-0.060	0.574	0.347	-0.227
Aril weight	0.350	-0.073	-0.028	-0.131	-0.127	-0.080	-0.075	0.042
Aril thickness	0.305	0.061	-0.031	-0.129	-0.117	-0.046	-0.042	-0.048
Seed length	0.235	-0.222	0.151	0.081	0.204	-0.056	0.137	0.075
Seed width	0.083	-0.092	0.465	-0.212	-0.177	0.051	-0.026	-0.107
Seed weight	0.140	-0.172	0.511	-0.099	0.007	-0.140	-0.040	-0.072
Aril to fruit ratio	0.193	0.144	-0.140	-0.375	-0.261	-0.257	-0.226	-0.048
Seed to fruit ratio	-0.264	0.037	0.393	-0.051	0.068	-0.184	-0.023	-0.191
Seed to aril ratio	-0.258	-0.058	0.379	0.146	0.133	-0.039	0.102	-0.059
Shelf life	0.031	0.091	-0.067	-0.083	0.248	-0.274	0.540	0.207
TSS	0.158	0.446	0.102	0.125	0.081	0.008	-0.000	-0.015
Titratable acidity	-0.072	-0.047	0.056	0.320	-0.096	0.229	-0.200	0.013
Total sugar	0.181	0.429	0.115	0.156	0.045	0.079	0.023	-0.046
Reducing sugar	0.120	0.434	0.108	0.133	0.042	0.030	-0.005	0.000
Non-reducing sugar	0.200	0.362	0.103	0.149	0.041	0.104	0.040	-0.074
Total carotenoids	0.017	0.021	-0.127	-0.096	0.459	-0.312	0.087	-0.368
Ascorbic acid	0.034	0.123	0.070	-0.219	0.276	-0.151	-0.329	-0.102
Eigen value	6.67	3.64	2.34	1.93	1.49	1.26	1.20	1.08
Variance (%)	25.6	14	9.0	7.4	5.7	4.8	4.6	4.1
Cumulative variance (%)	25.6	39.7	48.6	56.0	61.8	66.6	71.2	75.3

weight, spine length, aril weight and aril thickness; seed weight, seed length and seed width as indicated by the acute angles between their vectors. As revealed by the approximate perpendicular vectors, a near zero relation was there between spine density and reducing sugar and between seed weight and reducing sugar. An angle of approximate by 180° between the vectors revealed a negative correlation between acidity and TSS, aril thickness and seed to aril ratio and between aril to fruit ratio and seed to aril ratio. However, the first two principal components contributed only 39.7 % of the total variation, hence some deviations could be expected but had to be relied on as only PC1 and PC2 can be accommodated in the two dimensional loading plot.

4.9 Cluster analysis

Cluster analysis was performed on the basis of qualitative characters using dendrogram for the elite selections of rambutan and clustering by score plot based on first two principal components which was carried out for thirty seven elite selections, twenty selections of export quality and twenty eight selections of industrial use as mentioned in 3.6.4.

4.9.1 Cluster analysis on the basis of qualitative traits using dendrogram

Cluster analysis of all the thirty seven elite selections of rambutan was carried out by using dendrogram based on fourteen qualitative characteristics namely leaf colour, crown shape, flower composition, inflorescence shape, flower composition, fruit shape, rind colour, spine texture, spine colour, aril colour, aril taste, aril texture, aril juiciness, attachment of aril to seed and seed shape.

The collections were grouped at the similarity coefficient status of 60 % which resulted in 10 non-overlaping clusters (Fig. 16). Cluster wise listing of collections according to qualitative characters are presented in Table 14 and the cluster wise summary is given in Table 15. Cluster II had the maximum number of collections (14) whereas clusters VII, IX and X included the minimum number of collections of one each.

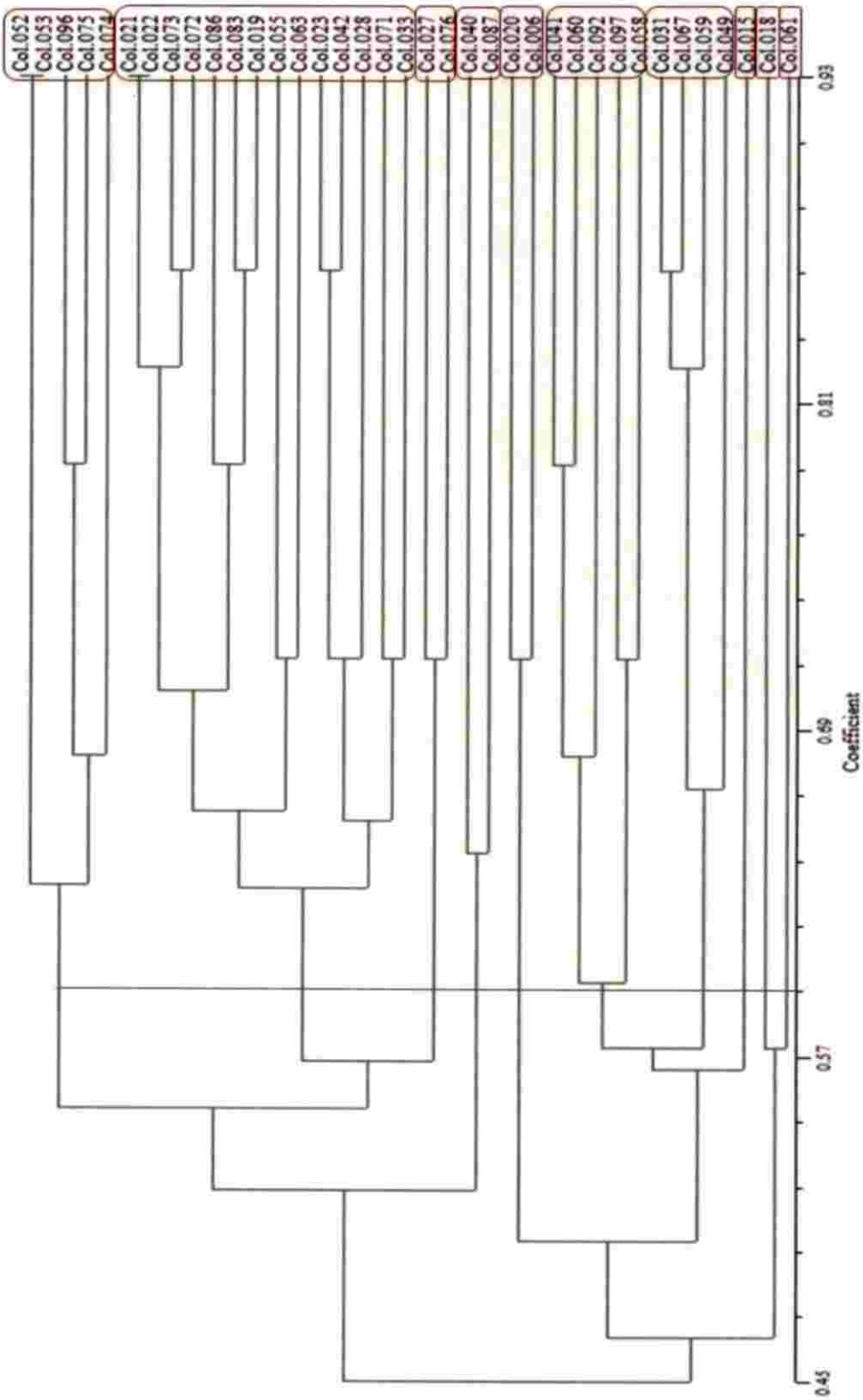

Fig. 16. Dendrogram on the basis of qualitative traits for elite selections of rambutan

Table 14. Cluster wise listing of rambutan collections according to qualitative characters

Cluster I	Cluster II	Cluster III	Cluster IV	Cluster V	Cluster VI	Cluster VII	Cluster VIII	Cluster IX	Cluster X
Col.052	Col.021	Col.027	Col.040	Col.006	Col.041	Col.031	Col.15	Col.018	Col.061
Col.053	Col.022	Col.076	Col.087	Col.020	Col.060	Col.067			
Col.096	Col.073				Col.058	Col.059			
Col.075	Col.072				Col.092	Col.049			
Col.074	Col.086				Col.097				
	Col.083								
	Col.019								
	Col.055								
	Col.063								
	Col.023								
	Col.042								
	Col.028								
	Col.071								
	Col.033								

Table 15. Cluster wise summary of qualitative characters

Characters	Cluster I	Cluster II	Cluster III	Cluster IV	Cluster V	Cluster VI	Cluster VII	Cluster VIII	Cluster IX	Cluster X
Leaf colour	Green, Dark green	Green	Green	Dark green	Green	Green	Green	Green	Green	Green
Crown shape	Spherical, pyramidal	Spherical, pyramidal, oblong, semi-circle	Spherical, semi-circle	Spherical, pyramidal	Spherical, semi-circle	Oblong, pyramidal	Pyramidal	Semi-circle	Oblong	Pyramidal
Flower composition	HFF	HFF	HFF	HFF	HFF	HFF	HFF	HFF	HFF	HFF
Inflorescence shape	Pyramidal, conical	Pyramidal, conical, obtriangular	Pyramidal, obtriangular	Pyramidal	Pyramidal, obtriangular	Pyramidal	Pyramidal	Pyramidal	Conical	Pyramidal
Fruit shape	Oblong	Globose, oblong, ovoid	Oblong, ovoid	Globose	Oblong	Globose	Globose, oblong	Globose	Oblong	Oblong
Rind colour	SRO, SR	SRO, SR, PY, DR, DPR, VR, SYP	SYP, PY	PY, VR	SRO	VR. SRO, DPR, DR	SR, SYP, SRO, DPR	SR	DPR	DPR
Spine texture	Soft, stiff	Soft, stiff	Soft	Soft	Stiff	Soft, stiff	Soft	Soft	Soft	Soft
Spine colour	Red with light green tip	Red, Red with light green tip, light green with pink base	Red with light green tip	Red with light green tip, light green with pink base	Red with light green tip	Red, Red with light green tip	Red with light green tip	Red with light green tip	Red with light green tip	Red
Aril colour	Creamy white, dull white	White, dull white	White, dull white	Dull white	Creamy white	Dull white	White, dull white	Creamy white	Creamy white	Dull white
Aril taste	Sweet	Sweet	Sweet, acid sweet	Sweet	Acid sweet	Sweet, acid sweet	Acid sweet	Sweet	Sweet	Sweet
Aril texture	Crispy	Crispy	Soft, crispy	Crispy	Soft	Soft, firm, crispy	Soft	Soft	Soft	Soft
Aril juiciness	Not juicy	Juicy, not juicy	Juicy, very juicy	Not juicy	Juicy, very juicy	Juicy, not juicy	Juicy, not juicy	Very juicy	Very juicy	Very juicy
Attachment of aril to seed	Poor, medium	Poor, medium, very good	Medium, very good	Medium, good	Very good	Very good	Very good	Very good	Good	Medium
Seed shape	Obovoid, obovoid elongated	Obovoid, obovoid elongated, roundish	Obovoid, obovoid elongated	Oblong, irregular	Obovoid, obovoid elongated	Oblong, obovoid, roundish	Oblong, obovoid, roundish	Obovoid	Obovoid	Obovoid elongated

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4.9.1.1 Leaf colour

Cluster I included collections having green or dark green coloured leaves whereas clusters II, III, V, VI, VII, VIII, IX and X were having collections with green leaves. Cluster IV contained collections with dark green leaves.

4.9.1.2 Crown shape

The collections in the cluster I and IV were characterized by either spherical or pyramidal type shape of the crown whereas cluster III and V were characterized by either spherical or semi-circular shaped crown. Cluster II consisted of 14 collections, in which the crown shapes fell in the category of oblong, pyramidal spherical and semi-circular. Cluster VI had either oblong or pyramidal type crown. Clusters VII and X only had the pyramidal type crown and clusters VIII and IX had only semi-circular and oblong shape respectively.

4.9.1.3 Flower composition

All the 10 clusters were invariably having inflorescences with only HFF flowers.

4.9.1.4 Inflorescence shape

Cluster I was consisted of collections with pyramidal or conical shaped inflorescence, cluster III and VI showed collections with pyramidal or obtriangular inflorescence and cluster II was characterized by three types of inflorescence namely pyramidal, conical and obtriangular. All the collections in clusters IV, VI, VII, VIII and X were characterized by pyramidal shaped inflorescence whereas cluster IX was having only conical shaped inflorescence.

4.9.1.5 Fruit shape

Among the ten clusters, four clusters (I, V, IX and X) came under the fruit shape oblong and three clusters (IV, VI and VIII) with the shape globose. Cluster II contained collections having oblong or globose or ovoid shaped fruits. On the

other hand, cluster III included collections with either oblong or ovoid fruit shape and cluster VII with the fruit shape oblong or globose.

4.9.1.6 Rind colour

The cluster II had seven colour of rind namely pale yellow, strong yellowish pink, strong reddish orange, strong red, vivid red, dark red and deep purplish red. Cluster VI exhibited four different colours namely strong reddish orange, vivid red, dark red and deep purplish red.

Cluster VII also came under 4 categories *viz,* strong yellowish pink, strong reddish orange, strong red, dark red and deep purplish red. Cluster IX and X exhibited dark purplish red colour while cluster V exhibited strong reddish orange colour and cluster VIII with strong red rind colour. Cluster III contained two collections one with strong yellowish pink and one with pale yellow coloured rind whereas cluster IV consisted of two collections, in which one collection was having pale yellow rind and one with the rind colour vivid red

4.9.1.7 Spine texture

All the collections of six clusters (III, IV, VII, VIII, IX and X) possessed soft textured spines whereas cluster V was having only stiff spines. Three clusters namely I, II and VI were characterized by both the categories of spine texture *viz*, soft and stiff.

4.9.1.8 Spine colour

The predominant spine colour red with light green tip was observed in all the collections of clusters I, III, V, VII, VIII and IX. The spine colour of cluster II fell in three groups namely fully red, red spines with light green tip and light green spines with pink base. Cluster X were with spine colour only red. Cluster IV contained collections with spine colour light green with pink base and red with light green tip. Cluster VI had the spine colour either only red or red with light green tip.

4.9.1.9 Aril colour

The clusters V, VIII and IX were having creamy white aril and clusters IV, VI and X were with dull white aril. White and dull white aril types were observed in clusters II and III and cluster I had either creamy white or dull white aril colour.

4.9.1.10 Aril taste

With regard to aril taste, the clusters I, II, IV, VIII, IX and X contained sweet type collections whereas cluster V and VII consisted of acidic sweet collections. Both sweet and acid sweet types were observed in clusters III and VI.

4.9.1.11 Aril texture

All the collections of clusters V, VII, VIII, IX and X had soft aril. Clusters I, II and IV had crispy aril whereas both soft and crispy types were observed in collections of cluster III. Three types of aril namely soft, crispy and firm were observed in collections of cluster VI.

4.9.1.12 Aril juiciness

The clusters VIII, IX and X fell under the category very juicy whereas clusters III and V contained both very juicy and juicy types. Clusters II, VI and VII were characterized by both juicy and non juicy types. The clusters I and IV included only non juicy types.

4.9.1.13 Attachment of aril to seed

Regarding the attachment of aril to seed the collections of cluster II contained collections with three categories namely poor, medium and very good, cluster I and IV with two types, the former containing poor and medium and the latter with medium and good attachment. Cluster III fell in two categories of either medium or very good. Cluster IX and X consisted of only one collection each that exhibited good attachment in case of former and medium attachment in case of the latter.

4.9.1.14 Seed shape

Collections of the cluster II were characterized by three types of seed shape namely roundish, obovoid and obovoid elongated. Clusters VI and VII fell in three types namely roundish, oblong and obovoid. Obovoid and obovoid elongated types of seeds were observed in clusters I, III and V. Cluster IV came under two groups namely oblong and irregular. Clusters VIII and IX were with the seed shape obovoid and cluster X with the seed shape obovoid elongated.

4.9.2 Clustering of rambutan collections using principal components (Score plot)

Clustering was carried out for each category of rambutan collections namely elite group, export types and of industrial uses using score plot of first two principal components (Fig. 17 to 19).

4.9.2.1 Clustering of elite selections of rambutan

The elite selections of rambutan (37 collections) could be categorised as ten major distinct clusters (Fig. 17). Cluster wise listing of collections are presented in Table 16 and the cluster wise summary is presented in Table 17.

Cluster I, II and III laid down at + ve side of PCI and PC2 (I^{st} quadrant) while cluster IV, V and VI were positioned at the - ve side of PC1 and + ve side of PC2 (II^{nd} quadrant). Cluster VII and VII were located mostly at the – ve side of PCI as well as PC2 (III^{rd} quadrant) whereas, cluster IX and X were laid down at the + ve side of PC1 and – ve side of PC2 (IV^{th} quadrant).

Cluster III included maximum number of collections (12) and cluster I, IV and V contained minimum number of collections of one each.

The score plot of elite selections of rambutan (Fig. 17) revealed that cluster I consisting of Col.061 was superior to all other clusters with preferred attributes such as TSS of 27.5° Brix, fruit weight of 32.23 g, very juicy aril, medium attachment of aril to seed, 37% of aril and 8% of seed. It was having the best TSS (27.5° Brix) among all the collections because of its prominent upper position in

Table 16. Cluster wise listing of elite selections of rambutan based on score plot

Cluster I	Cluster II	Cluster III	Cluster IV	Cluster V	Cluster VI	Cluster VII	Cluster VIII	Cluster IX	Cluster X
Col.061	Col.020	Col.042	Col.059	Col.015	Col.058	Col.060	Col.040	Col.071	Col.053
	Col.018	Col.072			Col.031	Col.087	Col.075	Col.063	Col.052
		Col.033			Col.067	Col.092	Col.076	Col.096	
		Col.028			Col.006		Col.074		
		Col.073			Col.049		Col.083		
		Col.055			Col.041		Col.097		
		Col.027							
		Col.023							
		Col.086							
		Col.022							
		Col.021							
		Col.019							

Table 17. Cluster wise summary of elite selections of rambutan based on score plot

Characters	Cluster I	Cluster II	Cluster III	Cluster IV	Cluster V	Cluster VI	Cluster VII	Cluster VIII	Cluster IX	Cluster X
Number of collections	1	2	12	1	1	6	3	6	3	2
Fruit weight (g)	32.23	28-40.2	22.5-52	31.8	14.5	19.25-27.4	15.12-24.6	24.4-42.3	27.7-42.18	45-61.5
Aril taste	Sweet	Sweet, acid sweet	Sweet	Acid sweet	Sweet	Acid sweet	Sweet, acid sweet	Sweet	Sweet	Sweet
Aril texture	Soft	Soft	Crispy	Soft	Soft	Soft	Soft, crispy	Crispy, firm	Crispy	Crispy
Aril juiciness	Very juicy	Very juicy	Juicy	Juicy	Very juicy	Juicy, not juicy	Not juicy	Not juicy	Juicy, not juicy	Not juicy
Attachment of aril to seed	Medium	Good, very good	Poor, medium, very good	Very good	Very good	Very good	Good, very good	Poor, medium, very good	Poor, medium	Poor
TSS (° Brix)	27.5	19.5-20	20-24	22	26	20-22	18-21	18-21	17-24	15.5
Aril to fruit ratio	0.37	0.27-0.36	0.35-0.51	0.47	0.37	0.30-0.43	0.26-0.35	0.26-0.46	0.34-0.42	0.34-0.36
Seed to fruit ratio	0.08	0.05-0.09	0.05-0.13	0.09	0.13	0.09-0.14	0.14-0.230	0.07-0.13	0.07-0.09	0.07-0.08

the first quadrant. Cluster II consisted of two collections (Col.018 and Col.020) which stand as elite particularly with respect to good characters like very juicy and soft aril and a TSS of 19.5-20° Brix.

Cluster III consisted of maximum of 12 collections possessing superior attributes such as sweetness and juiciness, good TSS between 20-24° Brix and aril to fruit ratio between 0.30-0.43. Six collections also (Col.019, Col.021, Col.022, Col.023 and Col.027) weighed above 40g. The highest fruit weight of 52 g within this group was recorded in Col.021 and the lowest in Col.042 (22.5g). Seven collections (Col.022, Col.023, Col.033, Col.042, Col.055, Col.072 and Col.073) had aril percentage above 40% and the largest edible portion among all the clusters was exhibited by Col.072. Ten collections (Col.019, Col.021, Col.022, Col.023, Col.027, Col.028, Col.033, Col.055, Col.072 and Col.086) recorded a seed content of less than 10% where Col.021 and Col.072 stood as superior with regard to per cent seed content (5%). In addition, eight collections (Col.021, Col.022, Col.023, Col.033, Col.042, Col.055, Col.072 and Col.073) possessed free stone aril, two collections (Col.019 and Col.027) with medium attachment and two collections (Col.028 and Col.86) had very strong adherence of aril to seed.

Cluster IV (Col.059) was having preferred qualities like fruit weight of above 30g, juicy and soft aril, TSS of 22° Brix and an aril content of 47% whereas, it exhibited inferior qualities like acid sweet aril and very good (very strong) attachment of aril to seed because of its position in the – ve side of PC1.

Cluster V (Col.015) was marked by inferior traits such as less fruit weight (14.5g) and very strong adherence of aril to seed, but it had the best TSS (26° Brix) as compared to other collections of IInd quadrant and next to cluster I because of its slight upper position in the quadrant.

All the collections of cluster VI positioned at the IInd quadrant exhibited superior qualities like soft aril and TSS ranging from 20 to 22° Brix. But the fruit weight ranged only from 19.25 to 27.4g and exhibited very good (very strong) attachment of aril to seed because of its slight lower position in the quadrant. The

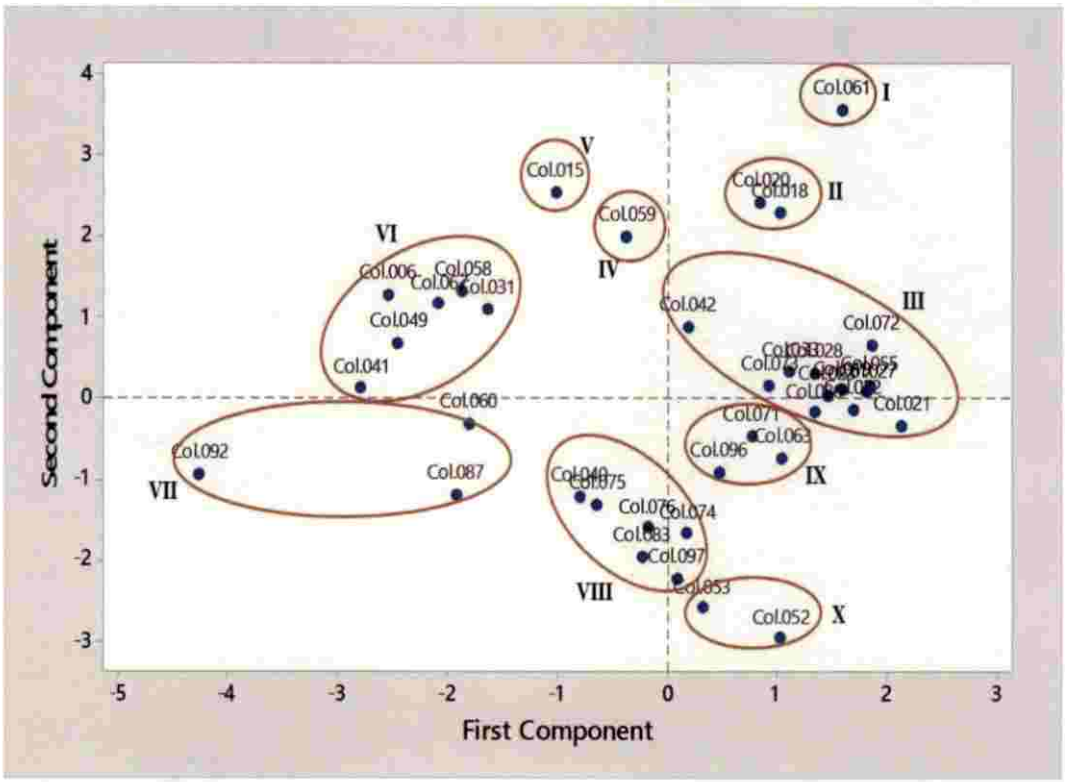


Fig. 17. Score plot based on first two principal components of elite selections of rambutan

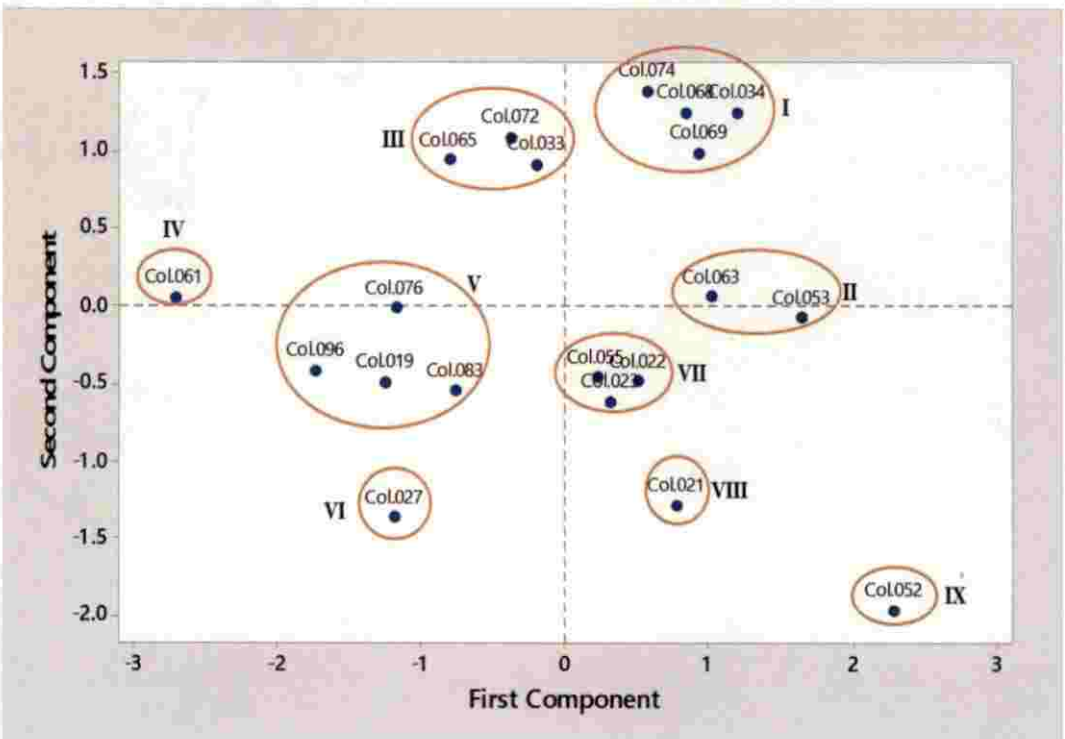


Fig. 18. Score plot based on first two principal components of rambutan selections of export quality

largest edible portion of 43% was recorded in Col.058 because of its slight upper position in the cluster while Col.041 was having the lowest percentage of aril (30%) in the cluster because of the comparatively lower position in the concerned quadrant. All the collections were also grouped under acid sweet type.

Cluster VII possessed inferior qualities like lesser fruit weight (15.12 to 24.6 g), non- juicy aril, strong or very strong attachment of aril to seed, higher seed percentage (14 to 23%) and lesser edible part (26 to 35%) because of its –ve –ve position in the score plot. Col.060 exhibited highest fruit weight (24.6g), aril percentage (35%) within the group and lowest seed percentage (14%) as compared to other two members of the cluster because of its upper position in the quadrant. Among all the clusters, Col.092 recorded its inferiority with the highest seed percentage of 23%.

In cluster VIII, the fruit weight varied between 24.4 and 42.3 g, TSS varied between 18 and 21° Brix and aril percentage between 26 and 46%. Col.074, Col.083 and Col.097 exhibited the largest edible portion (above 40%) because of their proximity to IVth quadrant.

In cluster IX, Col.071 and Col.063 recorded preferred attributes such as juicy and free stone aril because of their slight upper position in the IVth quadrant and proximity towards the Ist quadrant while Col.096 was having non juicy aril with medium attachment to seed as indicated by the slight lower position in the quadrant.

Cluster X consisted of two collections (Col,052 and Col.053) that recorded their superiority due to characters like good fruit weight above 45g and free seed aril whereas they were inferior to all other clusters with respect to TSS (15.5° Brix) and juiciness (non-juicy) as indicated by the lower position in the IVth quadrant. Among all the collections, Col.052 recorded the highest fruit weight of 61.5 g.

4.9.2.2 Clustering of rambutan collections of export quality

The selections of export quality (20 collections) were grouped in to nine major distinct clusters and the score plot showing the clusters based on the first two principal components are presented in Fig. 18. Cluster wise listing of collections are given in Table 18 and the cluster wise summary is presented in Table 19.

The distribution pattern revealed that the maximum number of collections (4) were in cluster I and V whereas clusters IV, VI, VIII and IX included the minimum number of collections of one each.

Cluster I with four collections (Col.034, Col.068, Col.069 and Col.074) positioned in the Ist quadrant of the score plot (+ ve side of PCI and PC2) was characterized by fruit weight of 30.7-34.8g, TSS of 15.5 to 18° Brix and free seed aril. The lowest TSS reading of 15.5° Brix was recorded in Col.034.

Cluster II containing two collections (Col.053 and Col.63) was located at the Ist quadrant of the score plot (+ ve side of PCI and PC2) and its fruit weight varied between 42.18 and 45g and TSS ranged from 15.5 to 18° Brix. Both collections were also characterized with free stone aril.

Cluster III consisting of three collections (Col.033, Col.65 and Col.072) was laid down at the IInd quadrant of the score plot (- ve side of PCI and + ve side of PC2). The fruit weight ranged from 30.35 to 32.2 g and TSS from 18 to 22.5° Brix. They also exhibited free seed aril.

Cluster 1V consisting of Col.061 was positioned at IInd quadrant of the score plot (- ve side of PCI and + ve side of PC2) and was superior over all other clusters with respect to TSS (27.5° Brix). But it recorded the less preferred quality of medium attachment of aril to seed as revealed by its extreme lower position compared to other clusters in the quadrant.

The fruit weight ranged from 37 to 42.3g and TSS from 20-24° Brix in cluster V (Col.019, Col.076, Col.083 and Col.096) which was located mostly at IIIrd quadrant of the score plot (- ve side of PCI and - ve side of PC2). Col.019 and

Table 18. Cluster wise listing of rambutan collections of export quality based on score plot

Cluster I	Cluster II	Cluster III	Cluster IV	Cluster V	Cluster VI	Cluster VII	Cluster VIII	Cluster IX
Col.074	Col.063	Col.072	Col.061	Col.076	Col.027	Col.055	Col.021	Col.052
Col.068	Col.053	Col.033		Col.096		Col.022		
Col.034		Col.065		Col.019		Col.023		
Col.069				Col.083				

Table 19. Cluster wise summary of rambutan collections of export quality based on score plot

Characters	Cluster I	Cluster II	Cluster III	Cluster IV	Cluster V	Cluster VI	Cluster VII	Cluster VIII	Cluster IX
Number of collections	4	2	3	1	4	1	3	1	1
Fruit weight (g)	30.7-34.8	42.18-45	30.35-32.2	32.23	37-42.3	47.5	44-45.5	52	61.5
TSS (° Brix)	15.5-18	15.5-18	18-22.5	27.5	20-24	23	21-22.2	21	15.5
Attachment of aril to seed	Poor	Poor	Poor	Medium	Medium	Medium	Poor	Poor	Poor

Col.083 weighed above 40 g and Col.096 recorded the highest TSS of 24° Brix. All these collections possessed aril with medium adherence to seed.

Regarding cluster VI containing only Col.027, the fruit weight was 47.5g, the TSS-23° Brix and had a medium attached aril. It was laid down at IIIrd quadrant of the score plot (- ve side of PCI and - ve side of PC2).

Cluster VII included three collections (Col.022, Col.023 and Col.055) with fruit weight ranging from 44 to 45.5 g, and TSS from 21 to 22.2° Brix and was characterized by free stone aril. This cluster was positioned at the IVth quadrant of the score plot (+ ve side of PCI and - ve side of PC2).

Cluster VIII (Col.021) positioned at IVth quadrant of the score plot (+ ve side of PCI and - ve side of PC2) was superior over cluster VII with respect to fruit weight (52g) whereas cluster IX (Col.052) laid down in the same quadrant was the best among all the clusters with regard to the fruit weight (61.5g). Both clusters showed poor aril attachment but Col.052 recorded inferiority with regard to TSS (15.5° Brix).

4.9.2.3 Clustering of rambuatn collections having promise for industrial use/processing attributes

Rambutan selections holding promise for industrial use (28 collections) were grouped in to ten major distinct clusters (Fig. 19). Cluster wise listing of collections are given in Table 20 and the cluster wise summary is presented in Table 21.

Cluster X contained maximum number of collections (9) whereas cluster I, II, III, V, VIII and IX included minimum number of collections of one each.

Cluster I consisted of only Col.061 fell under the first quadrant of the score plot (+ ve side of PCI and + ve side of PC2) and recorded the best values with regard to TSS (27.5° Brix) and total sugar (18.41%) compared to all the other clusters as indicated by the extreme upper position in the first quadrant.

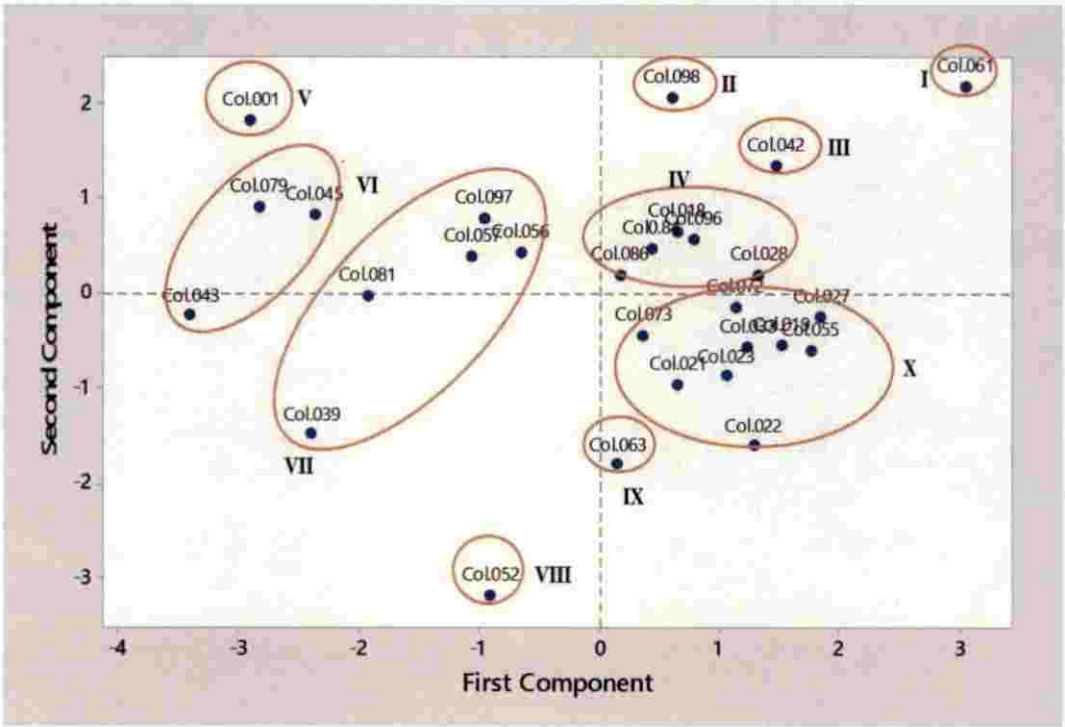


Fig. 19. Score plot based on first two principal components of rambutan collections having promise for processing attributes

Table 20. Cluster wise listing of rambutan collections of industrial use based on score plot

Cluster I	Cluster II	Cluster III	Cluster IV	Cluster V	Cluster VI	Cluster VII	Cluster VIII	Cluster IX	Cluster X
Col.061	Col.098	Col.042	Col.018 Col.096 Col.084 Col.086 Col.028	Col.001	Col.079 Col.045 Col.043	Col.097 Col.057 Col.056 Col.081 Col.039	Col.052	Col.063	Col.072 Col.027 Col.073 Col.019 Col.033 Col.055 Col.023 Col.021 Col.022

Table 21. Cluster wise summary of rambutan collections of industrial use based on score plot

Characters	Cluster I	Cluster II	Cluster III	Cluster IV	Cluster V	Cluster VI	Cluster VII	Cluster VIII	Cluster IX	Cluster X
Number of collections	1	1	1	5	1	3	5	1	1	9
Aril weight (g)	12	11	9.6	10-16.7	7	10-12	11.5-16	21	14.4	13.5-19.2
Aril juiciness	Very juicy	Juicy	Juicy	Very juicy, juicy, not juicy	Not juicy	Not juicy	Juicy, not juicy	Not juicy	Juicy	Juicy
Attachment of aril to seed	Medium	Very good	Poor	Medium, good, very good	Very good	Very good	Good, very good	Poor	Poor	Poor, medium
TSS (° Brix)	27.5	23.5	24	20-24	19	16-18.8	16-21	15.5	18	20-23
Total sugar (%)	18.41	17.24	17.22	14.75-17.32	13.44	11.45-13.33	12.09-15.34	13.57	13.23	14.89-17.6
Titratable acidity (%)	0.64	0.7	0.64	0.32-0.7	1.08	0.83-1.02	0.57-0.83	0.51	0.25	0.25-0.83

Cluster II (Col.098) and III were also in the first quadrant of the score plot (+ ve side of PCI and + ve side of PC2) and were characterized by a preferred TSS of 23.5° Brix and 24° Brix respectively. Both clusters had juicy aril and total sugar content of above 17%. With regard to attachment of aril to seed, cluster III exhibited superiority with poor attachment while cluster II showcased very strong adherence to seed.

Cluster IV positioned at first quadrant of the score plot (+ ve side of PCI and + ve side of PC2) was characterized with an aril weight of 10 to 16.7 g, TSS of 20 to 24° Brix, total sugar content of 14.75 to 17.32% and acidity of 0.32 to 0.7%. Col.028 exhibited superior qualities such as better aril weight (16.7g) and better total sugar content (17.32%) with less acidity (0.32%) over other collections of the cluster whereas Col.096 stood as the best among the collections with respect to TSS (24° Brix). Among the five collections, Col.096 recorded free stone aril while the adherence of aril to seed was not preferable in Col.028, Col.086 and Col.084. With regard to aril juiciness, very juicy aril was observed in Col.018 and Col.084 while Col.096 exhibited non juicy aril.

Cluster V comprised of Col.001 was located at second quadrant of the score plot (- ve side of PCI and + ve side of PC2) and was having less preferable attributes of less aril weight (7g), non-juicy aril with very strong adherence to seed and high acidity of 1.08%.

All the collections of cluster VI were having non-juicy aril with very strong attachment to seed and the aril weight ranged from 10 to 12 g. The TSS varied between 16.6 and 18.8° Brix. Col.043 exhibited the lowest TSS value of 16° Brix and total sugar (11.45%) as indicated by the proximity to the third quadrant.

In cluster VII, the fruit weight ranged from 11.5 to 16g, TSS from 16 to 21° Brix, total sugar from 12.09 to 15.34% and acidity varied between 0.57 and 0.83% which was positioned at second quadrant of the score plot except for Col.039. All the five collections exhibited inferiority in aril juiciness and adherence of aril to seed. Col.097 recorded the lowest acidity of 0.57 % and the highest total sugar

content of 15.34% within the group as revealed by the slight upper position in the quadrant.

Cluster VIII included only one collection (Col. 52) positioned in the third quadrant of the score plot, which was having the best value of aril weight (21g) among all the clusters with free stone aril and less acidity (0.51%). But it was inferior with respect to TSS (15.5°Brix) and aril juiciness (not juicy).

Cluster IX and X were located at fourth quadrant of the score plot. Cluster IX (Col.063) and Col.019 of cluster X recorded the highest acidity of 0.25%) compared to all other clusters. Among the nine collections of cluster X, seven collections (Col.019, Col.021, Col.022, Col.023, Col.027, Col.055 and Col.072) were having an aril weight of above 15g with the highest aril weight of 19.2g in Col.055. Cluster IX containing only Col.063 and seven collections (Col.021, Col.022, Col.023, Col.033, Col.055, Col.072 and Col.073) of cluster X possessed free seed aril. The TSS of cluster X varied between 20 and 23°Brix (highly preferable) and the maximum TSS was registered in Col.027. The total sugar ranged from 14.89 to 17.6% and the maximum total sugar content was recorded in Col.055.

Discussion

5. DISCUSSION

Rambutan (*Nephelium lappaceum* L.) is an exotic fruit crop with tremendous potential for cultivation in the whole state of Kerala. There exists great variability in rambutan because of the natural cross pollination and seed propagation that was in practice. Wide morphological variations are also observed among plants as a consequence of which little uniformity is observed in the orchards and the fruits realised from them (Smith *et al.*, 1992).

Variability is the basis for crop improvement programme and wider the variability greater is the scope for selection. Success of plant breeding depends on the identification of superior genotypes. There is great scope for selection from the large collection of natural variability of rambutan existing in the homesteads of entire Kerala state.

It is in this context that the hundred variable types of rambutan collected from the important rambutan growing tracts of Kerala were evaluated for various morpho-physiochemical traits in addition to sensorial perception with the prime objectives of recording the existing variability and genetic wealth available in order to select and conserve the elite/promising types and thereby to serve as a basis for promotion of cultivation of this exotic fruit in Kerala.

The results pertaining to 'Variability studies in rambutan (*Nephelium lappaceum* L.) are duly discussed in this chapter under the following headings.

5.1 Morpho-physiochemical traits of rambutan collections

The study revealed that rambutan fruits varied widely in their morpho-physiochemical traits. This was undoubtedly due to the natural cross pollination that exists in this crop and the resultant progenies were found to vary. This is also in accordance with the report of Tindall (1994). He confirmed that there is considerable genetic diversity in rambutan with respect to the morpho-physical and biochemical traits such as growth and tree size, colour and leaf size, flower composition and panicle shape, fruit colour, aril texture, brix, acidity, adherence of

aril to seed ,seed size and seed shape, susceptibility to pests and diseases and tolerance to cold and drought.

5.1.1 Tree and inflorescence characters

The study consisted of 100 rambutan trees belonging to various age groups. Among these, 71 trees came under the age group of 3-10 years, 22 trees in the age group of 11-20 years, 4 trees in the age group of 21-30 and 3 trees fell in the age group of above 30 years and all these were invariably of rough trunk surface. Four types of crown shape were observed among the collections viz., pyramidal, oblong, semi-circle and spherical with irregular branching pattern. The rambutan accessions used for morphological characterization by Andrade *et al.* (2009) exhibited only spherical/globular shape with irregular branching pattern. Crown shape and branching pattern are mainly decided by genetic make-up but still environmental parameters also play a role (Muthulakshmi, 2003).

Leaf colour varied from green to dark green, in which 90per cent of the collections were of green leaves. All the collections had an elliptic leaflet shape with no pubescence, but Andrade *et al.* (2009) observed lanceolate leaves with no pubescence while studying the morphological diversity in rambutan. In addition, quantitative leaf traits like number of leaflets per leaf, rachis length, petiolar length, leaflet length and leaflet width were also recorded which coincided with the findings of Tindall (1994), Andrade *et al.* (2009) and Barreto *et al.* (2015).

To know the extent of contribution of each variable towards the total variation, principal component analysis was performed. The first three principal components were having Eigen value > 1 which accounted for 58.8 per cent of the total variation. The first factor (PCI), which explained 21.4 per cent of the total variation, was correlated with length of petiole, leaflet length and rachis length. The second factor (PC2) accounted for 20.1 per cent of the total variance, and was associated with tree age, number of leaflets per leaf and leaflet length. The third factor (PC2) which explained 17.3per cent of the total variance featured the leaflet width. The results are in agreement with the studies of Andrade *et al.* (2009) and

Barreto *et al.* (2015) who have reported the major contribution of leaflet length, leaflet width and petiole length towards the genetic divergence in rambutan and also in litchi by Wu *et al.* (2016).

Their research on morphological characterization of rambutan plants to verify whether it is possible to differentiate rambutan trees in the early stages of development even when they have not produced flowers and/or fruits or in the nursery stage as has been reported in several fruit trees like purple passion fruit (Meletti *et al.*, 2005) and carambola (Andrade and Martins, 2007). They inferred that use of morphological characters of tree including foliar aspects is efficient in cataloguing the genetic variability between rambutan plants, but visual distinction is not possible, since no outstanding characteristic exists that helps to differentiate plants. Our results also support these findings.

Flower buds developed completely at the end of reproductive bud development stage. Flowering occurs following a dry period, but the amount and duration of flowering is dependent on the drought stress, the maturity of the terminals, flushing activity and tree health. In Hawaii, it is reported that rambutan flowers twice a year during the months of March-May and July-August in response to two short periods of dry weather followed by occasional showers (Kawabata *et al.*, 2005). Two flowering periods can also occur in Malaysia from March-May and August-October depending on the climatic condition. The flowering and fruiting are observed to be a function of weather conditions and the status of the stored food reserves within the trees (Shaari *et al.*, 1983). However, only one flowering season was observed in Kerala. Flowering continued for about 35-45 days. Flowering was earliest in Thrissur (end of January to mid of March) followed by Kottayam and Idukki (end of February to end of March) and Pathanamthitta (mid of March to end of April). Within Pathanamthitta two distinct flowering periods were observed one typical of the plain (end of March to end of April) and of the hilly reach (May). This clearly throws light on the requirement to satisfy a defined hours of sunlight and growing degree days. Though the relationship has not been worked out it is amply clear that places which had received higher temperature came to flowering earlier

and the gradation in reduction of mean temperature was correspondingly matched with more time taken for onset of flowering and consequent maturity and ripening.

With regard to flower composition of panicle, rambutan trees were categorized into three types namely trees with only true male flowers (TM) (Col.003 and Col.011), trees having only hermaphroditic female flowers (HF) and trees with both HF flowers and hermaphroditic functionally male flowers (HM) (Col.004) which proved that rambutan is an androdioecious with separate male and hermaphrodite trees. This observations corroborate the classification suggested by Valmayor *et al.* (1970). All the flowers were born on terminal cymose inflorescences. Most of the collections (97per cent) were born with only HF flowers which in turn set fruits. Cultivars have been selected for their high percentage of HF flowers and low percentage of HM flowers. The percentage of HM flowers produced is as low as 0.05-0.90per cent of the total flowers (Almeyda *et al*., 1979; Chin and Phoon, 1982; Tindall, 1994; Nakasone and Paull, 1998). On panicles having both HF and HM flowers, HM flowers usually open first and are found in highest frequency during the first three weeks of anthesis, but as anthesis progresses nearly all of the remaining flowers are HF flowers (Kawabata *et al*., 2005).

Anthers of male flowers release pollen that dispersed by both insects and wind and pollinate trees bearing HF flowers. The HF flowers have an ovary and stigma, but their anthers do not dehisce to release the well developed pollen grains whereas HM anthers shed pollen during anthesis. Thus the HM and true male flowers are the real pollen sources during pollination for fruit set (Ravishankar and Sakthivel, 2014). Tindall (1994) recommended to plant one male tree for every ten trees for getting adequate fruit set in cultivars which lack staminate flowers. But the orchards monocropped with HF collections reported viable fruit set and yield without the presence of any adjacent male trees which pave the way to overlook the recommendation of Tindall 1994 that for adequate fruit set there should be a pollenizer (male tree) for every ten trees.

Three types of inflorescences were observed namely pyramidal (73per cent), conical (14per cent) and obtriangular (13per cent). The male trees, Col.003 and Col.011 exhibited conical and obtriangular type inflorescence respectively. These male trees will be useful in further studies on the effect of pollenizers on yield and quality of fruits in rambutan.

5.1.2 Fruit and quality attributes

Fruit development begins shortly after anthesis. In rambutan although 2 ovaries are present on a female flower, one ovary aborts leaving the other to develop into a normal fruit. Occasionally, both ovaries develop and two fruits mature on the same peduncle. Rambutan fruit are green when immature and eventually turn red or yellow which is cultivar dependent (Kawabata *et al*., 2005). Our observations are in harmony with this. Fruiting and harvesting were more a reflection of the flowering period. Flowering to fruit maturity took about 90-120 days. Plants came to harvest in May in Thrissur, in June in Kottayam, in June-early July in plains of Pathanamthitta and in August - September in hills of Pathanamthitta. The study opens out a new area on the availability of fresh fruits of rambutan. The fruits are available from May-July (if cultivated in the humid tropical plains as in Thrissur, Kottayam and Pathanamtitta), and from August-September (if cultivated in hilly tracts of Pathanamthitta) thus making the availability of fresh fruits for nearly half period of a calendar year. Further study is required to confirm the influence of prevailing climatic factors on different phenological growth stages (crop weather relations of rambutan) and also to verify whether fruiting period can be extended to still later periods if it is grown in much more higher altitudes of Idukki, Wayanad and Pathanamthitta districts.

Percentage fruit set ranged from 12per cent to 35per cent with the highest fruit set in Col.099 and lowest in Col.033, Col.071 and Col.074 respectively. These records are on par with that of Tindall (1994) that the intial fruit set may reach 25per cent but a high level of abortion contributes to a much lower level of production at harvest (1-3per cent).

Reports say that rambutan fruit shape varies from roundish to oval, 5-8 cm long, 4-6 cm wide, pericarp soft with many abundant hairy growths, which changes its colour from green to red on ripening (Kothagoda and Rao, 2012). Rambutan fruits are green when immature and eventually turn red or yellow which is cultivar dependent (van Welzen and Verheij, 1991). In our studies, more than half of the collections (57.14per cent) came under the shape oblong. This particular aspect can be traced back to the point from where it spread to India. Undoubtedly the earliest introduced materials were from South East Asiatic countries which is proven (Hiranpradit *et al.*, 1992). They recorded this fruit shape as a characteristic feature of most of the Asiatic cultivars. Some collections (29.59per cent) came under the shape globose and 13.27per cent with the shape ovoid. Fruit length varied between 3.5 cm to 7.5 cm with the highest value in Col.052 and the lowest value in Col.012 and the fruit diameter ranged from 2 cm to 4.2 cm. The highest fruit diameter was observed in Col.047 and the lowest in Col.041. The rind thickness varied between 2 mm and 7 mm with the highest value in Col.037 and lowest value in Col.046.The collections with a rind thickness of 5 mm or above (24.49per cent of the collections) can be categorised as thick and those with less than 5 mm in the category thin (IPGRI, 2003).

Spine length varied between 6 mm to 22 mm. The maximum spine length was noticed in Col.034 and minimum in Col.006. Most of the collections (82.65per cent) possessed soft textured spines whereas 17.35per cent of the collections exhibited stiff spines. The density of spine in a 2m x 2m area varied between 12 to 45 with the highest density in Col.030 and the lowest in Col.052.The spine density of above 30 can be grouped as dense (34.7per cent) , 20-30 (50per cent) as medium and less than 20 (15.31 per cent) as sparse (IPGRI, 2003). With regard to spine colour, the predominant spine colour observed was red with light green tip (79.59per cent) followed by red (7.14per cent), yellow (4.08per cent), light green (4.08), light green with pink base (4.08per cent) and pink with light green tip (1.02per cent).

The collections varied in rind colour from light greenish yellow (5.1per cent) to pale yellow (11.22per cent) to strong yellowish pink (14.29per cent), from strong reddish orange (31.63per cent) to strong red (17.35per cent) to vivid red (12.24per cent) and from dark red (3.06per cent) to deep purplish red (5.1per cent) when described with UCL. (Col.020, Col.061) to strong red (Col.015, Col.016, Col.052, Col.053, Col.096) and from strong reddish orange (Col.021) to pale yellow (Col.023, Col.042).

The individual fruit weight reported for rambutan in the studies of Paul and Chin (1987) was 20 to 60 g. According to Codex Standard, a size code of 1 is given for fruits weighing above 43g (Codex Alimentarious, 2008). However, the international market suggests fruits weighing more than 30 g for the category 'extra class' (Kader, 2009). The highest maximum fruit weight obtained from Mexican selections was 34.7 g (Arenas *et al.*, 2010) and a highest fruit weight of 42.38g was observed in IE 20 among the hybrids studied in Thailand (Aifaa *et al.*, 2013). Our results show that Kerala selections not only compare favourably with these references but even excelled over the prevailing varieties. Among the selections studied from Kerala state, thirty eight collections (Col.007, Col.014, Col.019, Col.020,Col.021,Col.022,Col.023,Col.025,Col.027,Col.028,Col.033,Col.034,Col. 039,Col.043,Col.052,Col.053,Col.054,Col.055,Col.056,Col.057,Col.059,Col.061, Col.063,Col.064,Col.065,Col.066,Col.068,Col.069,Col.070,Col.072,Col.074,Col. 076,Col.081Col.083,Col.085,Col.086, Col.093 and Col.096) weighed above 30 g and hence could be classified in 'extra class'. With regard to the individual fruit weight highest fruit weight of 61.5 g was recorded in Col.052 and the lowest fruit weight of 12 g was observed in Col.012 and Col.013. The collections that weighed 43 g and above (Col.052, Col.021, Col.027, Col.023, Col.022, Col.053, Col.055 and Col.086) fell under the category I of the Codex Alimentarious.

Aril weight, the character of paramount importance and the economic part varied from 2.2 to 21 g with the highest in Col.052 and lowest in Col.008 and aril thickness from 3 to 10 mm. The largest edible portion (aril percentage) was found in Col.072 (52per cent), while Col.008 had the lowest percentage of aril. A comparison with some of the internationally accepted varieties revealed that some

of the Mexican selections have 40.2 to 41.4per cent edible portion (Arenas *et al.*, 2010), some others in Brazil have 18 to 50per cent (Andrade *et al.*, 2008), the best known cultivar of Thailand, 'Rong Rien' has an aril that makes up to 30 to 50per cent of the entire fruit (Paull and Chen, 1987) and 'Amarillo' the first Philippine yellow variety of rambutan recorded relatively large edible portion (60.7per cent) (Magdalita and Valencia, 2009). Thus the selections made by us are equally if not more superior than the improved available varieties. Vanderlinden *et al.* (2004) revealed that fruit weight, spintern appearance and colour, as well as fruit diameter and aril to fruit weight are the indicators for identifying fruit quality which are modified by environment and management practices.

With regard to aril juiciness, a desirable character for processing industry, 8.16per cent of the collections produced fruits which could be characterized as very juicy types, 47.99per cent were juicy type and 43.88per cent were non-juicy type. Free seed aril was found in 19.39per cent of the collections, while the attachment was medium in 16.33per cent of the collections which all are preferred from the consumer point of view, export trade and in processing industry (Landrigan *et al.*, 1996).

According to Kader (2006) the most preferable quality attributes for fresh rambutan fruits are 16° Brix, low acidity (0.3per cent) and Vitamin C content of 70mg/100g of flesh. In selections from Brazil, the total soluble solids ranged from 8.0° Brix to 19.5° Brix (Andrade *et al.*, 2008). In our study, about half of the collections (48.97per cent) had a total soluble solids content of above 20° Brix. The collections that showed TSS above 25° Brix (Col.015 with 26° Brix and Col.061 with 27.5° Brix) can be classified under the category 'very sweet'. The titrable acidity in our collections (0.12 to 1.4per cent) is higher than acidity found in 'Rong Rien'(0.25-0.29per cent) (Ketsa and Klaewkasetkorn, 1992). The highest acidity of 1.4 per cent was recorded in Col.020 but had an acid sweet taste because both total sugar and acidity were equally high. Total sugar ranged from 13 to 18.4per cent and ascorbic acid from 26.2 to 45.45 mg/100g. All the collections recorded a meagre content of total carotenoids which ranged from 0.011 to 0.036 mg/100g. Col.020,

Col.035 and Col.089 recorded the highest value of 0.036 mg/100g whereas Col.080 and Col.099 recorded the lowest value of 0.011 mg/100g.

The comparative studies of rambutan collections of Kerala with the existing standards and popular varieties in the world revealed that Kerala selections possess improved traits which are not only comparable with the best known cultivars in the world, but even exhibit superiority over them (Table 22).

The principal component analysis performed with twenty six quantitative traits of fruit revealed eight significant principal components which accounted for 75.3per cent of the total divergence among the collections with Eigen value > 1. The first principal component (PC1) explained 25.6per cent of the total divergence and was determined by aril weight, fruit weight and aril thickness. The second component (PC2) contributed 14per cent of the total variance and was correlated with titratable acidity, total soluble solids, reducing sugar and total sugar. The third component (PC3) explained 9per cent of the total divergence and was composed of characters such as seed weight, seed width, seed to fruit ratio and seed to aril ratio. The fourth component (PC4) which accounted for 7.4per cent of the total variance, was contributed by characters such as aril to fruit ratio, spine length and titratable acidity. The fifth component (PC5) contributed 5.7per cent of the total divergence and was correlated with characters such as total carotenoids, percentage fruit set, number of fruits per bunch and fruit length. The sixth component (PC6) exhibited 4.8per cent of the total variation and was associated with spine density, length of fruit bunch and total carotenoids. The seventh component (PC7) contributed 4.6per cent of the total variation, which was determined by characters such as shelf life, spine length, percentage fruit set and spine density. The eighth component (PC8) described 4.1per cent of the total divergence, which was mainly contributed by length of fruit bunch and rind thickness. There is no reported work of this kind in rambutan or for that matter on other Sapindaceous fruits.

Shelf life of all the collections until peel browning varied from 3 to 4 days under ambient conditions. Majority of the collections (79.59per cent) had a shelf life of 4 days. According to Landrigan *et al.* (1994) rambutan fruit lose visual quality rapidly as a consequence of rapid desiccation and browning of the

Table 22. Comparative studies of rambutan collections of Kerala with the prevailing standards and cultivars

Quality standards/cultivars	Quality attributes	References	Kerala collections	
Export specifications	Extra class (fruit weight > 30g)	(Landrigen *et al.*, 1996 ; Kader, 2001)	Fruit weight ≥ 30g : 38 collections	10 collections
	TSS ≥ 16° Brix		TSS ≥ 16° Brix : 84 collections	
	Free stone aril		19 collections	
Codex Standard	Category I (fruit weight > 43g)	(Codex Alimentarious, 2008)	Fruit weight > 43g : 8 collections	
Thailand varieties				
Rong-rien	Extra class (fruit weight ≥ 40g)	(Hiranpradit *et al.*, 1992)	Fruit weight ≥ 40g : 14 collections	
See-chompoo	Extra class (fruit weight ≥ 35g)		Fruit weight ≥ 35g : 20 collections	
Thailand hybrid (IE 20)	Maximum fruit weight- 43g	(Aifaa *et al.*, 2013)	Fruit weight > 43g : 8 collections	
Mexican selections	Maximum fruit weight – 35g	(Arenas *et al.*, 2010)	Fruit weight ≥ 35g : 20 collections	
IIHR Selections				
Arka Coorg Arun	Fruit weight : 45 g, Aril percentage : 42%, TSS : 17.5° Brix	(Kumar *et al.*, 2016)	Fruit weight ≥ 45g : 6 collections Aril percentage ≥ 42% : 15 collections TSS ≥ 20° Brix : 48 collections	
Arka Coorg Patib	Fruit weight : 30 g, Aril percentage : 30% TSS : 18.5° Brix			

spinterns,. Browning of the spinterns usually occur within 4-5 days after harvest at ambient temperature and relative humidity. Browning of the rind and spinterns are the major factors affecting the shelf life of rambutan which result in weight loss during storage and transportation. The major cause of browning is water loss (Landrigan *et al.*, 1996; Nathiwatthana, 1981; Mendoza *et al.*, 1972; Wells and Bagshaw, 1989). Spintern browning was more strongly correlated with weight loss than rind browning.

According to Landrigan *et al.* (1996) and Kader (2001) collections having a spine length of more than 1 cm are not preferred for export. But later, Yingsanga *et al.* (2006) found that the rate of water loss from rambutan fruits is greatly affected by the stomatal density rather than the number and length of spinterns.In this study no correlation was recorded between spine length and shelf life. In this context, the quality specifications suggested by Landrigan *et al.* (1996) and Kader (2001) also necessarily needs to be reviewed.

5.2 Correlation studies

The association of various qualitative traits were studied by Spearman correlation coefficient which provided the information on the nature and relationship among various traits. The collections having soft textured aril exhibited very strong adherence of aril to seed whereas the collections having crispy aril were of free seed aril as indicated by the high negative genotypic correlation between aril texture and aril adherence (-0.713). The taste sweetness found to tend towards soft textured (0.411) and creamy white aril (0.314), but moved away from free seed aril (-0.318). The studies of Hiranpradit *et al.* (1992) confirmed that aril colour, flavour and texture are not associated with fruit weight as observed in this study.

Correlation studies of quantitative variables by Pearson coefficient revealed significant positive correlations between rachis length and spine length (0.200), petiole length and seed width (0.261), leaflet width and fruit length (0.202) and percentage fruit set and number of fruits per bunch (0.331).

The loading plot based on principal components of tree characters explained positive correlation between rachis length and leaflet width; leaflet width and leaflet length; tree age and number of leaflets per leaf as indicated by the small acute angles between their vectors (r=cos0=+1). It was also observed a near zero correlation between leaflet width and number of leaflets per leaf as indicated by mutually near perpendicular vectors (r=cos90=0) and a negative correlation between leaflet width and length of petiole as indicated by the approximate angle of 180° between their vectors (r=cos180= -1)

Fruit weight expressed high significant positive correlations with aril weight (0.864), rind weight (0.837), seed length (0.699), fruit length (0.694), fruit diameter (0.636), aril thickness (0.627), seed weight (0.449) and rind thickness (0.435). These results confirms the findings of Hiranpradit *et al.* (1992) that fruit size (width, length, thickness), rind weight and thickness, aril weight and thickness and seed weight are highly associated with fruit weight.

Aril weight had got high significant positive correlations with fruit weight (0.864), aril thickness (0.728), aril to fruit ratio (0.638) and seed length (0.530). On the other hand, it was negatively correlated with seed to aril ratio (-0.630), seed to fruit ratio (-0.628) and age of the tree (-0.297).

Spine length showed significant positive correlation with aril weight (0.341), aril thickness (0.303), seed length (0.281), seed weight (0.252) and rind weight (0.222) whereas it had significant negative correlation with petiole length (-0.255).

It was observed that total soluble solids had got very high significant positive correlations with total sugar (0.946), reducing sugar (0.937) and non-reducing sugar (0.812) whereas there was no correlation among TSS, ascorbic acid and total carotenoids as confirmed by Wall *et al.* (2006). The loading plot drawn with first two principal components of fruit and quality characters also showed strong positive associations between reducing sugar, total soluble solids, total sugar and non-reducing sugar; fruit weight, fruit diameter, rind weight, spine length, aril

weight and aril thickness; seed weight, seed length and seed width as indicated by the acute angles between their vectors. The angle of approximate 180° between the vectors revealed a negative correlation between acidity and TSS

5.3 Path coefficient analysis

The negligible residual effect (0.023) indicates that almost all characters which contribute to fruit weight were considered in the study. The highest positive direct genotypic effect on fruit weight was exhibited by aril weight (0.546) and its correlation with fruit weight was also positive (0.864) which reveals true relationship between them and direct selection for this trait will be rewarding for fruit weight improvement.

Seed weight showed high and positive direct effect on fruit weight (0.339) and its correlation with fruit weight was also positive (0.449). The negative direct effects of percentage fruit set (-0.033) and seed width (-0.059) on fruit weight were negligible.

In addition, number of fruits per bunch (0.007), fruit length (0.061), fruit diameter (0.02), rind thickness (0.037), rind weight (0.027), spine length (0.005), aril thickness (0.05) and seed length (0.014) showed negligible positive and direct effects on fruit weight.

Aril weight showed moderate positive and indirect effect on fruit weight (0.275) through the negligible and positive direct effect of fruit length (0.061) and expressed high positive and indirect effect on fruit weight (0.377) through the negligible positive and direct effect of fruit diameter (0.020).

Aril weight (0.144) got low positive and indirect effect on fruit weight through the negligible positive and direct effect of rind thickness (0.037) and expressed high positive and indirect effect on fruit weight (0.392) through the negligible positive and direct effect of rind weight (0.027).The indirect effect of seed weight (0.111) through the negligible positive and direct effect of rind weight (0.027) was low and positive. Also aril weight (0.186) exhibited low positive and

indirect effect on fruit weight through the negligible positive and direct effect of spine length (0.005).

5.4 Cluster analysis

Clustering of all the thirty seven elite selections of rambutan based on qualitative traits of tree and fruit using dendrogram gave rise to ten distinct clusters at the similarity coefficient status of 60 per cent and at about 45 per cent similarity all the collections were united indicating that the genetic distance among them is small as observed by Andrade *et al.* (2009) while characterizing rambutan plants by foliar aspects. This can be due to the fact that though basically heterozygous the early introductions to the state were from a narrow small area as the full crossing that occurred in the early introductions were confined to a narrow small population

5.4.1 Clustering of elite selections of rambutan

Clustering of elite selections of rambutan (37 collections) based on the first two principal components formed ten major distinct clusters. The score plot indicated that cluster I (Col.061), II (Col.020 and Col.018) and III (Col.042, Col.072, Col.033, Col.028, Col.073, Col.055, Col.027, Col.023, Col.086, Col.022, Col.021 and Col.019) positioned at the first quadrant (+ve side of PCI and +ve side of PC2) were exhibited their superiority over other clusters. Hence they can be categorized as the super elite among the collections. Col.052 (61.5 g) and Col.053 (45 g) located in the fourth quadrant and fell under the category 1 of the Codex Alimentarious (2008) with free seed aril can also be considered as superior among the elite selections. The importance of the first three groups is that they were superior in almost all the improved traits.

5.4.2 Clustering of rambutan collections of export quality

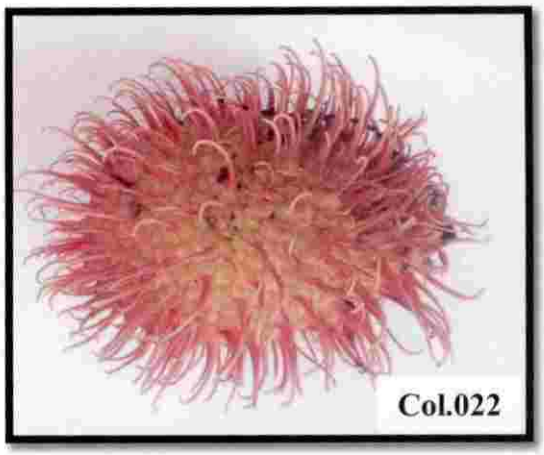
The score plot constructed based on PCI and PC2 for the clustering of rambutan collections of export quality (20 collections) revealed that clusters I (Col.074, Col.068, Col.034, Col.069) and cluster II (Col.063 and Col.53) possessed the best export attributes compared to all other clusters. In addition, clusters VI

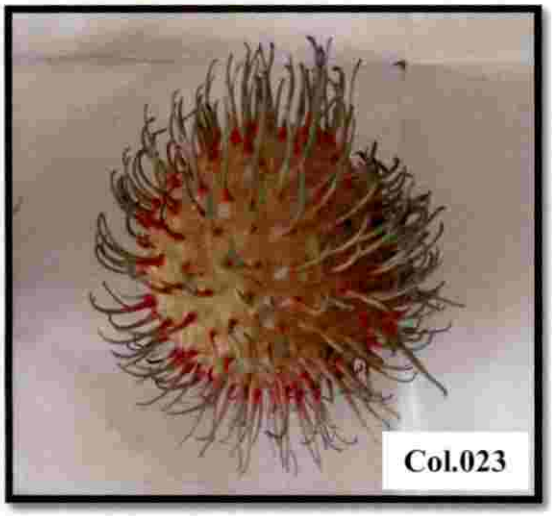
(Col.027), VII (Col.022, Col.023 and Col.055) and VIII (Col.021) which exhibited preferred qualities such as fruit weight above 43 g and compare favourably with the superior category suggested by Codex Alimentarious (2008) with better TSS of above 20° Brix and free seed aril were also taken or could be classed as superior export types. Cluster IV (Col.061) satisfied all the export attributes with the highest TSS of 27.5° Brix except the adherence of aril which was found to be medium and Cluster IX containing only Col.052 showed its superiority over other collections with a distinctive fruit weight of 61.5 g and free seed aril but lagged behind other clusters with regard to TSS (15.5° Brix) and was slightly short of basic requirement of 16° Brix. Hence, the farmer who wants to grow export quality rambutan can select from a wide array of collections made available from the study.

5.4.3 Clustering of rambutan collections having promise for processing attributes

With regard to processing attributes, clusters I (Col.061), II (Col.098), III (Col.042) and IV (Col.018, Col.096, Col.084, Col.086 and Col.028) exhibited the best values compared to other clusters as indicated by their position in the score plot (first quadrant). Besides these, clusters VIII (Col.052) and X (Col.019, Col.021, Col.023, Col.027, Col.033, Col.055, Col.072 and Col.073) also possessed favourable processing attributes and hence could be categorized as superior among the selections of processing/industrial use. Thus, again the study presents another distinct group of improved selections that favourably combines all the important traits and meets the requirement of the processing industry.

From the above clustering of each category of rambutan selections, an attempt was made to classify a 'super group' that can be grouped as elite and fulfills the requirements of an export class and also satisfies the needs of a processing industry. Six collections (Col.021, Col.022, Col.023, Col.052, Col.055 and Col.061) came under all the three categories which can be recommended as elite for commercial cultivation, export purpose and for industrial use.





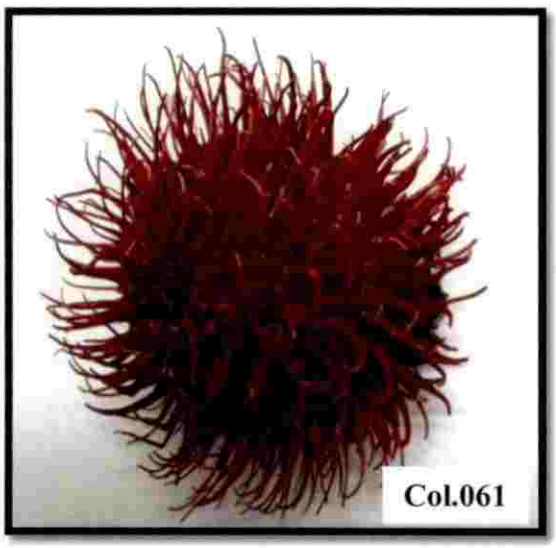


Plate 27. Selected collections of rambutan which fell under all the three categories *viz.*, elite, export and industrial use groups.

The quality profile of these selected collections of rambutan is presented in Fig. 20.

5.5 Selection criteria for rambutan

Six collections, namely Col.021, Col.022, Col.023, Col.052, Col.055 and Col.061 possessing most optimal properties with respect to the major fruit characters; fruit weight, aril weight, percentage aril, percentage seed, juiciness, total soluble solids, total sugar and acidity were selected towards developing a selection criteria for rambutan. The characteristics ranged as 32.23g-61.5g, 12g-21g, 34%-44%, 5%-9%, 32.07%-88.33%, 15.5° Brix-27.5° Brix, 13.57%-18.41% and 0.51%-0.83% in order of fruit weight, aril weight, percentage aril, percentage seed, juiciness, total soluble solids, total sugar and acidity respectively (Fig. 21 and Fig. 22). A tree possessing above optimal characteristics may be hypothesized as having all the maximal values and can be called as 'ideotype'. It is identified as possessing a fruit weight of 61.5g; aril weight of 21g; percentage aril of 44%; percentage seed of 5%; juiciness of 88.33%; TSS of 27.5° Brix; total sugar of 18.41% and an acidity of 0.51%. A tree possessing above mid values computed from the range as fruit weight-46.865g; aril weight-16.5g; percentage aril-39%; percentage seed-7% ; juiciness-60.2% ; TSS-21.5° Brix; total sugar-15.99% and acidity-0.67% can be labelled as 'super elite'. Further, the base values for all the attributes are identified from the minimal values as fruit weight- 32.23g; aril weight- 12g; percentage aril-34%; percentage seed- 9%; juiciness- 32.07%; TSS- 15.5° Brix; total sugar-13.57%; acidity-0.83% and the trees possessing these minimal values can be labelled as 'elite'. Thus we are giving a directional principle to the breeders from the maximum potential realised from this study that what should be an ideotype, super elite and elite type.

5.6 Sensory evaluation

All the collections were scored for different attributes like appearance, colour, flavour, taste, texture, aril juiciness, adherence of aril to seed and overall acceptability on 9 point hedonic scale. The fundamental attributes of fruit quality

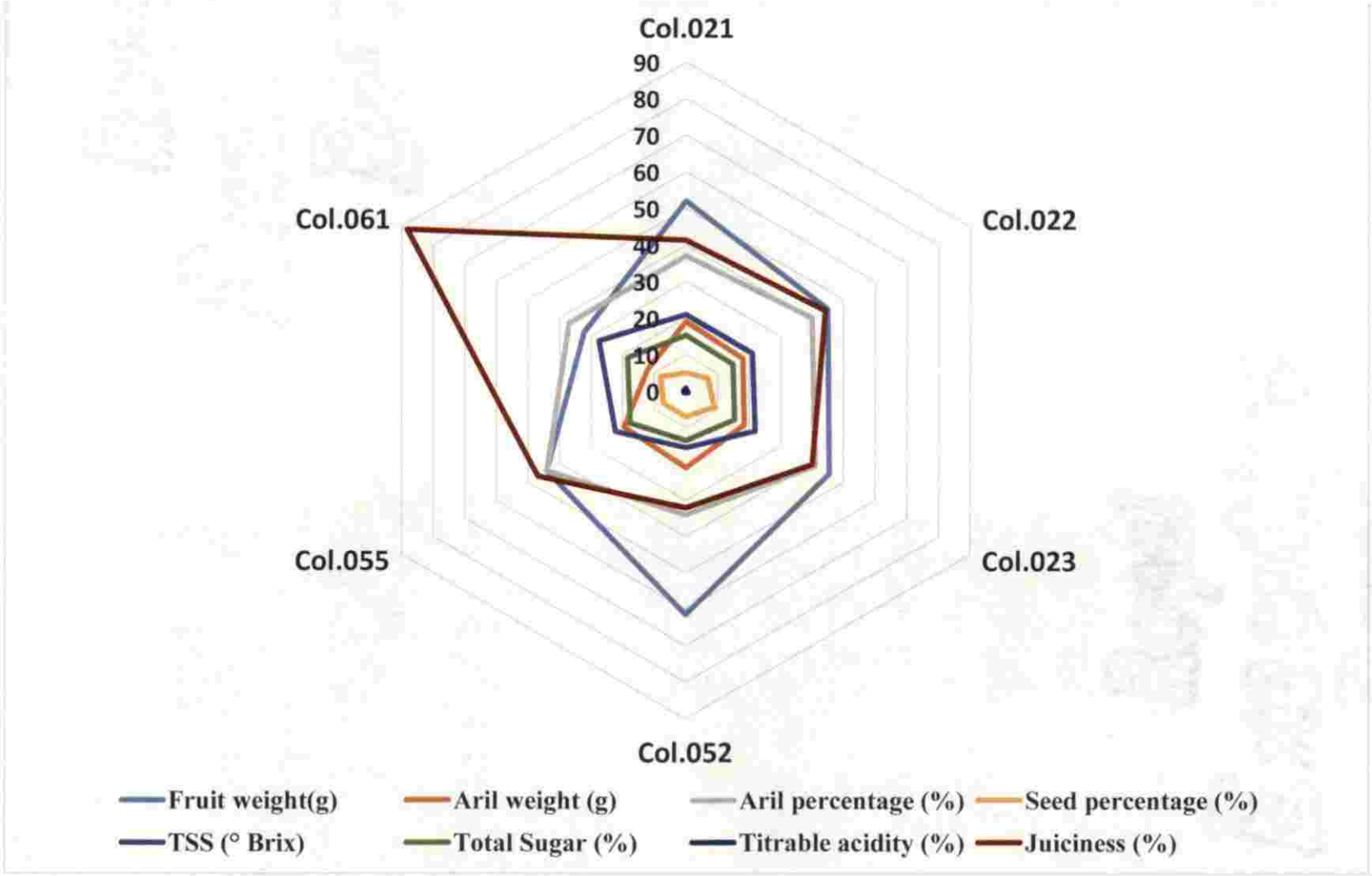
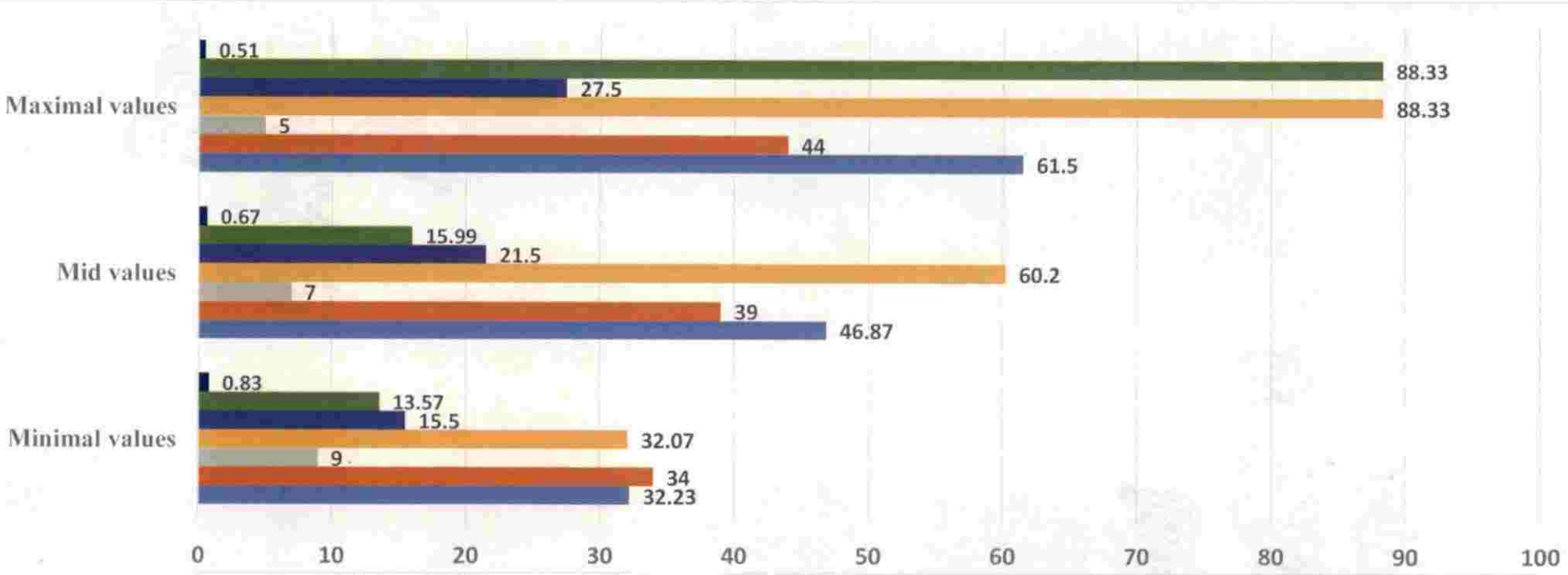


Fig. 20. Quality profile of selected collections of rambutan



	Minimal values	Mid values	Maximal values
Acidity (%)	0.83	0.67	0.51
Total sugar (%)	13.57	15.99	88.33
TSS (° Brix)	15.5	21.5	27.5
Juiciness (%)	32.07	60.2	88.33
% seed	9	7	5
% aril	34	39	44
Fruit weight (g)	32.23	46.87	61.5

Fig. 21. Range of quality attributes of selected collections of rambutan

Fruit weight (g)	% aril	% seed	Juiciness (%)	TSS (° Brix)	Total sugar (%)	Acidity (%)	Category
61.50	44	5	88.33	27.50	18.41	0.51	**Ideotype** (no collections)
46.87	39	7	60.20	21.50	15.99	0.67	**Super elite type** (no collections)
32.23	34	9	32.07	15.50	13.57	0.83	**Elite type** (13 collections)

Col.019, Col.021, Col.022, Col.023, Col.027, Col.028, Col.033, Col.052, Col.055, Col.056, Col.061, Col.086, Col.096

Fig.22. Selection criteria for rambutan

from the consumer point of view are its visual aspects such as appearance, size, colour, texture, firmness and absence of defects, flavour, juiciness, poor attachment of aril to seed and nutrient content (Kader, 2001)

Col.061, Col.021 and Col.042 were most preferred/accepted by panellists because of their better fruit weight, taste, juiciness and easy detachment of aril from seed. The sensory profile of most preferred rambutan collections (Col.061, Col.021, Col.042, Col.033 and Col.018) is presented in Fig. 23.

5.7 Pests and diseases incidence

An attempt was also made to study the incidence of pests and diseases. The major pests observed during the course of the study were fruit borer (*Conogethes (Dichocrocis) punctiferalis*), fruit webber (*Eublemma anguilifera)*, leaf folder (*Thalassodes quadraria)* and mealy bug (*Planococcus citri)*. Besides these, other pests of minor importance like fruit fly (*Bactrocera dorsalis*), armored scale of unknown species, lobster caterpillar (*Neostauropus alternus*) *etc* have also been observed during the study. Among these pests, leaf folder, fruit borer, fruit webber and lobster caterpillar have not yet been reported in rambutan in India and this is the first report of all the four pests in rambutan from India. Osman and Chettanchitara (1987) reported the incidence of *Conogethes punctiferalis* and armoured scale in other Asiatic countries and the incidence of pests like mealy bug (*Planococcus citri*), red borer (*Zeuzera sp.*), bostrichid beetle (*Sinoxylon sp.*) and fruit fly (*Bactrocera dorsalis* and *B. caryeaea*) have been reported from different rambutan growing tracts of South India (Mala *et al.*, 2015).

Fruit rot or anthracnose caused by *Colletotrichum gloeosporioides* is an important postharvest disease of rambutan worldwide particularly in the high rainfall regions which was observed in both harvested fruit and ripening fruit in the field. Symptoms appear as circular, dark brown to black lesions on the fruit rind and thus make unfit or unmarketable (O'Hare, 1995).

Fruit splitting was also observed in few collections during our study as observed in litchi. There are many factors that influence fruit cracking such as

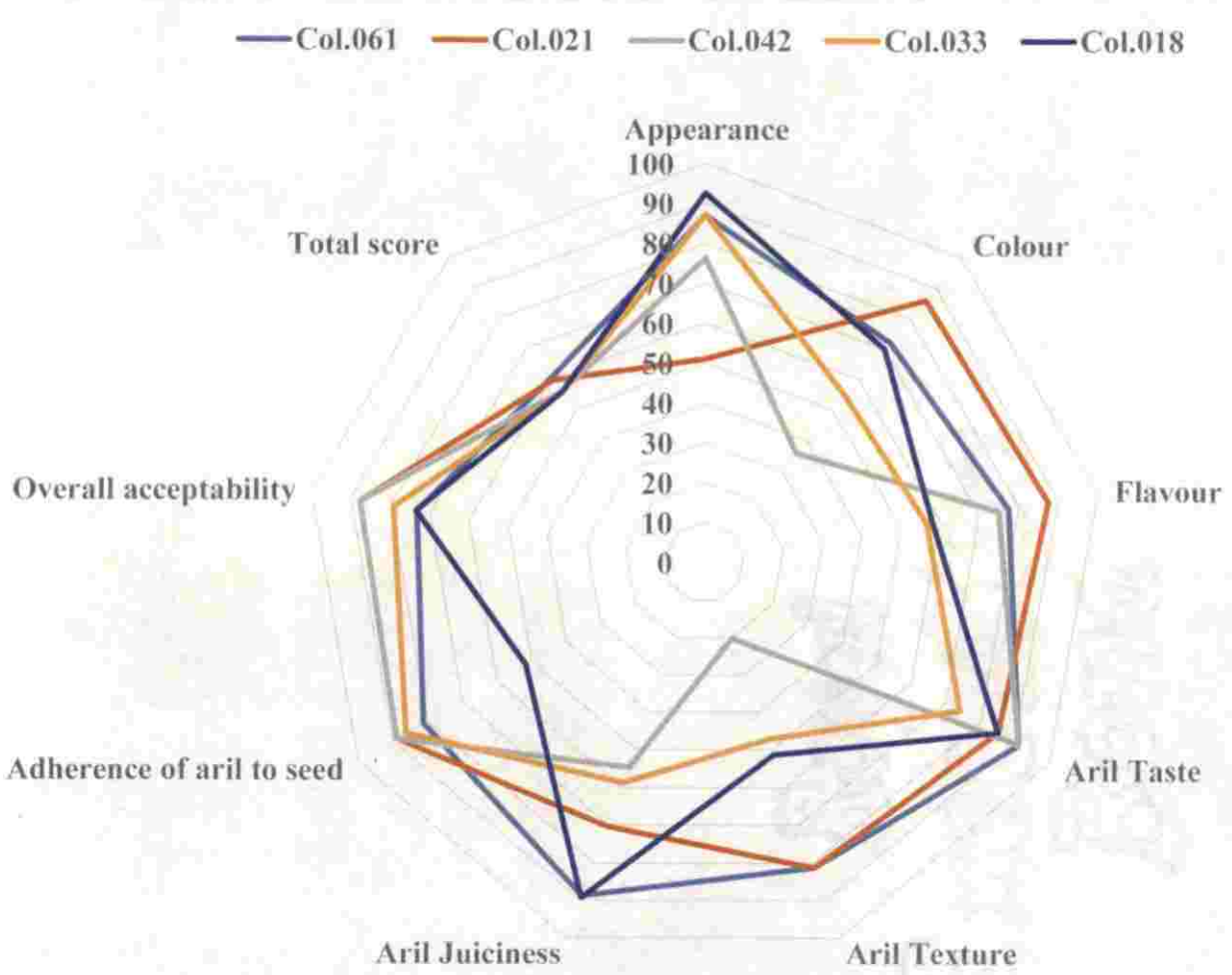


Fig. 23. Sensory profile of most preferred rambutan collections

genectic, morphological environmental and physiological factors (Khadivi-Khub, 2015). Heavy rain or sudden uptake of water during the last stages of fruit development can causes the pulp to expand at a faster rate than the skin, resulting in skin rupture (Lam and Tongumpai, 1987). According to Mandal and Mitra (2014), fruit pressure at maturity and tubercle density were found to be higher in cracked fruits.

Our studies revealed that fruit borer, fruit webber and fruit splitting are the new threats in rambutan cultivation in Kerala. Almost all the trees observed had incidence of mealy bug, leaf folder and fruit rot. Considering the extent of damage and yield loss, fruit borer and fruit webber stand as pests of major importance. The disease or pest incidence severity can be expressed in percentage disease severity index (PDS) by scoring each pest and disease. This study shows that there is an urgent need to standardize the management strategies for controlling pests and diseases as they have invaded the major rambutan growing tracts of Kerala for which an effective study is recommended.

Summary

6. Summary

The experiment on "Variability studies in rambutan (*Nephelium lappaceum* L.)" was conducted in major rambutan growing tracts of Kerala *viz.*, Pathanamthitta, Kottayam, Thrissur and Idukki from December, 2014 to April, 2016.

The study was conducted with the prime objectives of studying the existing variability of rambutan types grown in Kerala in order to select and conserve the elite/promising types and thus to serve as a basis for promotion of cultivation of this exotic fruit crop in Kerala.

The salient findings and important conclusions drawn out from the investigation are summarized hereunder.

- Wide variability was observed among the rambutan collections of Kerala with regard to both morpho-physical and biochemical traits because of the natural cross pollination and seed propagation which was in practice. This variability can serve as a basis for future crop improvement programme in rambutan.
- Phenological growth stages of rambutan were characterized according to the BBCH (Biologische Bundesansalt Bundessortenamt und Chemische industrie) scale in to seven principal growth stages starting from vegetative bud development followed by leaf development, shoot development, inflorescence emergence, flowering, fruit development and ending with fruit maturity and in to respective secondary growth stages.
- Study on phenological growth stages of rambutan in different locations of Kerala revealed that flowering and fruiting were characters more observed to be a function of the location. The variability in flowering season and subsequent harvesting season in each location shows that there is possibility of staggered fruit production of rambutan in Kerala. The fruits are available from May to October (if cultivated in the humid tropical plains as in Thrissur, Kottayam and Pathanamthitta as well as in the humid sub-tropical

belts as in the high ranges of Wayanad), thus making the availability of fresh fruits for nearly half period of a calendar year.

- The collections having soft textured aril exhibited very strong adherence of aril to seed whereas the collections having crispy aril were of free stone aril. The taste sweetness found to tend towards soft textured and creamy white aril, but moved away from free seed aril.
- The principal component analysis performed based on tree characters revealed that the first three components accounted for 58.80 per cent of the total variation and was correlated with the traits such as leaflet length, leaflet width, petiole length and rachis length.
- The use of morphological characters of tree including foliar aspects is efficient in cataloguing the genetic divergence between rambutan plants, but visual distinction is not possible, since no outstanding characteristic exists.
- The loading plot based on tree characters revealed significant positive correlations between rachis length and leaflet width; leaflet width and leaflet length and between tree age and number of leaflets per leaf. A zero correlation was observed between leaflet width and number of leaflets per leaf and a negative correlation between petiole length and leaflet width.
- The principal component analysis based on fruit characters inferred that the first eight principal components of data accounted for 75.30 per cent of the total variation and was mainly determined by characters such as fruit weight, aril weight, aril thickness, TSS and sugar content.
- Strong positive associations were observed between TSS and sugar content and among fruit weight, fruit diameter, rind weight, aril weight and aril thickness whereas, a significant negative correlation was observed between titrable acidity and TSS.
- Rind colour of rambutan was described by using UCL and categorized in to 8 distinct colour groups namely light greenish yellow, pale yellow, strong yellowish pink, strong reddish orange, strong red, vivid red, dark red and deep purplish red.

- Six types of spintern colour was recorded among the rambutan collections namely red, red with light green tip, yellow, light green, light green with pink base and pink with light green tip.
- Clustering of rambutan collections using dendrogram based on qualitative tree and fruit characters showed that there exists 40 per cent similarity (60 per cent variation) among the collections
- Clustering of rambuatn collections of different categories namely elite, export and industrial use by using first two principal components confirmed the superiority of six collections (Col.021, Col.022, Col.023, Col.052, Col.55 and Col.061) over others which were selected further for developing a selection criteria in rambutan.
- A comparison with the existing quality standards and popular varieties revealed that Kerala collections of rambutan are not only comparable with the prevailing standards/ varieties, but even excelled them.
- The minimal, mid and maximal values of selected six collections of rambutan were taken for redefining the existing standards and categorized as elite, super elite and ideotype respectively.
- Col.061, Col.021 and Col.042 were most preferred/accepted by panellists in the sensory evaluation because of their better fruit weight, taste, juiciness and easy detachment of aril from seed.
- Incidence of pests like leaf folder (*Thalassodes quadrarifolia*), fruit borer (*Conogethes punctiferalis*), fruit webber (*Eublemma angulifera*) and lobster caterpillar (*Neostauropus alternus*) and a physiological disorder fruit splitting was observed during the study and being reported for the first time in rambutan from India.

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Appendices

APPENDIX - I

Meteorological data during the period of study (Dec. 2014 – April. 2016)

Month	Maximum temperature (°C)	Minimum temperature (°C)	Relative humidity (%)	Rainfall (mm)
Wayanad district				
December'14	27.47	16.6	81.32	15
January'15	27.34	16.1	83.31	0.4
February'15	27.65	16.23	78.23	0.00
March'15	27.5	17.1	79.21	2.2
April'15	31.00	19.38	77.67	187.2
May'15	29.81	19.24	78.54	175.0
June'15	24.08	18.17	83.61	490.0
July'15	23.81	18.57	80.14	180.0
August'15	25.50	18.44	81.28	128.4
September'15	26.03	17.61	79.32	176.0
October'15	26.60	18.12	79.26	122.2
November'15	26.86	18.14	81.12	106.0
December'15	26.40	18.20	80.43	59.8
January'16	26.56	18.31	80.13	0.00
February'16	27.43	18.23	79.13	0.00
March'16	28.21	18.30	77.71	0.00
April'16	28.81	18.13	78.12	0.00
Thrissur district				
December'14	31.9	23.2	65	151.2
January'15	32.5	22.1	58	0
February'15	34.3	23.0	55	0
March'15	35.8	24.9	63	72
April'15	34.0	24.6	77	162.2
May'15	32.9	24.7	80	259.0
June'15	31.0	23.7	85	629.8
July'15	30.3	23.5	85	510.1
August'15	29.5	23.7	83	320.8
September'15	31.3	23.7	81	248.2
October'15	31.9	24.1	79	203.8
November'15	31.6	23.8	75	151.2
December'15	31.9	23.3	65	88.3
January'16	33.2	23.0	56	23.8
February'16	35.3	23.5	57	11.4
March'16	36.3	25.2	67	9.8
April'16	35.8	26.2	69	25.8

Month	Maximum temperature (°C)	Minimum temperature (°C)	Rainfall (mm)
Kottayam district			
January'15	33	23	4
February'15	34	23	8
March'15	34	24	7
April'15	34	25	12
May'15	32	25	12
June'15	28	24	191
July'15	27	24	144
August'15	28	24	81
September'15	29	24	54
October'15	30	24	60
November'15	31	23	48
December'15	32	23	16
Pathanamthitta district			
January'15	32	22	5
February'15	34	22	8
March'15	35	24	11
April'15	34	25	18
May'15	32	25	59
June'15	28	24	117
July'15	28	24	98
August'15	28	24	71
September'15	29	24	71
October'15	30	24	111
November'15	30	24	94
December'15	31	23	23

APPENDIX - II

Score card for sensory evaluation of rambutan collections

Name of the judge:

Date:

Characteristics	Score						
	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7
Appearance							
Colour							
Flavour							
Texture							
Taste							
Juiciness							
Adherence of aril to seed							
Overall acceptability							

9 point Hedonic scale

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

Signature:

Threshold values fixed for each quality attribute

Quality attributes	Values	Score
Fruit weight (g)	> 40	5
	35-40	4
	30-35	3
	25-30	2
	20-25	1
	<20	0
Aril weight (g)	>20	4
	15-20	3
	10-15	2
	5-10	1
	1-5	0
Aril taste	Sweet	3
	Acid-sweet	2
	Acid	1
	Insipid	0
Aril texture	Soft	2
	Crispy	1
	Firm	0
Aril juiciness	Very juicy	2
	Juicy	1
	Not juicy	0
Adherence of aril to seed	Poor (free seed aril)	3
	Medium	2
	Good	1
	Very good	0
Aril to fruit ratio	>0.4	2
	0.2-0.4	1
	<0.2	0
Seed to fruit ratio	<0.1	1
	>0.1	0
TSS (° Brix)	>25	3
	20-25	2
	15-20	1
	<15	0
Acidity (%)	<0.5	2
	0.5-1	1
	>1	0
Total sugar (%)	>15	2
	10-15	1
	<10	0

1. Scores obtained for elite selections of rambutan

	Fruit weight	Aril taste	Aril texture	Aril juiciness	Attachment of aril to seed	TSS (° Brix)	Aril to fruit ratio	Seed to fruit ratio	Tot sco
Col.022	5	3	1	1	3	2	2	1	
Col.023	5	3	1	1	3	2	2	1	
Col.055	5	3	1	1	3	2	2	1	
Col.021	5	3	1	1	3	2	1	1	
Col.061	3	3	2	2	2	3	1	1	
Col.019	5	3	1	1	2	2	1	1	
Col.027	5	3	1	1	2	2	1	1	
Col.033	3	3	1	1	3	2	2	1	
Col.063	5	3	1	1	3	1	1	1	
Col.072	3	3	1	1	3	2	2	1	
Col.083	5	3	1	0	2	2	1	1	
Col.018	2	3	2	2	1	2	1	1	
Col.020	5	2	2	2	0	1	1	1	
Col.028	4	3	1	1	0	2	2	1	
Col.052	5	3	1	0	3	0	1	1	
Col.053	5	3	1	0	3	0	1	1	
Col.071	2	3	1	1	3	1	2	1	
Col.073	2	3	1	1	3	2	2	0	
Col.074	3	3	1	0	3	1	2	1	
Col.076	4	3	1	0	2	2	1	1	
Col.086	5	3	1	1	0	2	1	1	
Col.096	4	3	1	0	2	2	1	1	
Col.042	1	3	1	1	3	2	2	0	
Col.059	3	2	2	1	0	2	2	1	
Col.040	2	3	1	0	2	2	2	0	
Col.075	1	3	1	0	3	2	2	0	
Col.015	0	3	2	2	0	3	1	0	
Col.031	2	2	2	1	0	2	1	1	
Col.058	1	2	2	1	0	2	2	0	
Col.067	1	2	2	1	0	2	2	0	
Col.060	1	3	2	0	0	2	1	0	
Col.097	2	3	0	0	0	2	2	0	
Col.006	0	2	2	1	0	2	1	0	
Col.041	1	2	2	0	0	2	1	0	
Col.049	0	2	2	0	0	2	1	0	
Col.087	0	3	1	0	1	1	1	0	
Col.092	0	2	1	0	0	1	1	0	

2. Scores obtained for rambutan selections of export quality

	Aril weight (g)	Aril juiciness	Attachment of aril to seed	TSS (° Brix)	Titrable acidity(%)	Total sugar (%)	Total
Col.055	3	1	3	2	1	2	12
Col.021	3	1	3	2	1	2	12
Col.023	3	1	3	2	1	2	12
Col.022	3	1	3	2	2	1	12
Col.027	3	1	2	2	2	2	12
Col.072	3	1	3	2	1	2	12
Col.019	3	1	2	2	2	2	12
Col.033	2	1	3	2	2	2	12
Col.061	2	2	2	3	1	2	12
Col.073	2	1	3	2	1	2	11
Col.052	4	0	3	1	1	1	10
Col.028	3	1	0	2	2	2	10
Col.096	3	0	2	2	1	2	10
Col.063	2	1	3	1	2	1	10
Col.018	2	2	1	2	2	1	10
Col.042	1	1	3	2	1	2	10
Col.084	3	2	0	2	1	1	9
Col.086	3	1	0	2	1	2	9
Col.056	3	1	0	2	1	1	8
Col.098	2	1	0	2	1	2	8
Col.039	3	0	1	1	1	1	7
Col.097	2	0	0	2	1	2	7
Col.081	3	0	0	1	1	1	6
Col.057	2	0	0	2	1	1	6
Col.043	2	0	0	1	1	1	5
Col.045	2	0	0	1	1	1	5
Col.079	2	0	0	1	0	1	4
Col.001	1	0	0	1	0	1	3

3. Scores obtained for rambutan selections having industrial use

	Fruit weight	TSS	Adherence of aril to seed
Col.019	5	2	2
Col.021	5	2	3
Col.022	5	2	3
Col.023	5	2	3
Col.027	5	2	2
Col.033	3	2	3
Col.034	3	1	3
Col.052	5	1	3
Col.053	5	1	3
Col.055	5	2	3
Col.061	3	3	2
Col.063	5	1	3
Col.065	3	1	2
Col.068	3	1	3
Col.069	3	1	3
Col.072	3	2	3
Col.074	3	1	3
Col.076	4	2	2
Col.083	5	2	2
Col.096	4	2	2

APPENDIX – IV

Mean value of each attribute and total score obtained for each collection in the sensory evaluation

	Appearance	Colour	Flavour	Aril Taste	Aril Texture	Aril Juiciness	Adherence of aril to seed	Overall acceptability	Total score
Col.061	7.8	7.4	6.8	8.2	7.8	7.8	7.2	7.2	60.2
Col.021	6.2	7.8	7.4	7.8	7.8	6.8	7.8	7.8	59.4
Col.042	7.4	6.2	6.6	8.2	5.8	6.2	7.8	7.8	56
Col.033	7.4	6.8	6	7.4	6.8	6.2	7.6	7.6	55.8
Col.018	8	7.4	6	7.8	6.8	7.8	4.8	7.2	55.8
Col.071	7.4	7.2	6.2	6.4	7.2	6.2	7.8	6.8	55.2
Col.016	7.4	7.8	6.4	7.8	6.2	6.8	6.4	6.4	55.2
Col.072	6	6.6	6.4	6.6	7	7.2	7.4	7	54.2
Col.063	7.2	7.4	6.8	6.2	6.4	7.4	6.4	6.2	54
Col.020	5.4	6.8	6.4	7.2	7.6	7.8	6.4	6.4	54
Col.055	5.6	7	5.8	7.8	6	6.6	8	6.8	53.6
Col.022	6.2	6.6	6	7	7.2	6	7.2	7.2	53.4
Col.023	6.5	6.3	6.9	6.8	6.1	6.3	7.2	7.2	53.3
Col.073	6.6	6.2	5	7	7.2	6.2	7.8	7.2	53.2
Col.040	7	6.8	6.2	7	7	5.2	6.8	7	53
Col.015	7.4	7.6	6.4	8.2	6.2	7.8	2.8	6.6	53
Col.019	7	6.8	5.6	6.8	6.6	6.8	5.8	7.4	52.8
Col.096	7.8	7.8	6	7.6	5.6	4.6	6.4	6.4	52.2
Col.046	5.2	6.4	6.8	6.6	7.6	6.8	6.2	6.4	52
Col.098	6.4	6.8	6.2	7.8	7	7.2	4.2	6.2	51.8
Col.059	7.6	6.8	6	6.2	7.2	7	3.8	7.2	51.8
Col.065	6.4	7	5	6.8	7.2	6.2	6	7	51.6
Col.035	6.6	6.6	6.4	7	7	6.4	4.2	7	51.2
Col.075	6.2	6.6	5.8	6.8	7.4	4	7.6	6.8	51.2
Col.056	7.4	7.2	6	6.2	6	7.2	4	7	51
Col.099	6.6	6.2	6.2	7.6	7.6	6.4	4	6.4	51
Col.031	6.4	7	6.4	6.4	7.2	6.6	4	6.8	50.8
Col.086	5.6	7.8	6.6	6.6	7	6.6	4	6.6	50.8
Col.034	7	6.2	6	6.2	6.8	4	7.8	6.6	50.6
Col.064	5.6	7	6.6	6.8	7	7.6	2.6	7.2	50.4
Col.032	5.8	7	6	7.6	7.2	6.2	3.2	7.2	50.2
Col.027	6	6.8	5	7.6	5.8	6	6	7	50.2
Col.066	7.8	6.6	6	6.2	7.6	6.6	2.8	6.4	50
Col.045	6.6	6.8	6.2	6.8	7.8	5.4	4.2	6	49.8
Col.074	6.4	5.8	6.6	6	7.2	3.8	7.4	6.6	49.8
Col.004	6.2	6.8	6.6	6.8	7	7.2	3	6	49.6
Col.083	6.4	6.4	4.4	6.6	7.4	5.2	6.2	7	49.6
Col.039	5.8	6.8	4.8	6	7.2	4.8	7	7.2	49.6
Col.091	6	6.6	6.6	7.2	6.6	6	4.2	6.4	49.6
Col.007	6	6.8	6.2	6.6	6.8	6	4.2	6.6	49.2

	Appearance	Colour	Flavour	Aril Taste	Aril Texture	Aril Juiciness	Adherence of aril to seed	Overall acceptability	Total score
Col.085	6	6.6	6.2	6.2	7.2	7.2	3.6	6	49
Col.005	6.2	7.2	7	6.6	6.4	6	3.2	6.4	49
Col.060	7.6	7.2	5.2	6.8	6.8	5	3.8	6.6	49
Col.047	5.6	6.2	6.6	6	7.4	7.2	3.8	6	48.8
Col.009	6.4	6	6.6	6.2	6.8	7.6	4	5	48.6
Col.058	6.4	6	5.2	7	7.2	6.6	3	7.2	48.6
Col.090	5.6	6.2	7	7.2	7.2	6.8	3	5.6	48.6
Col.048	6.2	6.6	6.2	6.4	6.8	3.8	6	6.4	48.4
Col.025	7.4	6.4	5.2	6.6	6.6	6	4	6	48.2
Col.052	5.4	7.4	4.6	6	6.2	4.2	7.2	7.2	48.2
Col.067	5.8	6.2	5.6	6.6	7.4	6.8	3.4	6.4	48.2
Col.029	5.4	6.8	6	6.8	7	6.2	3.6	6.2	48
Col.053	6.2	7.2	4.6	6	5.6	4	7.2	7.2	48
Col.076	5.6	6.2	5.8	6	7	5	6.4	6	48
Col.084	6	6.8	6.4	3.6	8	8	3.4	5.8	48
Col.028	6.4	6.8	5.2	7	6.4	5.8	3.4	6.8	47.8
Col.041	5.8	7	6.4	6.8	7	4.4	4.2	6	47.6
Col.077	5.8	6	6.6	6.2	7.2	3.6	6	6.2	47.6
Col.017	6.6	6.6	6.4	4.4	6.6	7	3.6	6.2	47.4
Col.006	5.4	6.2	6.6	6.6	6.6	7.2	2.4	6.2	47.2
Col.026	5	6	6.2	6	6.6	8	3.2	6.2	47.2
Col.093	5.8	6.6	5	6.4	7.4	6.8	3.6	5.6	47.2
Col.014	6.4	6.2	6.2	7	6	6.2	2.8	6.2	47
Col.062	5.2	6.6	5	6.4	7.4	6	4	6.4	47
Col.087	3.8	6	5	6.4	6.8	5	8	6	47
Col.057	7.6	7.6	5	5.8	6	5.4	2.8	6.8	47
Col.078	5.8	6.6	4.8	6.2	7	4	6	6.4	46.8
Col.092	6.6	6.2	5	6.4	7	5.4	4	6	46.6
Col.002	4.2	6	6.2	7.2	7.6	6	3.2	6	46.4
Col.010	4.6	6	6.6	6.2	6.4	6	4	6.6	46.4
Col.024	5.4	6	5.2	6.2	6.2	4.8	6	6.6	46.4
Col.036	6.4	7	5	6.2	7.4	5	3.4	6	46.4
Col.051	6.8	7.2	4.8	7.2	7	3.6	3.4	6.4	46.4
Col.069	6	6.8	4.8	5.2	6.8	4.2	8	4.4	46.2
Col.094	6.6	6	5	4.4	6.6	7	6	4.6	46.2
Col.054	6.2	7.2	4.8	6.6	6	5	4	6.2	46
Col.097	6.6	6.8	4.8	6	6.6	5.2	4	6	46
Col.068	5	6	5	5.8	6.2	4	7.8	6	45.8
Col.081	6.8	6.6	5.2	5.2	6.6	5.4	4	5.8	45.6
Col.043	6.8	7	5	5.4	6.6	5	3.4	6.2	45.4
Col.001	5.2	6.4	6	6.2	6.6	5.4	3.6	6	45.4
Col.089	6.4	6.2	6.4	6.2	6.4	5.2	2.8	5.8	45.4
Col.050	6	6.2	6	7.2	6.8	3	3.4	6.8	45.4
Col.079	6.4	6.8	5	6	6	5.6	3	6	44.8

	Appearance	Colour	Flavour	Aril Taste	Aril Texture	Aril Juiciness	Adherence of aril to seed	Overall acceptability	Total score
Col.044	5.8	6.8	5.2	5.2	6.4	6.4	4.2	4.6	44.6
Col.049	6.4	6.6	4.4	6.6	6.6	3.8	3.8	6	44.2
Col.070	5	6.2	5.2	5.4	6.8	4.2	7.6	3.8	44.2
Col.088	5.4	6.2	6.2	5.8	6.8	6	2.6	5	44
Col.080	5.6	6	5.2	4.6	6.2	5.2	6	4.4	43.2
Col.012	6.2	6	5	3.8	6.4	6	3.8	5.6	42.8
Col.082	4.4	6.2	5	3.8	6.8	5	7	3.8	42
Col.037	4.8	6	4.8	4	7	5.6	4.2	5	41.4
Col.030	5.2	6.6	6.2	4.2	6.2	5	3.4	4.4	41.2
Col.100	5	6.4	4.8	5.8	6.2	3.6	3	5.4	40.2
Col.095	4.8	6.2	6	4.2	7.6	5	3	3	39.8
Col.038	5.8	6.6	5.2	3.4	6.8	4.8	2.6	3.8	39
Col.008	4.6	6	4.8	4	5.8	5.4	4	3.8	38.4
Col.013	4.4	6	4.2	4	6	3.2	3.6	3.8	35.2

Abstract

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VARIABILITY STUDIES IN RAMBUTAN

(*Nephelium lappaceum* L.)

by

SAMEER MUHAMED

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ABSTRACT OF THE THESIS

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COLLEGE OF HORTICULTURE
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KERALA, INDIA

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Abstract

Rambutan (*Nephelium lappaceum* L.) or 'hairy litchi' is an exotic fruit crop with tremendous potential for cultivation in the whole state of Kerala. There exists great variability in rambutan because of the natural cross pollination and seed propagation, which in turn provides great scope for selection.

It is in this context that the hundred variable types of rambutan collected from important rambutan growing tracts of Kerala (Pathanamthitta-40, Kottayam-37, Thrissur-18 and Idukki-5) were evaluated for various morpho-physiochemical traits in addition to sensorial perception. The study was taken up with the prime objectives of recording the existing variability and genetic wealth available in order to select and conserve the elite/promising types and thereby, to serve as a basis for promotion of cultivation of this exotic fruit crop in Kerala. The study confirmed that rambutan fruits varied widely in their morpho-physical and biochemical traits such as tree characters, inflorescence characters, fruit characters and quality parameters, which were recorded as per IPGRI crop descriptor.

Flowering and fruiting were characters more observed to be a function of the location. The study on phenological growth stages of rambutan according to BBCH scale in different locations opens out a new area on the possibility of staggered fruit production of rambutan in Kerala. The fruits are available from May to October (if cultivated in the humid tropical plains as in Thrissur, Kottayam and Pathanamthitta as well as in the humid sub-tropical belts as in the high ranges of Wayanad), thus making the availability of fresh fruits for nearly half period of a calendar year.

With regard to the individual fruit weight, highest fruit weight of 61.5 g was recorded in Col.052 and the lowest fruit weight of 12 g was observed in Col.012 and Col.013. The largest proportionate edible part was found in Col.072 (52%) and the lowest in Col.008 (15%). Free seed aril was found in 19.39 per cent of the collections, while the adherence of aril to seed was medium in 16.33 per cent of the

collections. Only 8.16 per cent of the collections produced fruits which could be characterized as very juicy types and 47.99 per cent were grouped as juicy type. About half of the collections (48.97%) had a TSS above 20° Brix. The collections having TSS above 25° Brix (Col.015 with 26° Brix and Col.061 with 27.5° Brix) were classified under the category 'very sweet'. The titrable acidity and total sugar content ranged from 0.12 to 1.4% and 13 to 18.4% respectively.

The loading plot based on tree characters revealed significant positive correlations between rachis length and leaflet width; leaflet width and leaflet length and between tree age and number of leaflets per leaf. Strong positive associations were also observed among fruit characters such as fruit weight, fruit diameter, rind weight, aril weight, aril thickness and spine length.

The principal component analysis performed based on tree characters revealed the major contribution of leaflet length, leaflet width and petiole length towards the genetic divergence in rambutan and about 75 per cent of the total variance in fruit characters was mainly determined by the traits such as fruit weight, aril weight, aril thickness, seed weight, seed width, titrable acidity, TSS and sugar content.

Clustering of all the three categories of rambutan collections namely elite, export and industrial use types using score plot confirmed the superiority of six collections (Col.021, Col.022, Col.023, Col.052, Col.55 and Col.061) over others, which were selected further for developing a selection criteria in rambutan. In the sensory analysis, Col.061, Col.021 and Col.042 were most preferred/accepted by panelists because of their better fruit weight, taste, juiciness and easy detachment of aril from seed.

Two new pests of economic importance (fruit borer, *Conogethes punctiferalis* and fruit webber, *Eublemma anguilifera*) have been identified from the rambutan growing tracts of Kerala from fruit set to fruit ripening stage. Their nature of damage

and symptoms of infestation have been clearly studied and being reported for the first time in rambutan from India.

The study revealed that rambutan selections from Kerala are not only comparable with the best known cultivars in the world, but even excell them. There is an urgent need to standardize the management practices including the varietal wealth in rambutan by using these genetic resources as this crop has already become one of the most treasured fruit particularly as a courtyard crop in Kerala.