EVALUATION OF DRAGON FRUIT (*Hylocereus* spp.) GENOTYPES GROWN IN KERALA

By

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2019-12-022

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COLLEGE OF AGRICULTURE, VELLANIKKARA,

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THESIS

Submitted in partial fulfilment of the requirement for the degree of

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DEPARTMENT OF FRUIT SCIENCE

COLLEGE OF AGRICULTURE, VELLANIKKARA,

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DECLARATION

I hereby declare that the thesis entitled **"Evaluation of dragon fruit (*Hylocereus* spp.) genotypes grown in Kerala"** is a bonafide record of research work done by me during the course of research and the thesis has not been previously formed the basis for the award to me any degree, diploma, fellowship or other similar title, of any other University or Society.

Vellanikkara

Date: 7.9.2021

Keerthana Sethunath

(2019-12-022)

CERTIFICATE

Certified that this thesis entitled **"Evaluation of dragon fruit (*Hylocereus* spp.) genotypes grown in Kerala"** is a bonafide record of research work done independently by **Ms. Keerthana Sethunath (2019-12-022)** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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CERTIFICATE

We, the undersigned members of the advisory committee of **Ms. Keerthana Sethunath (2019-12-022)** a candidate for the degree of **Master of Science in Horticulture**, with major field in **Fruit Science**, agree that the thesis entitled **"Evaluation of dragon fruit (*Hylocereus* spp.) genotypes grown in Kerala"** may be submitted by her in partial fulfilment of the requirement for the degree.

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INTRODUCTION

1. INTRODUCTION

Dragon fruit (*Hylocereus* spp.), also referred to as pitaya or pitahaya in various countries is a perennial climbing vine belonging to the Cactaceae family. It is a crop which has received recognition as an ornamental plant initially and later as a fruit crop (Kristanto, 2003). Though this fruit has originated in the tropical and subtropical regions of Central and South America, its cultivation has spread widely in the Asian countries like Vietnam, China, Malaysia, Indonesia, Philippines, Thailand, India and Sri Lanka. In India, dragon fruit is mainly grown in Gujarat, Maharashtra, Andhra Pradesh, Telangana, Karnataka, Tamil Nadu, West Bengal, Kerala and Andaman and Nicobar islands.

Plants are perennial, fast-growing climbing cacti with triangular or rarely four or five-sided stems (Gunasena *et al*., 2007). Stems are fleshy, vine-like with many branched segments having spines. They produce aerial roots that adhere to the support and help in climbing. According to Korotkova *et al*. (2017), they are a group of epiphytic, hemi-epiphytic or climbing cacti. The plants are hermaphrodite in nature, producing large and showy flowers. Bees are the main agents for pollination. Assisted pollination helps in obtaining increased fruitset. The plants can be propagated through seeds and stem segment cuttings. Growth of the seedlings are very slow and starts bearing only after two to three years of planting, whereas the plants from stem cuttings have less juvenile phase and bear fruits within one to two years of planting.

Dragon fruit is known to grow in any type of soil with good drainage and a pH ranging from 5.5 to 6.5. The crop is well adapted to the tropical climatic conditions with well distributed annual rainfall of 100-150 cm and comes up well upto an altitude of 1500m. However, heavy rainfall and extremely low or high temperatures are not suitable for the growth of this fruit crop. The phenological aspects of dragon fruit was found to vary from type to type. The commercially grown dragon fruit in India (purple or white fleshed with pink peel) exhibited a general pattern of one month duration from flowering to fruit ripening. Fruits have to be harvested within 4 to 5 days,when the first colour change is noticed on the fruit. Presently dragon fruits from the domestic orchards are found to reach the market from May-June and continues till September-October. The fruits are highly priced and costs around Rs. 180 to 200 per kilogram.

Nowadays, dragon fruit is found to be in cultivation throughout our state. With the increase in health consciousness, the popularity and demand for dragon fruit is showing an increasing trend as the fruit is known to have numerous health promoting properties like anti-cancerous, anti-diabetic, anti-microbial, anti-oxidant and anti-ageing. Analysis of *Hylocereus undatus* fruits revealed the presence of alkaloids, amino acids, carbohydrates, glycosides, phenolic compounds, saponins, reducing sugars and flavonoids. The fruits have high moisture and low fat content and are good source of vitamins and minerals (Htwe, 2020). Though it is found to be a potential future crop of Kerala, the extent of available information on its cultivation and related aspects is very scarce. The increasing demand for the fruit makes it highly remunerative and has got immense potential for commercialization.

In urban horticulture, dragon fruit plants are gaining importance due to their large showy nocturnal flowers which can be used in moon gardens. A webinar on "Farmers constraints in dragon fruit cultivation", conducted by the National Institute of Abiotic Stress Management (NIASM), Baramati, Pune on 1st September 2020, revealed that there has been a sudden upsurge in the production of dragon fruit in India which can even lead to a glut in the market. Hence, the need for strong marketing strategies and post-harvest technologies for export is the need of the hour for benefiting the farmers and also for reducing the cost of fruits, so that it becomes easily available to the common man.

As this fruit crop is subjected to high intra and inter-specific hybridization, high morphological and genetic heterogeneity is observed in dragon fruit, resulting in great difficulty in distinguishing the species and the varieties.This heterogeneity is causing problems in analysing the performance of dragon fruit for deciding upon the quality standards (Abirami *et al*., 2021). Hernandez and Salazar (2012) reported that the genus *Hylocereus* exhibited greater polymorphisms with respect to stem, flower and fruit characters, which made the taxonomic identification and classification cumbersome.

Large scope for the commercial cultivation of the species belonging to *Hylocereus* (syn. *Selenecereus*) and *Epiphyllum* exists as there is high genetic variability within the species of these climbing cacti. Information on adopted genotypes, production technology followed and the crop management practices along with the crop

production economics is highly essential for any crop improvement programme and for popularising the crop region wise. Hence, the present work was taken up with the objective of studying the morphology, flowering, yield and quality attributes of dragon fruit (*Hylocereus* spp.) genotypes grown under humid tropical conditions of Kerala, so as to provide more information regarding the above aspects which will eventually contribute to the popularisation and commercialization of dragon fruit cultivation in Kerala.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

The review of literature relevant to the objective of the study is discussed in this chapter. The literature collected is presented under the sub-heads namely, variability studies, growth and development under different climatic conditions, phenology, flowering and pollination, fruit characters and yield, quality attributes, storage and value addition, propagation, cultivation practices and postharvest management and finally pest and diseases.

2.1 Variability studies

Britton and Rose (1920) mentioned about 18 species in the genus *Hylocereus* that were found in West Indies, Mexico, Central America and northern South America, namely *H. guatemalensis*, *H. purpusii*, *H.ocamponis*, *H. bronxensis*, *H. polyrhizus*, *H. venezuelensis*, *H. costaricensis*, *H. undatus*, *H. cubensis*, *H. lemairei*, *H. monocanthus*, *H. stenopterus*, *H. extensus*, *H. napoleonis*, *H. trigonus*, *H. triangularis*, *H. antiguensis* and *H. calcaratus.* The evaluation of *Hylocereus* genus led to the conclusion that most of the species were having 3-angled stems with 2 to 6 brown coloured spines seated on the areoles which were 2 to 6 cm apart on the vines. The species *H. polyrhizus* and *H. costaricensis* were differentiated based on their stem and fruit characters, even though both the species had a pink skin. Stem was slender in *H. polyrhizus* with red fleshed oblong fruits while *H. costaricensis* exhibited stout stem with purple-red fleshed ovoid fruits.

Barthlott and Hunt (1993) mentioned that another genus *Epiphyllum* exhibited stem which was devoid of spines and resembled leaves, initially four-ribbed and became two-ribbed at maturity unlike the *Selenicereus* species which had multi-ribbed, spiny stems and fruits with spiny peel.

Mizrahi and Nerd (1999) detailed the usage of the term Pitaya and explained that the term “Pitaya” was commonly used to refer a group of edible fruits in general belonging to four different genera of the Cactaceae family, namely *Stenocereus*, *Cereus*, *Hylocereus* and *Selenicereus*, each one of which is comprised of several species.

Lichtenzveig *et al*. (2000) studied the cytology of the climbing cacti and revealed that the *Hylocereus* spp. were diploid with a chromosome number of 2n=22 and the species *Selenicereus megalanthus* was tetraploid with 2n=44.

The high morphological and genetic heterogeneity created by high intra and inter-specific hybridization created problems in evaluating the performance and the quality standards in dragon fruit (Tel-zur *et al*., 2004). There were reports of hybridization programmes in Taiwan and some elite selections like Vietnam-1 were also released (Zee *et al*., 2004). Study conducted by Castille-Martinez *et al*. (2005), in Mexico revealed that several dragon fruit genotypes differed from each other in their reproductive characteristics.

Crane and Balerdi (2006), has mentioned certain named varieties of dragon fruit. American Beauty, Cosmic Charlie, Dark Star, Halleys Comet, Makisupa, Physical Graffiti, Purple Haze and Wodoo Child with pink flesh. Bloody Mary, Costa Rican Sunset and Red Jaina were mentioned as red fleshed varieties of dragon fruit. David Bowie, Delight, Nietzl, Guyute, Harpua, L. A. Women, Lake Atitlan, Seoul Kitchen, Thompson, Vietnam Jaina and Yellow Dragon were cited as the varieties having white flesh.

However, *Hylocereus* spp. attained more popularity as a fruit crop even though more edible fruits were present in the *Selenicereus* genus (Le Bellec *et al*., 2006). Grimaldo-Juarez *et al*. (2007), in Mexico, evaluated and described twenty-one dragon fruit genotypes based on the differences in their cladode and flower characteristics.

. Tel-zur *et al*. (2011) observed that there were no significant correlations among stomatal length, density and nuclear DNA content and also between fruit weight and seed number for the different accessions belonging to the genera *Hylocereus*, *Selenicereus* and *Epiphyllum*, indicating the high genetic variability among these species. These morphological variations may be attributed to the different geographical origin of the species. The genus *Hylocereus* was found to exhibit maximum number of viable seeds when compared to other genera. There existed high genetic variability within the species of the climbing cacti like *Hylocereus*, *Selenecereus* and *Epiphyllum*.

According to Esquivel and Quasada (2012), red skinned dragon fruits were more attractive than yellow ones as it had no thorns on the fruits and exhibited intensive red colour due to high content of betalain pigments. The red or purple fleshed dragon fruits growing in the regions of Nicaragua, Costa Rica and Guatemala were identified as *Selenicereus costaricensis* and *Selenicereus polyrhizus*.

Hernandez and Salazar (2012) opined that though 14 species were identified under *Hylocereus,* the number of primarily cultivated species were confined to four, which were *H. undatus*, *H. monocanthus*, *H. costaricensis* and *H. megalanthus*. The species *H. monocanthus* was earlier referred to as *H. polyrhizus* and hence, these two species are being used as synonyms.

Plume *et al*. (2013), conducted a study using plastid and nuclear sequences where he revealed that *Hylocereus* to be fit within the paraphyletic *Selenicereus*.

Tran and Yen (2014) reported that certain morphological characters like fruit size, fruit colour and number of spines at the areole can differentiate the dragon fruit varieties. White, pink, purplish-red and red fleshed dragon fruits were similar with respect to characters like bared- narrow cone spines, dark orange spines, golden yellow style, absence of spines on flowers and fruits, and small seeds. A study conducted in Taiwan showed morphological variations among four clones of *Selenicereus* spp. They differed in cladode measurements, distance of areoles, spine characteristics and fruit observations like skin and flesh colour, bract characteristics and so on.

Cruze *et al*. (2016), indicated that the Hylocereae clade consist of two morphologically distinct subclades namely, Hylocereoid subclade and Phyllocactoid subclade. Hylocereoid members were with scandent or epiphytic species having spiny and ribbed stems and nocturnal flowers and the Phyllocactoid clade contained mainly the epiphytic species with flattened, spineless leaf-like stems.

Recently, Hunt (2017), merged both the genera and cited *Hylocereus* as a synonym of *Selenicereus*. According to Korotkova *et al*. (2017), the common usage of "*Hylocereus*" continued, as its circumscription was more clear and solid. Also,

Hylocereus genera had always been well known for its edible fruits whereas the *Selenicereus* for its ornamental nature.

According to Korotkova *et al*. (2017), *Hylocereus* was identified as monophyletic whereas *Selenicereus* was designated as the grade under which *Hylocereus* was placed. From the anatomical and morphological comparison of *Hylocereus* and *Selenicereus*, they also concluded that there was no separation between these two. The members of Hylocereae clade were extremely diverse in morphology and were identified mainly by its hemi- or holoepiphytic habit. The species were with spiny and ribbed succulent stems that were flattened or leaf-like and with varied flowering nature.

Mallik *et al*. (2018) reported that the Bangladesh Agricultural University's Germplasm Centre has released two varieties, namely the BAU Dragon fruit 1 which is a red fleshed variety and another white fleshed variety called BAU Dragon fruit 2.

Perween *et al*. (2018) stated that there were about 16 species in the genus *Hylocereus* which were endemic to the Latin America and were not known to the common man. The popular species, all with leathery peel and leafy bracts, were identified to be *Hylocereus undatus* with white flesh and pink skin, *Hylocereus polyrhizus* with red flesh and pink skin, *Hylocereus costaricensis* with violet flesh and pink skin and *Hylocereus* syn. *Selenicereus megalanthus* with white flesh and yellow skin.

Work by Betancur *et al*. (2020) on different accessions of *S. undatus* reported that there exists high variability with regard to cladode, flower and fruit characters of certain accessions.

Abirami *et al*. (2021) studied the distinguishing characters of three different *Hylocereus* species suitable for growing in the Andaman and Nicobar islands, namely *H. undatus*, *H. costaricensis* and *H.megalanthus*. They were of the opinion that the stem characters such as number of spines (3–5), length of areoles (1-4mm), margin of ribs of cladode (convex or concave) and its waxiness (weak or strong, white waxy or light waxy) could be effectively employed for their identification. Among the wide range of

characters considered, the highest co-efficient of variation was observed for the pulp weight (88.7) and the lowest for the distance of anthers below the stigma (3.3). The rib margins of cladode were convex in both *H. undatus* and *H. costaricensis* but concave in *H. megalanthus*. Cladode characters such as arch height (cm), cladode width (cm) and distance between areoles (cm) ranged from 0.2–0.6, 3.5–5.3 and 3.4–4.0 respectively. Length of flower and style had a mean value of 20.7 and 10.2 respectively. The style length in *H.costaricensis* was found to be 7.02 cm and 7.34 cm.

Chatarsingh (2021) stated that though the different dragon fruit genotypes showed significant variations, they all shared a common lineage.

2.2 Growth and development under different climatic conditions

Geller and Nobel (1984), stated that the reduced rib depth under high shade depicts the tendency of stems to become cylindrical in order to increase the interception of photosynthetically active radiation (PAR) per unit area of stem. Mizrahi *et al*. (1997) reported that dragon fruit plants were grown not only in the tropical regions but also in the subtropical regions with provision of protection from intense solar radiation and extremely low temperatures.

Nerd and Mizrahi (1998) found that the time taken for yellow pitaya (*S. megalanthus*) for fruit maturation depend on the temperatures that prevailed. *H. undatus* showed the greatest sensitivity to the extremely high temperatures of the hot valleys.

Raveh *et al*. (1998) reported that 30% shade was found to be ideal for the growth and development of *H. polyrhizus* in the Neveg desert of Israel. Species like *S. megalanthus* was able to tolerate shade up to 60% and was found more sensitive to increased light intensity than *H.polyrhizus*. The waxy coating and deep-seated stomata in *H. polyrhizus* made it more tolerant to higher light flux densities than *S.megalanthus* which lacked these adaptations. However, both species showed an increase in the amount of chlorophyll per unit area proportional to the shade level. Under the shady conditions, plants developed shallow stem ribs, reduction in root dry weight and increase in the amount of water present in the shoots. In both *H. polyrhizus* and *S. megalanthus*, the stem elongation was found to take place during the hotter months,

when grown under different percentages of shade. When *H. polyrhizus* produced 2.2 times more flowers under 30% shade compared to those grown under 60% shade, *S. megalanthus* didn't show much variations in the number of flowers produced under 30% and 60% shades.

The climbing cactus was known to be originated in the shady habitats of subtropical and tropical America (Mizrahi and Nerd, 1999). Species belonging to *Hylocereus* were found to be more sensitive to low temperatures and they suffered cold injury at temperatures below 4°C (Mizrahi and Nerd, 1999).

Nobel and Barrera (2002) reported that the hemi epiphytic cacti like *H.undatus* belonging to the tropical region differed from other desert cacti because they lacked the ability to withstand higher day and night temperatures above 40°C and 30°C respectively. However, net CO_2 uptake was found optimal for *H. undatus* at high day and night temperatures of 30°C and 20°C respectively.

Nie *et al*. (2005) observed that dragon fruit had a remarkable acclimatization to unfamiliar environments due to the morphological and physiological adaptations of the plants such as stem modification for conserving water, absence of leaves, waxy coating of the cladodes, presence of scotoactive stomata and crassulacean acid metabolism (CAM). Jaya (2010) stated that a temperature of 30-32°C and relative humidity ranging from 60-80% was necessary for the dragon fruit flower buds to bloom.

Hernandez and Salazar (2012) reported that dragon fruit cultivation was spread mainly across the Mesoamerican lands where the altitude was 1840 m above sea level receiving a rainfall of 350-2000 mm or above. Heavy rain during the flowering period often led to flower rot. The species of *Hylocereus* genus usually comes up well in regions where the temperature range from 11-40°C.

H. polyrhizus showed better performance with respect to yield and quality in the Chittagong region of Bangladesh (Patwary *et al*., 2013).

Tripathi *et al*., (2014) reported that dragon fruit could be efficiently grown in tropical conditions with optimum temperature range of 20-30°C receiving proper

sunlight and average rainfall of 100-150 cm in any soils having good drainage and pH ranging from 5.5 to 6.5, up to 1500 m above sea level. They observed that untimely and heavy rain caused excessive flower drop and fruit drop in dragon fruit.

Kishore (2016) observed that the flowering in dragon fruit is depended upon the availability of favourable weather conditions like longer days (more than 13 hours), humidity (above 80%), moderate annual rainfall (100-150 cm) and temperature (around 28°C).

Mallik *et al*. (2018) conducted an experiment in Bangladesh to study the influence of flowering time on the physio-morphological and chemical traits of dragon fruit varieties and they found that the environment influenced the development of fruits. The fruits formed from flowers that bloomed during June to July exhibited highest fruit length and fruit diameter.

According to Perween *et al*. (2018), widely distributed species of dragon fruit in India is *Hylocereus undatus* followed by *Hylocereus costaricensis*. The species *H. undatus*, *H. polyrhizus* and *H. purpusii* were found to be suitable for growing under full sun.

In Israel, *H. polyrhizus* and *H. costaricensis* were found to be the most light-tolerant among different *Hylocereus* species as they had unique skin characters like wax cover and thick skin. Sub-freezing temperatures were detrimental to the growth of different species of dragon fruit and 0°C was the minimal threshold for cultivation for most of the species. Annual flower production seemed to be only 15 to 20% of that obtained in more moderate temperatures. Dragon fruit (*Hylocereus* spp.) became an economically important fruit species worldwide, due to its nutrient content and ability to grow well in varied environmental conditions (Rifat *et al*., 2019).

According to Rojas-Sandoval and Praciak (2020), *Hylocereus undatus* production concentrated mainly in the areas where the temperature did not exceed 38°C and also, the fruit never tolerated frost and very low temperatures. The ideal temperature for plant growth was found to be 18-25°C. Though it is known to be a full sunlight crop, extreme sunlight exposure caused sun injuries on the vines. But they tolerate moderate

shade, windy conditions and saline soils. The low water requirement of the crop is associated with the typical CAM pathway which is common in the cacti family.

2.3 Phenology

Mizrahi *et al*. (1997) reported that *S. megalanthus* fruits took nearly 150 days for its complete development whereas *H. undatus* completed the fruit development in a span of 50 days. According to Mizrahi and Nerd (1999), the flowering time varied according to the changes in temperature. Flowering started in *Hylocereus* species from May to November in areas with more moderate temperatures.

Nerd *et al*. (1999) reported that the first change in the peel colour occurred 24-25 days after anthesis (DAA) in *H. undatus* whereas it took 26-27 DAA for *H. polyrhizus*. But both the species took the same duration of 4-5 days to attain the final colour from the initial colour change.

To *et al*. (2002) observed that the fruits reached optimum maturity and were ready for harvest in 28-30 DAA in Vietnam. Pushpakumara *et al*. (2005) found that there could be 4-6 flushing cycles in dragon fruit under the tropical climate.

Khaimov and Mizrahi (2006) stated that the application of CPPU (N-(2-Chloro-4-pyridyl) N-phenyl urea) induced early flowering and aided in obtaining higher number of flowers in *H. undatus* and *H. megalanthus*. In contrary, application of gibberellic acid (GA3) delayed the flowering and reduced the number of flowers in the two species.

Gunasena *et al*., (2007) reported that the flowering in dragon fruit commenced from April and extended up to November in Sri Lanka. Yah *et al*. (2008) observed that 25-31 days are required for dragon fruit to fully ripen after anthesis. Tel-zur *et al*. (2011), in a study conducted in Israel, observed that generally *Hylocereus* species took 28-41 DAA to mature into a fully ripe fruit but *H. megalanthus* which flowered in the early autumn took only 90 days to mature and those which flowered late in the months of November and December took nearly 160 DAA to mature.

Jiang *et al*. (2012) confirmed that dragon fruit was a long-day plant and the flower bud formation depended on the duration of light hours. The study revealed that provision of artificial lighting during the night could encourage off-season production of flowers and fruits in red pitaya, from September to March. Much longer time of artificial lighting was required in the winter months when compared to that required in early spring.

In Taiwan, the fruiting season started in May and extended till first week of September with almost 6-7 flowering cycles. The time taken from flower bud initiation to anthesis was about 15-19 days and 30-32 days were required for the complete maturation of fruits after anthesis (Tran and Yen, 2014). In China, *Hylocereus undatus* flowering season was observed to be July to December (Flora of China, 2015).

In Brazil, *H. undatus* fruits matured in 30-32 DAA during which the fruits achieved complete red colour, optimum TSS, titrable acidity, pH and TSS/TA ratio (Ortiz and Takahashi,2015).

Kishore (2016) defined the phenological stages in dragon fruit according to the extended BBCH (Biologische Bundesantalt, Bundessortenamt und Chemische Industrie) scale. The phenological stages were divided into seven principal growth stages which consisted of three stages for vegetative growth (vegetative bud development, shoot development and development of vegetatively propagated organ) and four stages for reproductive growth (formation of reproductive bud, flowering, fruit development and fruit maturation). Under the principal growth stages, 40 secondary growth stages were also described with two meso stages included under each principal growth stage. The reproductive buds required three weeks to mature and form the fully developed flowers. In the phenological studies conducted at Central Horticultural Experimental Station Bhubaneswar, it was observed that from first colour change that was visible about 21 days after pollination, it took four days for the fruit to turn deep red in colour.

Warusavitharana *et al*. (2017) reported that dragon fruit took 2 years from planting for first flowering in the wet zones of Sri Lanka. The flowering season started in April and fruits were available till November in 4-7 flowering cycles. Harvest of

maximum number of fruits was recorded in the month of August. The fruits matured in 45-50 days from flower bud formation and in 30-35 days from full bloom.

In Bangladesh, the flowering season of dragon fruit was observed to be April to September regardless of the varieties and they responded to photoperiodic requirement as long-day plants. It was also seen that the varieties differed in their duration required for complete fruit maturation depending upon the time of flowering. For example, the variety BAU Dragon fruit 2 (from Bangladesh Agricultural University) took maximum duration (35 days) to mature when flowering was in the month of June and the minimum duration (30days), when the flowering took place in August month (Mallik *et al*., 2018).

Abirami *et al*. (2021) observed that the apex of flower buds of different species were showing variation. When *H. undatus* and *H. megalanthus* exhibited round apex, *H. costaricensis* plants showed both round and acute apices, similarly the bud shape also differed. The flower buds were elliptic in case of *H. undatus* and *H. megalanthus* whereas it was either ovate or elliptic in *H. costaricensis*. The flowering and fruiting normally took place during April to November in the Andaman and Nicobar Islands with slight variation in timing among different species.

2.4 Flowering and pollination

Britton and Rose (1920) studied the nature of flowers and explained that they were large, hermaphrodite, nocturnal and fragrant with funnel-shaped corolla that was comprised of white and thin petals with a nectary chamber placed at the bottom of the long flower tube.

Weiss *et al*. (1994) evaluated the flowering and pollination behaviour of *H. polyrhizus* in the Negev deserts of Israel and found that they were self-incompatible in nature. They required proper pollination and genotype combinations to produce fruits that weighed above 500g. They found that *H. polyrhizus* flowered when the warm season was prevailing (June-October) and *S. megalanthus* flowered towards the end of warm season (in November). Flowering in all the commercially important species of dragon fruit took place nearly at the same time, opening about 1-1.5 hours before sunset and closing nearly 6 hours after sunrise. Among the species of *Hylocereus*, *H.*

polyrhizus and *H. costaricensis* were self-unfruitful in nature and they required cross pollination for good fruit set whereas *H. undatus* and *S. megalanthus* were self-fruitful. But, *H. undatus* still required a pollen vector for efficient fruit set while *S. megalanthus* did not and this is related to the flower morphology of the two species. The stigma lies 2 cm above the level of anthers in case of *H. undatus* whereas in *S. megalanthus*, the stigma is at the same level of anthers such that the anthers touched the stigma when flowers are closed.

Raveh *et al*. (1998) observed that both *H. polyrhizus* and *S.megalanthus* possessed CAM pathway of carbon dioxide fixation.

Lichtenzveig *et al*. (2000) proved a relation between the fertility status of different species and fruit set and concluded that cross pollination result in 100% fruit set in dragon fruit. It was also observed that cross pollination aided by bees resulted in the formation of bigger fruits when compared to those formed through artificial pollination. They also reported that it took about 2 days for the pollen tube to reach the basal portion of style to fertilize the ovules.

Mizrahi *et al*. (2004) stated that dragon fruit exhibited metaxenia and that the pollen source and its compatibility influenced the fruit set. When this phenomenon was tried for exploiting the duration for fruit maturity in *H. monocanthus,* by pollinating *H. monocanthus* with *S. grandiflorus* and *H. megalanthus* pollen but not with *H. undatus* pollen, the fruit ripening was found to be delayed by 1-3 weeks.

Pushpakumara *et al*. (2005) reported that the flowers were large and showy with a size of 25-28 cm. The reproductive phase of the plant started with the development of spherical, cream-coloured floral buds from the areoles. According to Valiente- Banuet *et al*. (2007), the flowers were found to remain open for approximately 17 hours and the pollinating agents were insects and birds out of which those visiting at night contributed more towards fruit production (76.9%) than those visited during day time (46.1%). The species *H. undatus* and *H. megalanthus* were found to be self-fruitful whereas *H. monocanthus* syn. *polyrhizus* and *H. costaricensis* were self- unfruitful as they required cross pollination with other species for higher fruit set.

Cohen and Tel-zur (2012) studied the possibility of auto polyploidization in *Hylocereus* species and as a result, autotetraploid lines of *H. monocanthus* were developed. But these lines exhibited a breakdown in self-incompatibility and were found to follow self-pollination. However, autopolyploidization did not prove advantageous in improving the yield or quality.

Jiang *et al*. (2012) observed that the recently emerged shoots which had undergone repeated thinning of floral buds resulted in higher floral bud production, irrespective of the photoperiod alterations during the experiment.

Almeida *et al*. (2013) explained that the flowers had a nectarial tissue which secreted nectar that aided in attracting the pollinating agents. They also examined the nature of the floral organs in dragon fruit and reported that the ovary was inferior, surrounded by receptacle which together combined to form the pericarpel which was again covered with photosynthetically active foliaceous bracts. Stamens were numerous arranged in layers but pistil was single-styled with a branched stigma.

Tran and Yen (2014) reported that when studies were conducted in self-compatible and self-incompatible species of the genus *Hylocereus* with respect to pollination behaviour, higher fruit set and fruit weight were observed in cross-pollinated species.

According to Kishore (2016), anthesis started late in the evening and it continued for nearly 12 hours during which the pollination was carried out with the help of agents like bats, hawk moth *etc*. Fertilization and formation of fruit began 2-3 days after the pollination process. The number of cycles wherein reproductive bud production occurred were only four to five but the number of flushes that produced vegetative buds were many. The reproductive buds appeared as single bud more usually than in pairs at the areoles.

2.5 Fruit characters and yield

Weiss *et al*. (1994) found that the source of pollen influenced the fruit weight in dragon fruit. Mizrahi *et al*. (1997) observed that the fruits of *S. megalanthus* had spines

(1-2 cm long) on the areoles which generally abscised on fruit ripening and the fully matured fruits showed yellow peel with elevated tubercles and white juicy sweet flesh. As the harvest is usually done before the fruits are completely ripen, these spines has to be brushed off while harvesting. The fruits of *H. undatus* were free of spines but were having large green scales which turned to various other shades as the fruit matured

Nerd *et al*. (1999) noticed that the fruits were non-climacteric like other cactus fruit crops and both *H. undatus* and *H. polyrhizus* showed a sigmoid pattern of fruit growth when attached to vine. Ramírez (1999) reported that the fruit weight and the time taken for fruit maturity in different Mexican *Hylocereus* accessions varied from 100-1200g and 27-120 days respectively.

The *H. undatus* fruits exhibited a polar and equatorial diameter of 8.9 cm and 8.2 cm respectively at 31 DAA (Yah *et al*., 2008).

In a study conducted by Tel-zur *et al*. (2011), *H. undatus* and *H. monocanthus* accessions gave the highest yields, 15.4 and 14.8 kg/plant/year respectively. Yield from a 2 years old orchard with one plant per pole erected at a distance of 4×3 m, was above 2000 kg/ ha and when the plants became three and four years old, it reached above 9000 and 12000 kg/ ha respectively.

The seed viability was found to differ among various species of *Hylocereus* and also within the same species (Cisneros and Tel-zur, 2012).

Tran and Yen (2014) recorded that the Orejona dragon fruit with red flesh and skin, had about 27 bracts per fruit and the width of the middle bracts were nearly 2.4±0.5 cm. These bracts were slightly held outside from the peel.

Warusavitharana *et al*. (2017) when studied about the cultivation of dragon fruit in wet zone of Sri Lanka, they observed that the fruits recorded weights ranging from 140g to 945g. The fruit length, width and girth were measured to be 11.3-14.2 cm, 8.2-9.5 cm and 25.5-29.1 cm respectively. The fruit peel had 15-22 scales and a thickness of 2-3.5 mm. The normal yield from a 2 years old plant was found to be 2.7 kg, reaching 11.0 and 15.3 kg at third and fourth years, respectively. Perween *et al*. (2018) reported

that dragon fruit cultivation was greatly rewarding as it yielded within 14-16 months of planting the stem cuttings, with an yielding potential up to 20 years with fruiting periods extended over several months, usually from May to December.

Betancur *et al*. (2020) reported that the fruit weight varied in different accessions of *S. undatus*. According to Abirami *et al*. (2021), *H. costaricensis* consisted of plants that had fruits in which the bracts were either held towards the fruit or strongly held away. But *H. undatus* and *H. megalanthus* had fruits in which the fruit bracts were slightly held out from the peel, with fruits having more elongated appearance in case of *H. undatus* and *H. megalanthus* and medium elongated or moderately rounded in *H. costaricensis*. Colour of pulp in *H. costaricensis* was either pink or dark purple and that of peel pinkish red or pink with 27-33 bracts on the fruit surface.

2.6 Quality attributes, storage and value addition

Nerd and Mizrahi (1998) observed that the yellow pitaya (*S. megalanthus*) attained the finest flavour when the fruit reached maximum colour stage. Wills (1998) stated that the acid content of fruits generally decreased as they ripe since the fruits utilized the organic acids as substrates for the purpose of respiration. Both *H. undatus* and *H. polyrhizus* fruits received maximum preference during 33-37 DAA and they had similarity in chemical changes, colour development and palatability during fruit ripening (Nerd *et al*., 1999).

A TSS of 16-17° Brix was reported during maximum colour stage for both *H. undatus* and *H.polyrhizus* and the water content in the peel decreased with fruit development in both the species, more prominently in *H. undatus*, with the water content in the pulp almost constant. The peel colour progression in *H. polyrhizus* coincided with an increase in the water-soluble pigment (betanin) present in the red-violet coloured pulp. A slight surge in the titrable acidity was seen at the initial change in fruit colour, but later falling down as the stages progressed in both *H. undatus* and *H. polyrhizus*. The fruits harvested at near full colour exhibited a shelf life of 2 weeks at 14° C and 1 week at 20° C. Storage at a lower temperature of 6° C and then transferred to room temperature resulted in speedy loss of fruit flavour and firmness (Nerd *et al*., 1999).

To *et al*. (2000) observed that the dragon fruits harvested 25 DAA, possessed a TSS above 12° Brix and continued to exhibit a TSS ranging from 12-16° Brix as it matured further. The acidity content in the dragon fruit ranged from 0.23% to 1.41% during 16 to 22 DAA and reduced below 0.4% from 28-32 DAA. The TSS/acidity ratio value for dragon fruit in the study was obtained as 40. The study revealed that the maximum consumer preference for the fruits was between 28-31 DAA and this quality was maintained till 43 DAA.

To *et al*. (2002), reported that the application of a mixture of gibberellic acid, α-naphthalene acetic acid (NAA) and β-NAA at a formulation of 8, 150 and 400 ppm respectively on the 11th DAA helped in increasing the fruit size and quality along with improved firmness of bracts.

Merton (2003) recorded a TSS of 13 to 16° Brix in *S. undatus* during the harvest. Stintzing *et al*. (2003) reported that the *Hylocereus* fruits recorded a TSS in the range of 9 to 11° Brix and a sugar: acid ratio of 20:1 to 22:1. As the dragon fruits are low in acidity, the fruit juice can be mixed with other high-acid fruit juices to balance the flavour.

De Dios (2005) reported that among all the species of the genus *Hylocereus*, *H. undatus* ssp. *leutocarpus* with yellow fruit epidermis seen in the dry deciduous forests of Yucatan peninsula, had the sweetest fruits which possessed a TSS of 11.5-16.4° Brix.

Esquivel *et al*. (2007) explained different methods for processing the fruits of *Hylocereus* spp., which included freezing, concentration, dehydration, fermentation, thermal processing and chemical preservation. Technologies were also developed to extract natural colorants and pectin from the pulp and peel of the fruits. Chuah *et al*. (2008) stated that apart from consuming dragon fruits as fresh fruits, these fruits were also used for preparation of jams, jellies, beverages, wine and marmalade.

The major pigments that contributed to the deep purple colour of the fruit pulp were the betalains, predominantly the betacyanins. Dragon fruit peel, usually thrown as waste, were also rich in betacyanin which could be extracted and used as natural colorant or dye in food industry. Maximum yield of betacyanin from the fruit peel was

obtained when the samples were subjected to 100°C for 5 minutes at pH 5 (Harivaindaran *et al*., 2008).

Yah *et al*. (2008) noticed an increase in the total soluble solids from 4.6 to 12.6% during the ripening of *H. undatus*. They reported a reduction in malic acid content from 0.4% to 1.4% and ascorbic acid content from 14.7 to 9.6 mg/100g, as the fruit ripened, which indicated a high °Brix/acid ratio in ripe fruits. They stated that the maximum acceptance for the fruits was at 29-31 DAA because the fruits changed their flavour from bitter-sweet to sweet during this stage.

Jaafar *et al*. (2009) reported that the dragon fruit cladodes showed improved values of moisture, glucose, protein and ascorbic acid when compared with those of fruit flesh concluding that the premature stems of dragon fruit too had beneficial properties.

Wichienchot (2010) reported that *H. undatus* and *H. monocanthus* had glucose, fructose and various oligosaccharides leading to the whole concentration of 86.2 and 89.6 g per kg respectively.

Jamilah *et al*. (2011) studied the biochemical properties of both the peel and pulp in pitaya and found that the pulp had a TSS of 11.40 °Brix attributed by the major sugars like glucose, maltose and fructose, whereas the peel recorded very low TSS with sucrose and galactose. The peel was also rich in soluble and insoluble dietary fibres.

In Mexico, when Martinez Chavez (2011) studied six different pitaya genotypes, found that the TSS varied from 14.5-17.6° Brix. Kleinhenz and Bumgarner (2012) indicated that TSS (°Brix values) of different fruits varied with year, season, environment, variety, maturity, growth stage and crop management practices.

Meija *et al*. (2013) obtained a highest TSS of 18° Brix in a population of wild species of *Hylocereus*. Ortiz and Takahashi (2015) observed a trend in the titrable acidity of fruits with a lower value of approximately 0.40% at 21 DAA followed by slight increase, reaching up to 1% and finally falling down to a much lower value of 0.27% at 32 DAA.

Warusavitharana *et al*. (2017) reported a TSS of 16-18° Brix in the ripe dragon fruits cultivated in the low country wet zones of Sri Lanka. In a study conducted by Betancur *et al*. (2020), the TSS was found to be in the range of 11.2 to 15.6° Brix in *H. undatus* and there was not much variation in the °Brix values among the different accessions of *H. undatus*.

Abirami *et al*. (2021) recorded a TSS of 11.2 °Brix for *H. undatus*, 9.1 °Brix and 15.9 °Brix for two types in *H. costaricensis* and 18.3 °Brix for *H. megalanthus*. Titrable acidity was recorded in the range of 0.16-0.28% in all the three species.

Arivalagan *et al*. (2021) stated that the red fleshed *H. polyrhizus* were rich in phenolics and antioxidants when compared to *H. undatus*, and were low in calories with good amount of vitamins and minerals. Chatarsingh (2021) reported that all the dragon fruit genotypes seen growing in various locations (Maharashtra, Karnataka and Kerala) displayed acidity at an average of 0.39%. The maximum TSS of 19.95 °Brix was found to be in *H. megalanthus*.

Yu *et al*. (2021) identified the potentiality of *H. polyrhizus* cultivar Zihonglong fruits in wine making in China mainly with the fruits harvested during the month of August.

2.7 Propagation, cultivation practices and postharvest management

Mizrahi *et al*. (1997) reported that in Columbia and Israel, the pitahaya plants were trained in trellis method. In Columbia, diverse range of materials were used for constructing the trellises which included large boulders. In Israel, the initial installation of the trellis was reported to be the major expense in establishing the orchard. Mizrahi and Nerd (1999) reported that dragon fruit was initially seen growing extensively in the family gardens of Central America, but now it is grown on a commercial scale in Israel, Malaysia, Thailand and United States giving an yield as high as 40 tonnes/ha.

Nerd *et al*. (1999) reported that the best storage temperature for *H. megalanthus* was 10°C and that for *H. undatus* and *H. monocanthus* were 20-26°C which offered a better storage life of 6-10 days. To *et al*. (2000) recommended the harvesting of fruits

between 30-35 DAA for better storage to circumvent any possible chilling injury and the fruits were recorded to have a shelf life of 30-45 days.

Gunasena *et al*. (2007) stated that the side shoots had to be pruned after the harvest in order to enhance the growth of vegetative buds. Novita (2008) observed that to ensure retention of quality and better storage life, red pitaya fruits have to be harvested during 30-40 DAA. The shelf life of *H. polyrhizus* was found to increase by the application of 1-MCP (1-Methylcyclopropene). The storage was possible for 28 days at 10° C, by decreasing the respiration rate without affecting the antioxidants present in the fruit. Lum and Norazira (2011) testified that the fruits could be stored for longer period by following hot water treatment wherein the fruits must be immersed in hot water (35°C) for 60 minutes.

Application of fertilizers during the shoot development and fruit growth were found to be best in order to increase the yield and quality, as dragon fruit crop had several cycles of vegetative and reproductive bud formation (Chakma *et al*., 2014).

Ortiz and Takahashi (2015), detailed the consequences of early and late harvest in dragon fruit. The fruits which were harvested much earlier suffered from cellular disorganization and those which were harvested late had poor quality and texture with high moisture content.

Kishore (2016) stated that the formation of primary and side shoots determined the vegetative growth of dragon fruit and that the basic framework of the plants was contributed by the primary shoots whereas the side shoots served the function of propagation. The side shoot pruning is thus a necessary operation to be followed in dragon fruit cultivation. Efficient methods of nutrient management at the right time contributed directly to yield and quality improvement. Composted cow dung and chemical fertilizers including urea, triple super phosphate and MOP were used as source of nutrients. They also observed that the fruits must be harvested at the advanced maturation stage for distant markets whereas they must be harvested at completely matured stage for sale in local markets.

According to Dhurve (2017), stem cuttings were found to be the most promising means of propagation of *Hylocereus* spp. in the coastal regions of Andhra Pradesh when compared to seed propagation. However, significant differences were exhibited by the species under different propagation methods. The species with red flesh was found to perform well both under seed and vegetative propagation methods.

Warusavitharana *et al*. (2017) conducted studies on dragon fruit under Sri Lankan conditions using concrete post with a frame fixed on the top to train the plant, so that it hanged down from the frame. The vines were tied onto the post using plastic threads as the vine length increased.

Verma *et al*. (2019) conducted a study on fertilizer application in dragon fruit and revealed that the combination of organic, inorganic and bio-fertilizers gave the best results with respect to the vegetative growth.

2.8 Pests and diseases

2.8.1 Diseases

As dragon fruit was a crop introduced recently to India, disease and pest infestations were comparatively lesser than other fruit crops. A bacterial disease, watery stem rot caused by *Xanthomonas* was observed in areas receiving heavy rainfall (Tripathi *et al*., 2014). Diseases like fruit rot, yellow cladode and stem canker were reported by Hoa *et al*. (2016). Red fleshed fruits were found to be more susceptible to the disease, fruit soft rot caused by *Erwinia chrysanthemi* and *Rhizopus* sp, whereas white fleshed fruits only by *E. chrysanthemi*. The disease infestation started with young flower buds, flowers and young fruits, making the whole fruits black within a short period of time. In addition, this attracted wounding insects which fastened the spread. Yellow cladode or the brown spot were found to affect the plants irrespective of the age. Brown spots surrounded by yellow halos which expanded with severity in infection produced large yellow regions. The fungi *Bipolaris crustacea* and *Fusarium equiseti* were found to be the major causal organisms detected for yellow cladode. Stem canker caused by *Nyoscytalidium dimidiatum* was characterised by numerous pin prick circular spots which coalesced to cover larger areas on the cladode or fruit leading to rot.

Different *Fusarium* spp. were also found to cause stem rots in dragon fruit (Rita *et al*., 2016). According to Zhang *et al*. (2017), stem rot caused by the bacteria *Paenibacillus polymixa* created havoc in China's dragon fruit orchards during the year 2014. Cactus virus X had been found to affect *H. undatus, H. monocanthus* and *H,megalanthus* equally and showed symptoms like necrosis, chlorotic spots and rotting (Masanto *et al*. 2018).

Among the diseases infecting dragon fruits, majority were caused by fungi and among the fungal diseases, anthracnose was reported to be most severe. The most common species of *Colletotrichum* causing anthracnose in dragon fruit was *C. gleosporioides.* The fungal disease reported recently from India was anthracnose caused by *C. siamense* (Abirami *et al*., 2019). The incidence of anthracnose which was reported from Brazil was caused by another species of *Colletotrichum*, namely *C. karstii* (Nascimento *et al*., 2019).

Evallo *et al*. (2021) reported that the plants infected by cactus virus X were sometimes asymptomatic and they could be spread through propagating materials, infected tools and also lead to complex infection with other viruses like zygocactus virus X and pitaya virus X. The virus even altered the plant's physiology.

Huda-Shakira *et al*. (2021) pointed out another disease infestation among the red-fleshed dragon fruits (*H. polyrhizus*) of Malaysia, the grey blight caused by *Diaporthe* species, wherein the affected stem had lesions of varying dimensions surrounded by red borders.

2.8.2 Pests

Barbeau (1990) reported the attack of ants belonging to genera *Atta*. Beetles and bugs are also reported to cause damage in dragon fruit cultivation. The best example of beetle attack was that of *Cotinus mutabilis* which perforated the stem. A bug that was found to create destruction to the plants by sucking the sap and producing lesions and distortions is the *Leptoglossus zonatus*.

According to Choi *et al*. (2013), the major pests of dragon fruit in Korea were the various ant species, aphids (*Aphis gossypii*) and the tobacco caterpillar (*Spodoptera litura*). Aphids and ants damaged the stem, flowers and fruits whereas the caterpillar wounded mainly the stem. Perween *et al*. (2018) reported that the fruits and flowers also suffered from severe aphid and scale problems. Birds and rats were also reported as important pests which spoiled the fruits.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present study on "Evaluation of dragon fruit (*Hylocereus* spp.) genotypes grown in Kerala" was carried out in four different districts of Kerala, *viz*., Thiruvanathapuram, Pathanamthitta, Ernakulam and Thrissur during the year 2020-21. The major objectives of the investigation were to study the morphology, flowering, yield and quality attributes of dragon fruit genotypes grown in Kerala. The materials utilized and the methodology followed are explained in this chapter.

3.1 Experimental site

A total of ten locations were selected, where dragon fruit was in cultivation, which were distributed in the four districts of Kerala, namely Thiruvanathapuram, Pathanamthitta, Ernakulam and Thrissur.These locations were identified after consultation with the agriculture department, followed by discussions with the concerned farmers. The locations selected were Karette (Thiruvanathapuram), Adoor, Keerukuzhy, Thatta, Aikkad, Kozhenchery and Athikkayam (Pathanamthitta), Muvattupuzha and Perumbavoor (Ernakulam) and Vaniyampara (Thrissur) (Plate 1A and 1B). A preliminary survey was conducted and further ten plants from each of these ten locations were selected for studying the morphological, flowering and phenological parametersof dragon fruit plants. Fruit characters and quality attributes were also recorded from the mature fruits collected from the plants grown in these ten locations.

The ten plants selected from each location were numbered as P1-P10 and for easy identification, as a prefix to the plant number, the first two letters of the location (first letter capital and second one small) were added in the following format.

Ka: Karette
Th: Thatta
Ke: Keerukuzhy
Ko: Kozhenchery
Ai: Aikkad
At: Athikkayam
Ad: Adoor
Mu: Muvattupuzha
Pe: Perumbavoor
Va: Vaniyampara

3.2 Stem characters

All the observations for stem were made on mature stem segments and the observations on areoles and spines were also taken from intact mature stems.

3.2.1 Stem segment length (cm)

Length of the stem segment was measured using a measuring scale in each plant under study and was expressed in centimetres (cm).

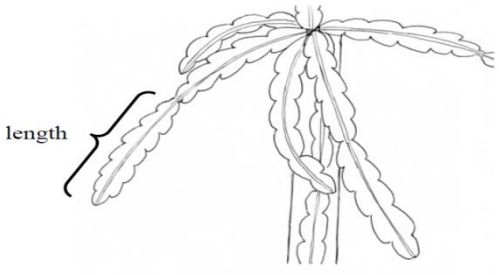


Fig. 1. Stem segment length

3.2.2 Stem segment width (cm)

The stem segment width observed at the middle part of the annual stem section was recorded.

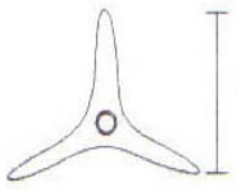


Fig. 2. Stem segment width

3.2.3 Distance between areoles (cm)

The distance between two areoles on the segment was measured.

3.2.4 Arch height (cm)

The height of arches on the ribs of stem segments was measured from the middle of the segment.

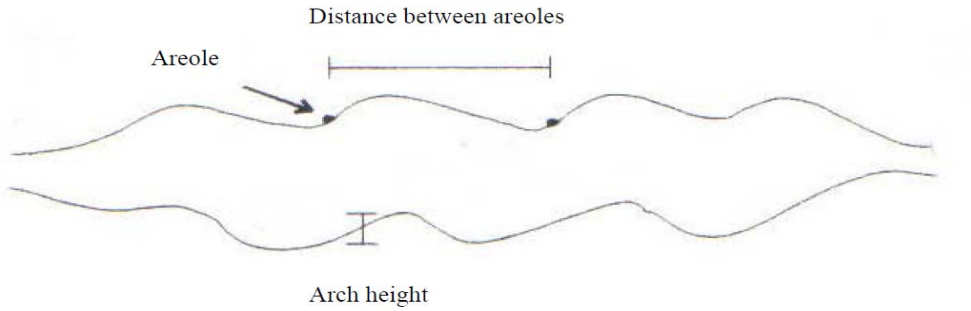


Fig.3. Distance between areoles and arch height

3.2.5 Stem waxiness

The extent of waxiness in the stem segment was observed to classify them into strong, medium and weak, based on the intensity of waxiness.

3.2.6 Stem sturdiness

The nature and texture of stem segments of the plants were visually observed closely and were classified into low and high sturdiness class.

3.2.7 Margin of rib

Stem segments of the group of plants were visuallyobserved and the margin of ribs were categorized as concave, flat or convex in appearance.

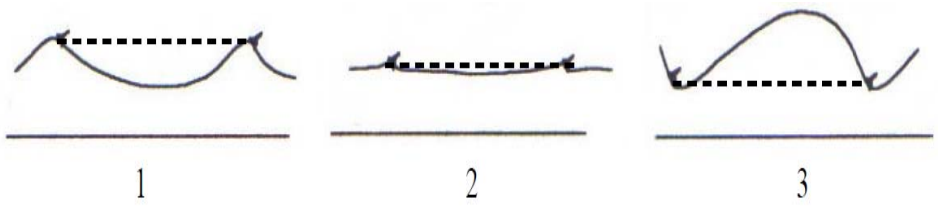


Fig.4. Margin of rib: (1) concave (2) flat (3) convex

3.2.8 Number of spines per areole

Spine number per areole was assessed by counting.

3.2.9 Spine colour

Spines had more than one colour. The main colour was the one with the largest surface area. The colours fell mainly under three categories namely grey, medium brown and dark brown.

3.2.10 Height of pole (ft)

The support structures for the plants were concrete poles. The height of the poles was recorded in feets.

3.2.11 Number of branches

The number of branches from the top of the pole, hanging down and capable of fruiting was recorded.

3.2.12 Number of stem segments per branch

The number of stem segments on the mature branches, hanging down from the top of the pole were counted and recorded.

3.3 Flower characters

3.3.1 Bud shape

Shape of the flower buds was observed for the different group of plants and were recorded as ovate, elliptic, circular or oblate.

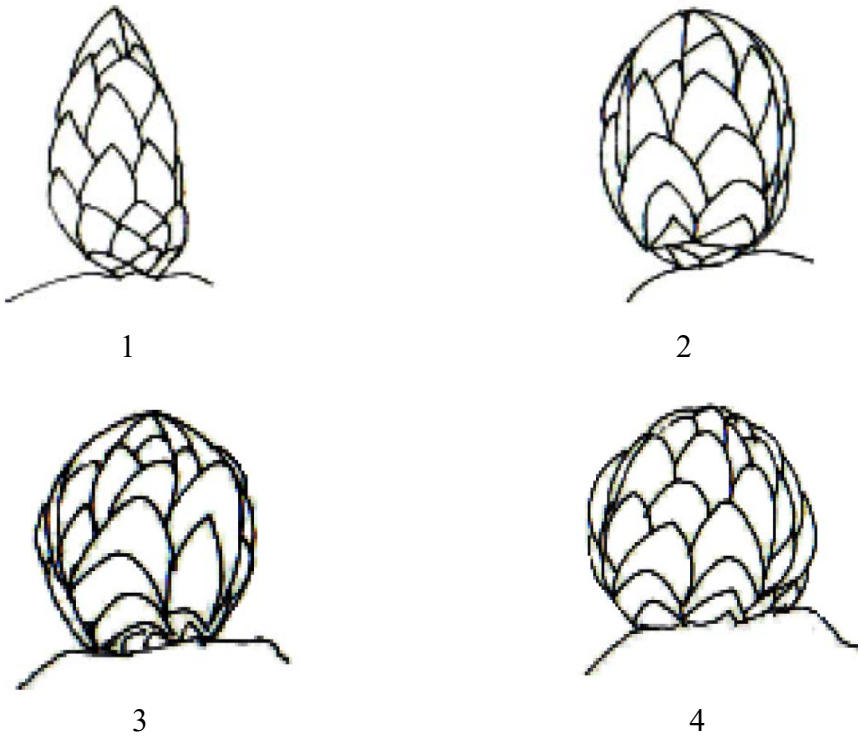


Fig.5. Flower bud shape: (1) ovate (2) elliptic (3) circular (4) oblate

3.3.2 Shape of bud apex

The flower bud apex was observed in each of the plants under study and were categorized under two groups namely acute and rounded.

1 2

Fig.6. Bud apex shape: (1) acute (2) rounded

3.3.3 Petal colour

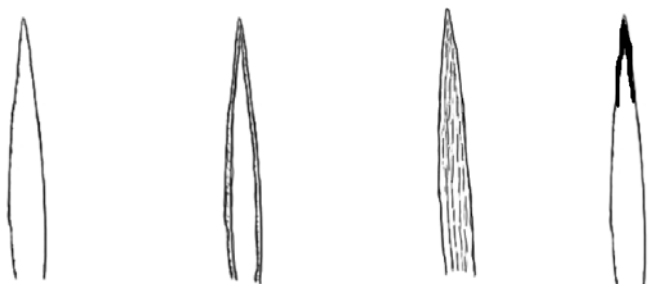
The petal colour of opened flowers were observed and grouped as white, cream, yelllow or yellowish green.

3.3.4 Sepal colour

The main colour was the colour that covered the maximum surface area.

3.3.5 Sepal: pattern of secondary colour

The tip and edge portions of the flower sepals were observed for the patterns they exhibited.



1 2 3 4

Fig.7. Sepal: pattern of secondary colour: (1) none (2) edged (3) striped (4) slightly edged

3.3.6 Intensity of red colour of bract

The pericarpel portion of the flowers were observed to classify the extent of red colour that covered the region as weak, medium and strong.

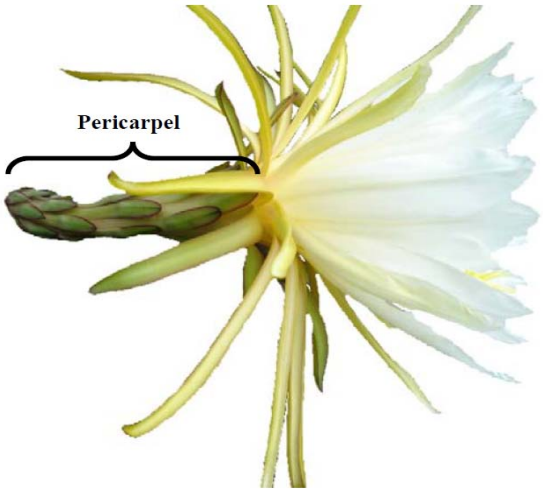


Fig.8. Pericarpel region of the flower

3.3.7 Length of style

Style length of the flowers were measured using a measuring scale and wasrecorded in centimetres (cm).

3.3.8 Number of stigma lobes

Stigma lobes of flowers were counted and the number was recorded.

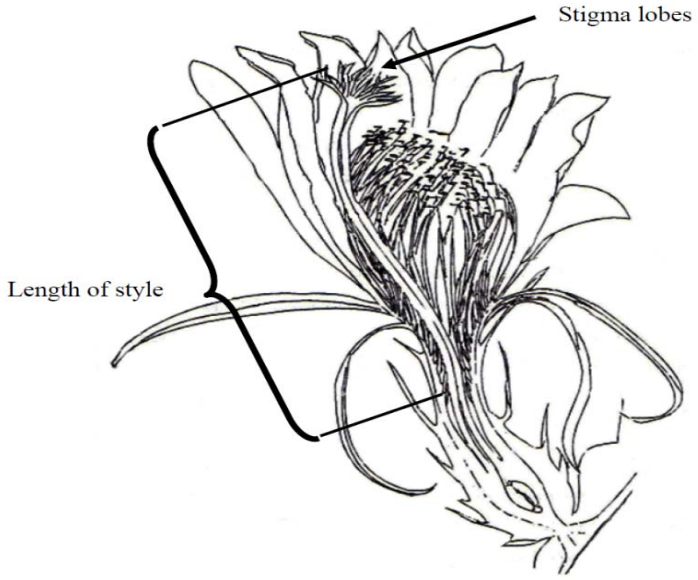


Fig.9. Length of style and number of stigma lobes

3.4 Phenological parameters

3.4.1 Flowering season

The flowering season was recorded in months from the beginningof development of flower bud to the end.

3.4.2 Duration of flowering (days)

The number of days were recorded upto which the flowering continued from bud initiation to anthesis.

3.4.3 Flowering to fruitset (days)

The number of days taken from flowering to observe the fruitset evidently were recorded.

3.4.4 Fruitset to harvest (days)

The duration for fruitset to harvest was recorded as number of days.

3.4.5 Flowering to harvest (days)

The number of days taken from flowering to harvest of the mature fruits were recorded.

3.4.6 Fruiting season

The fruiting season was recorded in months from the beginning to the end of fruiting.

3.5 Meteorological data

The locations of study fall under tropical region with the characteristic tropical warm and humid climate. The meteorological data during the period of study were collected and are given as Appendix I.

3.6 Yield characters

3.6.1 Fruit weight (g)

The weight of each fruit was recorded in grams (g) using a standard electronic weighing balance.

3.6.2 Length of fruit (cm)

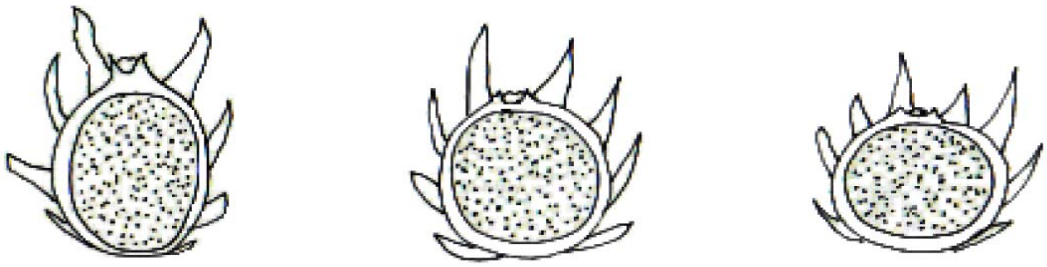
Ten fruits from each location were collected and the length of their cross-section was measured in centimetre (cm) using a measuring scale.

3.6.3 Width of fruit (cm)

Ten fruits were collected from each location and the width of their cross-section was measured at the widest point in centimetre (cm) using a measuring scale.

3.6.4 Length/width ratio of fruit

The ratio of the length to width of the fruits were calculated by dividing the values obtained for length and width of individual fruits of all the locations in order to classify the fruits into different groups like moderately elongated, medium or moderately compressed.



1 2 3

Fig.10. Length/width ratio of the fruit (1) Moderately elongated (2) Medium (3) Moderately compressed

3.6.5. Number of bracts

The number of bracts spread over the fruit peel were counted and recorded.

3.6.6. Length of apical bract (cm)

The length of the bract at the apex portion of the fruit was measured in centimetre using a measuring scale (cm).

3.6.7. Width of the base of the bract (cm)

The width of the middle bract of the fruit was measured in centimetre (cm) using a measuring scale.

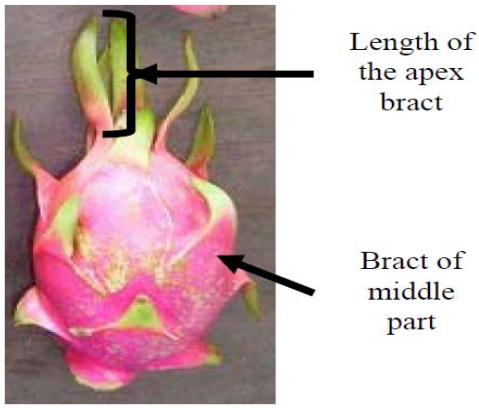


Fig.11. Apical and middle bracts of dragon fruit

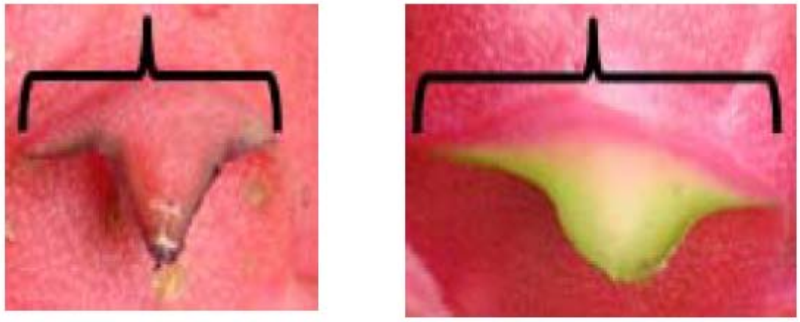


Fig.12. Width of the base of bract

3.6.8. Position of bracts towards the peel

The fruit bracts were observed for the arrangement of the bracts on the peel and were classified as adpressed, slightly held out and strongly held out.

1 2 3

Fig.13. Position of bracts towards the peel: (1) adpressed (2) slightly held out (3) strongly held out

3.6.9. Fruit weight without peel (g)

The fruits were weighed individually after peeling them and the weight was recorded in grams (g) using a standard electronic weighing balance.

3.6.10. Fruit shape

The fruits were observed for their shape visually and with respect to the length to width ratio of the fruits and were classified as spherical and oval shapes.

3.6.11. Colour of peel (excluding bract)

The main colour of the peel was observed excluding the bract colour and were classified under categories like whitish, yellow, green, medium pink, dark pink, red and purple.

3.6.12. Flesh colour

The flesh colour of ripe fruits was observed and were noted as white, dark pink and purple.

3.6.13. Yield per post (kg/year)

The average yield of fruits per post was recorded from each of the location and were expressed in kilogram (kg) per year.

3.7. Quality attributes

3.7.1. Total soluble solids (° Brix)

The fruit pulp was examined for its TSS content using a hand refractometer having a range of 0-32°Brix and was recorded as degree brix (°Brix).

3.7.2. Titrable acidity

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

3.7.3. TSS/acid ratio

TSS/acid ratio was calculated by dividing the observed values of TSS by respective values of the titrable acidity.

$$\text{TSS/acid ratio} = \frac{\text{Total soluble solids (° Brix)}}{\text{Titrable acidity (\%)}}$$

3.7.4. Organoleptic scoring of the fruit

The fruits collected from different locations were randomly coded and the sensory evaluation of these samples was done according to the score chart prepared based on the nine-point hedonic scale ranging from one to nine, where one represents poor and nine depicts excellent qualities. The evaluation was done by a panel of ten semi trained individuals for different quality characters including appearance, colour, flavour, taste, after-taste, texture, odour and overall acceptability. The score card used is attached as Appendix II.

3.8. Economic data

3.8.1. Farm size

The total land area under cultivation of different crops by each of the farmers at the ten locations were recorded.

3.8.2. Area under dragon fruit

Out of the total cultivated land, the area under dragon fruit cultivation was recorded separately for each of the farmers at different locations.

3.8.3. Age of the plants

The age of dragon fruit orchard was estimated by calculating the number of years from planting in each of the ten locations and they were further classified into phases like establishment phase, yield increasing phase and yield stabilizing phase.

3.8.4. Cultivation practices

Details were collected from the farmers regarding the cultivation practices adopted by them.

3.8.5. Cost of cultivation

Since dragon fruit is a perennial crop with a high economic life, which comes into bearing within two years, the cost of cultivation was calculated by splitting it into establishment cost and maintenance cost. Establishment cost included the expenses in the pre-yielding period whereas maintenance cost was calculated by estimating the

weighted mean for overall yielding phase of dragon fruit. Weightage was given for both the yielding phases (yield increasing phase and yield stabilizing phase) based on the number of farmers cultivating dragon fruit which were under the specific yielding phase.

The total establishment cost was amortized by multiplying it with an amortized value to distribute a component of the establishment cost throughout the life span of the crop, while estimating the total cost of cultivation. The amortized value was calculated by the formula given below.

$$Ai = [i\ (1+i)^n] / [(1+i)^n-1]$$

3.8.6. Yield

The total yield that each farmer received currently from their orchard as a whole was calculated based on the average yield obtained from one post.

3.8.7. Marketing details

Different ways of marketing the produce and the marketing channels involved in movement of the fruits from the farmer to the consumer were identified through the survey.

3.8.8. Returns

The total returns obtained by the farmers from selling the produce were also recorded from the survey and the benefit cost ratio (BCR) was calculated.

3.8.9. Constraints

The problems faced by the dragon fruit growers with respect to the cultivation aspects were recorded through a ranking method where the farmers were asked to rank the constraints like infestation of pests, disease attack, marketing problems, water availability, climatic conditions, fertilizer availability and affordability, lack of labour, weeding, bud or flower drop and lack of storage facilities in the order of severity of the problems. The constraints ranking card is given in Appendix III.

3.8.10. Source of planting material

Details of various sources from where the farmers have obtained the dragon fruit planting material initially for planting were recorded.

3.9. Incidence of pests and diseases

The plants from the locations under study were visually examined at different stages during the time span of the work for the incidence of any pest and disease attack. The observations were listed from each of the locations.

3.10. Statistical analysis

Factor analysis and cluster analysis were done for the assessment of variability among the 100 plants with respect to their qualitative and quantitative characters using R software. Frequency distribution of the qualitative characters was done with the help of R 4.1.0 software.

Karette, Thiruvananthapuram

Athikkayam, Pathanamthitta

Aikkad, Pathanamthitta

Kozhenchery, Pathanamthitta

Plate 1A. Experimental locations

Muvattupuzha, Ernakulam

Perumbavoor, Ernakulam

Adoor, Pathanamthitta

Vaniyampara, Thrissur

Keerukuzhy, Pathanamthitta

Thatta, Pathanamthitta

Plate 1B. Experimental locations

RESULTS

4. RESULTS

This chapter encompasses the results from the study "Evaluation of dragon fruit (*Hylocereus* spp.) genotypes grown in Kerala" conducted in four districts of Kerala, namely Trivandrum, Pathanamthitta, Ernakulam and Thrissur during the year 2020-21. Morphology, flowering and yield characters along with the phenological parameters of ten plants from ten locations spread over the four districts were recorded in accordance with the guidelines from UPOV (2011). The results obtained from the observations were recorded separately for stem characters, flower characters, phenological parameters, yield characters and quality attributes and are detailed in this chapter.

4.1 Stem characters

The characters of the stem which were considered for the entire set of plants under study included stem segment length, stem segment width, distance between areoles, arch height, margin of rib, number of spines per areole, spine colour, height of pole, number of branches and number of stem segments per branch. Data related to the above-mentioned observations are presented as Table 1a to 1e and Table 2a to 2e. The descriptive statistics of minimum, maximum, range, average, standard error of mean, standard deviation and coefficients of variation (CV) from quantitative data are depicted in Table 3.

4.1.1 Stem segment length

Length of the segments showed an average of 116 cm with a CV of 39%. Maximum length of 210 cm was recorded for AdP5 and the minimum length of 33cm for MuP4. The stem segment length was found to vary within the plants from the same location and between the plants of different locations. As the plants progressed in growth, the stem segment length was also found to increase.

4.1.2 Stem segment width (cm)

The stem segment width had an average value of 4.06 cm with CV 23%. The maximum width was observed in VaP4 and VaP8 (6.60 cm) and minimum in MuP4 (1.80 cm).

4.1.3 Distance between areoles (cm)

Distance between areoles varied from 2.0 cm to 5.5 cm with a mean value of 3.50 cm and a coefficient of variation of 20%. The minimum value was observed for PeP1 (2.0 cm) and the maximum value for KoP1 and KoP7 (5.50 cm).

4.1.4 Arch height

The arch height ranged from 1.0 cm to 4.2 cm with an average of 1.86 cm and CV of 31%. The value for arch height was the lowest (1.0 cm) for ThP3 and ThP8, and highest (4.2 cm) for KaP8.

4.1.5 Stem waxiness

When the extent of waxiness seen in the stem segments were classified as strong, medium and weak, 88% plants displayed strong waxiness while rest of the plants (12%) showed weak waxiness. (Plate 1)

4.1.6 Stem sturdiness

Out of the 100 plants under study, only 12% of the plants exhibited highly sturdy nature whereas the remaining 88% plants exhibited lower sturdiness. (Plate 2)

4.1.7 Margin of rib

When the margin of the rib of the stem segments was examined for the shape, 88% of the plants were found to have convex margin and 12% had flat margin. It was also noticed that when the plants which earlier had convex margin later showed flat margins with ageing of the stem segments (Plate 3).

4.1.8 Number of spines per areole

Number of spines per areole ranged from 3 to 5 in all the plants under study. Majority of the plants (80%) had 4 spines per areole, 13% plants had 3 spines and 7% plants had 5 spines per areole.

4.1.9 Spine colour

Spines showed typical colours of medium brown, dark brown and grey. Majority of the plants examined (88%) had medium brown coloured spines while the rest had

dark brown coloured spines (12%). The spine colour showed a trend of turning into grey colour with ageing (Plate 4).

4.1.10 Height of the pole (ft)

The length of the pole used for supporting the climbing cactus vines ranged from 6.5 feet to 8 feet at different locations, with 1 to 2 feet (usually 1.5 feet) remaining buried underground, resulting in variation (5 to 6.5 feet) of the height of the pole above ground.

4.1.11 Number of branches

All the plants under study produced many branches arising from the top of the pole, which were capable of bearing fruits in the fruiting season.

4.1.12 Number of stem segments per branch

The number of stem segments per branch was found to vary from 1 to 6 in different plants. The percentage frequency of 1, 2, 3, 4, 5 and 6 segments occurring per branch when statistically analysed was found to be 17%, 40%, 18%, 16%, 8% and 1% respectively.

Table 1a. Quantitative characters of stem of dragon fruit plants AtP1-ThP10

Plants	Stem segment length (cm)	Stem segment width (cm)	Distance between areoles (cm)	Arch height (cm)	Number of spines	Number of stem segments per branch
AtP1	130.00	3.10	4.00	1.20	4.00	3.00
AtP2	200.00	4.00	4.00	1.50	4.00	3.00
AtP3	200.00	4.20	4.00	1.40	4.00	2.00
AtP4	100.00	3.80	3.50	1.20	3.00	3.00
AtP5	100.00	3.50	5.00	1.40	4.00	2.00
AtP6	150.00	4.00	4.00	1.50	3.00	3.00
AtP7	100.00	3.60	3.40	1.20	4.00	3.00
AtP8	200.00	4.30	4.00	1.50	4.00	3.00
AtP9	120.00	3.50	4.00	1.20	4.00	2.00
AtP10	200.00	4.20	4.00	1.50	4.00	3.00
ThP1	43.00	4.20	3.00	2.00	5.00	2.00
ThP2	140.00	4.00	4.50	2.00	4.00	2.00
ThP3	37.00	3.60	2.70	1.00	4.00	2.00
ThP4	150.00	2.90	2.50	1.50	4.00	1.00
ThP5	66.00	4.60	2.80	1.70	4.00	2.00
ThP6	150.00	3.00	3.00	1.50	4.00	2.00
ThP7	158.00	3.00	2.50	2.00	4.00	1.00
ThP8	47.00	4.30	3.00	1.00	4.00	2.00
ThP9	78.00	4.50	2.50	1.50	4.00	2.00
ThP10	110.00	4.00	4.50	1.50	4.00	2.00

Table 1b. Quantitative characters of stem of dragon fruit plants KaP1-KoP10

Plants	Stem segment length (cm)	Stem segment width (cm)	Distance between areoles (cm)	Arch height (cm)	Number of spines	Number of stem segments per branch
KaP1	124.00	3.70	3.00	2.50	3.00	4.00
KaP2	150.00	4.50	3.00	2.00	4.00	5.00
KaP3	137.00	4.50	3.70	2.50	3.00	4.00
KaP4	200.00	4.30	3.70	2.20	4.00	4.00
KaP5	82.00	6.20	4.00	4.00	4.00	3.00
KaP6	200.00	4.50	3.50	2.20	4.00	4.00
KaP7	138.00	4.50	3.80	2.60	4.00	5.00
KaP8	200.00	6.30	4.00	4.20	4.00	5.00
KaP9	125.00	3.70	3.00	2.00	4.00	4.00
KaP10	155.00	4.50	3.00	2.30	4.00	3.00
KoP1	140.00	3.50	5.50	1.50	4.00	1.00
KoP2	123.00	3.00	4.30	1.20	4.00	3.00
KoP3	152.00	3.00	3.50	1.80	4.00	3.00
KoP4	38.00	4.80	4.00	2.60	4.00	4.00
KoP5	50.00	2.50	4.50	1.20	4.00	4.00
KoP6	70.00	3.00	4.50	1.80	4.00	4.00
KoP7	144.00	3.50	5.50	1.30	4.00	3.00
KoP8	35.00	4.80	4.00	2.70	4.00	4.00
KoP9	78.00	3.50	4.30	1.80	4.00	3.00
KoP10	56.00	2.80	3.50	1.50	4.00	4.00

Table 1c. Quantitative characters of stem of dragon fruit plants AiP1-MuP10

Plants	Stem segment length (cm)	Stem segment width (cm)	Distance between areoles (cm)	Arch height (cm)	Number of spines	Number of stem segments per branch
AiP1	53.00	4.20	2.70	2.50	4.00	5.00
AiP2	70.00	4.80	4.00	2.40	5.00	4.00
AiP3	130.00	3.50	3.30	2.10	4.00	5.00
AiP4	48.00	3.00	2.50	2.20	4.00	3.00
AiP5	50.00	4.20	3.00	1.50	4.00	4.00
AiP6	58.00	4.20	3.20	2.60	4.00	6.00
AiP7	60.00	4.50	4.20	2.50	5.00	4.00
AiP8	122.00	4.30	4.00	2.20	4.00	5.00
AiP9	151.00	4.00	2.50	2.20	4.00	4.00
AiP10	68.00	4.60	3.00	2.40	5.00	5.00
MuP1	123.00	5.00	3.20	2.50	4.00	2.00
MuP2	135.00	4.80	3.00	2.50	4.00	1.00
MuP3	110.00	5.00	3.00	2.50	5.00	3.00
MuP4	33.00	1.80	3.50	1.50	4.00	3.00
MuP5	100.00	3.50	5.00	1.70	4.00	5.00
MuP6	80.00	3.80	4.20	1.80	4.00	3.00
MuP7	128.00	4.00	4.30	1.50	4.00	2.00
MuP8	164.00	3.60	4.00	1.30	4.00	4.00
MuP9	130.00	3.50	3.50	1.50	4.00	4.00
MuP10	100.00	3.60	4.00	1.40	4.00	3.00

Table 1d. Quantitative characters of stem of dragon fruit plants VaP1-KeP10

Plants	Stem segment length (cm)	Stem segment width (cm)	Distance between areoles (cm)	Arch height (cm)	Number of spines	Number of stem segments per branch
VaP1	120.00	4.20	2.20	2.30	3.00	2.00
VaP2	145.00	4.50	4.50	1.50	3.00	2.00
VaP3	120.00	5.50	2.50	2.50	3.00	2.00
VaP4	133.00	6.60	3.00	2.50	4.00	2.00
VaP5	126.00	4.50	3.50	1.40	5.00	2.00
VaP6	130.00	6.30	3.00	2.50	5.00	2.00
VaP7	128.00	6.00	2.50	1.30	4.00	2.00
VaP8	126.00	6.60	3.00	1.20	4.00	2.00
VaP9	42.00	4.50	4.50	2.50	4.00	2.00
VaP10	132.00	6.50	3.00	1.30	4.00	2.00
KeP1	150.00	4.50	4.00	2.50	4.00	1.00
KeP2	90.00	4.00	4.60	1.50	4.00	1.00
KeP3	40.00	4.20	3.00	2.00	4.00	2.00
KeP4	120.00	4.70	3.60	1.70	4.00	2.00
KeP5	90.00	4.00	3.00	2.00	4.00	1.00
KeP6	130.00	5.00	3.00	1.30	4.00	1.00
KeP7	120.00	4.90	3.50	2.00	4.00	2.00
KeP8	110.00	4.20	3.40	1.30	4.00	2.00
KeP9	118.00	4.60	3.60	1.70	4.00	2.00
KeP10	96.00	4.00	4.30	1.30	4.00	1.00

Table 1e. Quantitative characters of stem of dragon fruit plants PeP1-AdP10

Plants	Stem segment length (cm)	Stem segment width (cm)	Distance between areoles (cm)	Arch height (cm)	Number of spines	Number of stem segments per branch
PeP1	120.00	4.00	2.00	1.70	4.00	2.00
PeP2	65.00	2.70	3.50	1.50	4.00	2.00
PeP3	38.00	3.00	2.80	1.40	4.00	2.00
PeP4	113.00	2.90	3.00	1.60	4.00	1.00
PeP5	127.00	3.00	2.70	1.50	3.00	2.00
PeP6	70.00	3.00	3.60	1.30	3.00	2.00
PeP7	132.00	2.60	2.80	1.50	3.00	1.00
PeP8	80.00	3.00	3.20	1.50	3.00	2.00
PeP9	77.00	2.80	2.80	1.50	3.00	2.00
PeP10	120.00	3.00	3.60	1.40	3.00	1.00
AdP1	128.00	4.20	3.00	2.50	4.00	1.00
AdP2	160.00	3.00	3.00	1.20	4.00	1.00
AdP3	153.00	3.50	4.00	2.00	4.00	2.00
AdP4	190.00	4.00	3.50	2.00	4.00	1.00
AdP5	210.00	3.50	3.00	2.00	4.00	2.00
AdP6	122.00	4.50	3.50	2.30	4.00	2.00
AdP7	135.00	4.00	3.00	2.00	4.00	1.00
AdP8	162.00	3.60	3.00	2.00	4.00	2.00
AdP9	168.00	4.20	3.50	2.50	4.00	1.00
AdP10	174.00	4.50	3.50	2.60	4.00	2.00

Table 2a. Qualitative characters of stem of dragon fruit plants AtP1-ThP10

Plants	Stem waxiness	Stem sturdiness	Margin of rib	Spine colour
AtP1	Strong	Low	convex	medium brown
AtP2	Strong	Low	convex	medium brown
AtP3	Strong	Low	convex	medium brown
AtP4	Strong	Low	convex	medium brown
AtP5	Strong	Low	convex	medium brown
AtP6	Strong	Low	convex	medium brown
AtP7	Strong	Low	convex	medium brown
AtP8	Strong	Low	convex	medium brown
AtP9	Strong	Low	convex	medium brown
AtP10	Strong	Low	convex	medium brown
ThP1	Strong	Low	convex	medium brown
ThP2	Strong	Low	convex	medium brown
ThP3	Strong	Low	convex	medium brown
ThP4	Strong	Low	convex	medium brown
ThP5	Strong	Low	convex	medium brown
ThP6	Weak	High	flat	dark brown
ThP7	Weak	High	flat	dark brown
ThP8	Strong	Low	convex	medium brown
ThP9	Strong	Low	convex	medium brown
ThP10	Strong	Low	convex	medium brown

Table 2b. Qualitative characters of stem of dragon fruit plants KaP1-KoP10

Plants	Stem waxiness	Stem sturdiness	Margin of rib	Spine colour
KaP1	Strong	Low	convex	medium brown
KaP2	Strong	Low	convex	medium brown
KaP3	Strong	Low	convex	medium brown
KaP4	Strong	Low	convex	medium brown
KaP5	Strong	Low	convex	medium brown
KaP6	Strong	Low	convex	medium brown
KaP7	Strong	Low	convex	medium brown
KaP8	Strong	Low	convex	medium brown
KaP9	Strong	Low	convex	medium brown
KaP10	Strong	Low	convex	medium brown
KoP1	Strong	Low	convex	medium brown
KoP2	Strong	Low	convex	medium brown
KoP3	Strong	Low	convex	medium brown
KoP4	Strong	Low	convex	medium brown
KoP5	Strong	Low	convex	medium brown
KoP6	Strong	Low	convex	medium brown
KoP7	Strong	Low	convex	medium brown
KoP8	Strong	Low	convex	medium brown
KoP9	Strong	Low	convex	medium brown
KoP10	Strong	Low	convex	medium brown

Table 2c. Qualitative characters of stem of dragon fruit plants AiP1-MuP10

Plants	Stem waxiness	Stem sturdiness	Margin of rib	Spine colour
AiP1	Strong	Low	convex	medium brown
AiP2	Strong	Low	convex	medium brown
AiP3	Strong	Low	convex	medium brown
AiP4	Strong	Low	convex	medium brown
AiP5	Strong	Low	convex	medium brown
AiP6	Strong	Low	convex	medium brown
AiP7	Strong	Low	convex	medium brown
AiP8	Strong	Low	convex	medium brown
AiP9	Strong	Low	convex	medium brown
AiP10	Weak	High	flat	dark brown
MuP1	Weak	High	flat	dark brown
MuP2	Weak	High	flat	dark brown
MuP3	Weak	High	flat	dark brown
MuP4	Strong	Low	convex	medium brown
MuP5	Strong	Low	convex	medium brown
MuP6	Strong	Low	convex	medium brown
MuP7	Strong	Low	convex	medium brown
MuP8	Strong	Low	convex	medium brown
MuP9	Strong	Low	convex	medium brown
MuP10	Strong	Low	convex	medium brown

Table 2d. Qualitative characters of stem of dragon fruit plants VaP1-KeP10

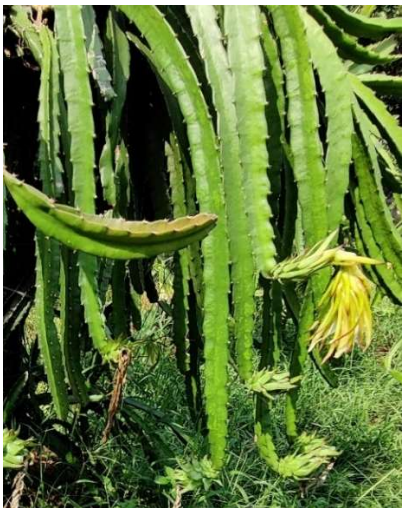
Plants	Stem waxiness	Stem sturdiness	Margin of rib	Spine colour
VaP1	Strong	Low	convex	medium brown
VaP2	Strong	Low	convex	medium brown
VaP3	Strong	Low	convex	medium brown
VaP4	Strong	Low	convex	medium brown
VaP5	Strong	Low	convex	medium brown
VaP6	Strong	Low	convex	medium brown
VaP7	Strong	Low	convex	medium brown
VaP8	Weak	High	flat	dark brown
VaP9	Strong	Low	convex	medium brown
VaP10	Strong	Low	convex	medium brown
KeP1	Strong	Low	convex	medium brown
KeP2	Strong	Low	convex	medium brown
KeP3	Strong	Low	convex	medium brown
KeP4	Strong	Low	convex	medium brown
KeP5	Weak	High	flat	dark brown
KeP6	Strong	Low	convex	medium brown
KeP7	Strong	Low	convex	medium brown
KeP8	Strong	Low	convex	medium brown
KeP9	Strong	Low	convex	medium brown
KeP10	Strong	Low	convex	medium brown

Table 2e. Qualitative characters of stem of dragon fruit plants PeP1-AdP10

Plants	Stem waxiness	Stem sturdiness	Margin of rib	Spine colour
PeP1	strong	Low	convex	medium brown
PeP2	strong	Low	convex	medium brown
PeP3	weak	High	flat	dark brown
PeP4	weak	High	flat	dark brown
PeP5	strong	Low	convex	medium brown
PeP6	strong	Low	convex	medium brown
PeP7	strong	Low	convex	medium brown
PeP8	strong	Low	convex	medium brown
PeP9	strong	Low	convex	medium brown
PeP10	strong	Low	convex	medium brown
AdP1	strong	Low	convex	medium brown
AdP2	strong	Low	convex	medium brown
AdP3	strong	Low	convex	medium brown
AdP4	strong	Low	convex	medium brown
AdP5	weak	High	flat	dark brown
AdP6	strong	Low	convex	medium brown
AdP7	weak	High	flat	dark brown
AdP8	strong	Low	convex	medium brown
AdP9	strong	Low	convex	medium brown
AdP10	strong	Low	convex	medium brown

Table 3. Descriptive statistics of stem and flower characters in dragon fruit

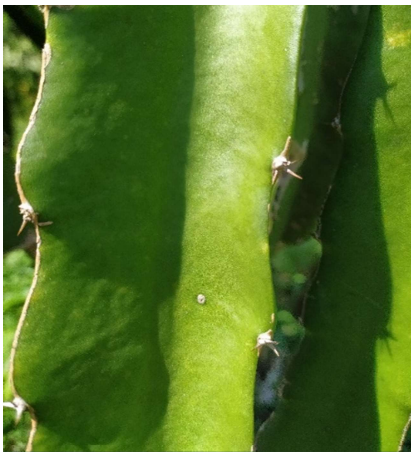
Descriptives	Stem segment length (cm)	Stem segment width (cm)	Distance between areoles (cm)	Arch height (cm)	Number of spines	Number of stem segments per branch	Style length (cm)	Number of stigma lobes
Range	177.00	4.80	3.50	3.20	2.00	5.00	7.50	10
Minimum	33.00	1.80	2.00	1.00	3.00	1.00	23.50	26.00
Maximum	210.00	6.60	5.50	4.20	5.00	6.00	31.00	36.00
Average	116.00	4.06	3.50	1.86	3.94	2.61	28.06	29.62
Standard error of Mean	8.97	0.18	0.14	0.11	0.09	0.24	0.36	0.40
Standard deviation	45.19	0.93	0.70	0.57	0.45	1.23	1.81	1.99
Co-efficient of variation (%)	39	23	20	31	11	47	06	07



Strong waxiness and less sturdy

Weak waxiness and highly sturdy

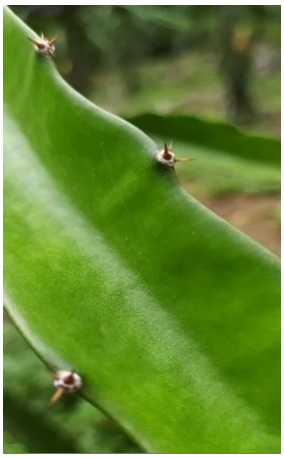
Plate 2. Stem waxiness and stem sturdiness



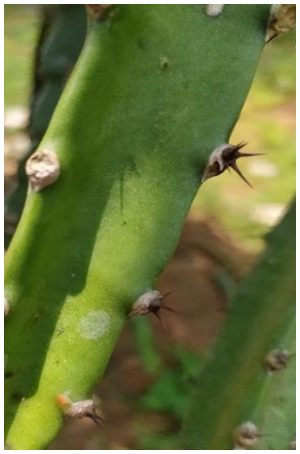
Convex

Flat

Plate 3. Margin of rib



Medium brown



Dark brown

Grey

Plate 4. Spine colour

4.2 Flower characters

Flower characters observed were found to differ for the plants under study. Data pertaining to the observations are furnished in Table 4a to 4e and Table 6a to 6e. The descriptive statistics of minimum, maximum, range, average, standard error of mean, standard deviation and coefficients of variation (CV) from the quantitative characters of flower are presented along with stem characters in Table 3.

4.2.1 Bud shape

Majority of the plants (88%) produced ovate shaped flower buds whereas 12% plants possessed elliptic buds (Plate 5).

4.2.2 Shape of bud apex

The bud apex was observed and categorized into acute and rounded. Out of the 100 plants, eighty-eight plants (88%) had their flower buds with acute apex and twelve plants (12%) had their flower buds with rounded apex (Plate 4).

4.2.3 Petal colour

All the flowers irrespective of the location displayed white coloured petals (Plate 6).

4.2.4 Sepal colour

Main sepal colour that covered the maximum area was observed to be green in all the flowers produced by the plants under study (Plate 6).

4.2.5 Sepal: Pattern of secondary colour

Red colour was found to be the secondary colour seen in the sepals of all the flowers but the pattern in which the secondary colour appeared in sepals differed from each other. Majority of the plants (58%) had their flowers with red edged sepals whereas 42% plants were having slightly red edged sepals (Plate 7).

4.2.6 Intensity of red colour on bracts

Intensity of red colour on bracts present on the pericarpel portion of the flowers was found to be strong in 12% plants, medium in 46% plants and weak in 42% plants (Plate 8).

4.2.7 Length of style

The length of flower style varied from 23.5 cm to 31.0 cm (Plate 9). The maximum length (31.0 cm) was seen in 7 plants (Plate 8), namely AtP4, AtP6, AtP10, KaP3, KaP5, KoP4 and KoP6 and the lowest length of style (23.5 cm) was recorded in VaP1.

4.2.8 Number of stigma lobes

Number of stigma lobes ranged from 26 to 36. Most frequently observed number was 28 and 29 (23% each) and the least observed was 26, 34, 35 and 36 (1% each).

Table 4a. Qualitative characters of flower of dragon fruit plants AtP1-ThP10

Plants	Bud shape	Bud apex shape	Petal colour	Sepal colour (primary)	Sepal colour (secondary)	Intensity of red colour of bract
AtP1	Ovate	Acute	white	Green	slightly red edged	weak
AtP2	Ovate	Acute	white	Green	slightly red edged	weak
AtP3	Ovate	Acute	white	Green	slightly red edged	weak
AtP4	Ovate	Acute	white	Green	slightly red edged	weak
AtP5	Ovate	Acute	white	Green	slightly red edged	weak
AtP6	Ovate	Acute	white	Green	slightly red edged	weak
AtP7	Ovate	Acute	white	Green	slightly red edged	weak
AtP8	Ovate	Acute	white	Green	slightly red edged	weak
AtP9	Ovate	Acute	white	Green	slightly red edged	weak
AtP10	Ovate	Acute	white	Green	slightly red edged	weak
ThP1	Ovate	Acute	white	Green	red edged	medium
ThP2	Ovate	Acute	white	Green	red edged	medium
ThP3	Ovate	Acute	white	Green	red edged	medium
ThP4	Ovate	Acute	white	Green	red edged	medium
ThP5	Ovate	Acute	white	Green	red edged	medium
ThP6	Elliptic	Rounded	white	Green	red edged	strong
ThP7	Elliptic	Rounded	white	Green	red edged	strong
ThP8	Ovate	Acute	white	Green	red edged	medium
ThP9	Ovate	Acute	white	Green	red edged	medium
ThP10	Ovate	Acute	white	Green	red edged	medium

Table 4b. Qualitative characters of flower of dragon fruit plants KaP1-KoP10

Plants	Bud shape	Bud apex shape	Petal colour	Sepal colour (primary)	Sepal colour (secondary)	Intensity of red colour of bract
KaP1	Ovate	Acute	white	Green	slightly red edged	weak
KaP2	Ovate	Acute	white	Green	slightly red edged	weak
KaP3	Ovate	Acute	white	Green	slightly red edged	weak
KaP4	Ovate	Acute	white	Green	slightly red edged	weak
KaP5	Ovate	Acute	white	Green	slightly red edged	weak
KaP6	Ovate	Acute	white	Green	slightly red edged	weak
KaP7	Ovate	Acute	white	Green	slightly red edged	weak
KaP8	Ovate	Acute	white	Green	slightly red edged	weak
KaP9	Ovate	Acute	white	Green	slightly red edged	weak
KaP10	Ovate	Acute	white	Green	slightly red edged	weak
KoP1	Ovate	Acute	white	Green	slightly red edged	weak
KoP2	Ovate	Acute	white	Green	slightly red edged	weak
KoP3	Ovate	Acute	white	Green	slightly red edged	weak
KoP4	Ovate	Acute	white	Green	slightly red edged	weak
KoP5	Ovate	Acute	white	Green	slightly red edged	weak
KoP6	Ovate	Acute	white	Green	slightly red edged	weak
KoP7	Ovate	Acute	white	Green	slightly red edged	weak
KoP8	Ovate	Acute	white	Green	slightly red edged	weak
KoP9	Ovate	Acute	white	Green	slightly red edged	weak
KoP10	Ovate	Acute	white	Green	slightly red edged	weak

Table 4c. Qualitative characters of flower of dragon fruit plants AiP1-MuP10

Plants	Bud shape	Bud apex shape	Petal colour	Sepal colour (primary)	Sepal colour (secondary)	Intensity of red colour of bract
AiP1	Ovate	Acute	white	Green	red edged	medium
AiP2	Ovate	Acute	white	Green	red edged	medium
AiP3	Ovate	Acute	white	Green	red edged	medium
AiP4	Ovate	Acute	white	Green	red edged	medium
AiP5	Ovate	Acute	white	Green	red edged	medium
AiP6	Ovate	Acute	white	Green	red edged	medium
AiP7	Ovate	Acute	white	Green	red edged	medium
AiP8	Ovate	Acute	white	Green	red edged	medium
AiP9	Ovate	Acute	white	Green	red edged	medium
AiP10	Elliptic	Rounded	white	Green	red edged	strong
MuP1	Elliptic	Rounded	white	Green	red edged	strong
MuP2	Elliptic	Rounded	white	Green	red edged	strong
MuP3	Elliptic	Rounded	white	Green	red edged	strong
MuP4	Ovate	Acute	white	Green	slightly red edged	weak
MuP5	Ovate	Acute	white	Green	red edged	medium
MuP6	Ovate	Acute	white	Green	slightly red edged	weak
MuP7	Ovate	Acute	white	Green	slightly red edged	weak
MuP8	Ovate	Acute	white	Green	red edged	medium
MuP9	Ovate	Acute	white	Green	red edged	medium
MuP10	Ovate	Acute	white	Green	red edged	medium

Table 4d. Qualitative characters of flower of dragon fruit plants VaP1-KeP10

Plants	Bud shape	Bud apex shape	Petal colour	Sepal colour (primary)	Sepal colour (secondary)	Intensity of red colour of bract
VaP1	Ovate	Acute	white	Green	red edged	medium
VaP2	Ovate	Acute	white	Green	slightly red edged	weak
VaP3	Ovate	Acute	white	Green	slightly red edged	weak
VaP4	Ovate	Acute	white	Green	slightly red edged	weak
VaP5	Ovate	Acute	white	Green	slightly red edged	weak
VaP6	Ovate	Acute	white	Green	slightly red edged	weak
VaP7	Ovate	Acute	white	Green	red edged	medium
VaP8	Elliptic	Rounded	white	Green	red edged	strong
VaP9	Ovate	Acute	white	Green	red edged	medium
VaP10	Ovate	Acute	white	Green	red edged	medium
KeP1	Ovate	Acute	white	Green	red edged	medium
KeP2	Ovate	Acute	white	Green	red edged	medium
KeP3	Ovate	Acute	white	Green	red edged	medium
KeP4	Ovate	Acute	white	Green	red edged	medium
KeP5	Elliptic	Rounded	white	Green	red edged	strong
KeP6	Ovate	Acute	white	Green	red edged	medium
KeP7	Ovate	Acute	white	Green	red edged	medium
KeP8	Ovate	Acute	white	Green	red edged	medium
KeP9	Ovate	Acute	white	Green	red edged	medium
KeP10	Ovate	Acute	white	Green	red edged	medium

Table 4e. Qualitative characters of flower of dragon fruit plants PeP1-AdP10

Plants	Bud shape	Bud apex shape	Petal colour	Sepal colour (primary)	Sepal colour (secondary)	Intensity of red colour of bract
PeP1	Ovate	Acute	white	Green	slightly red edged	weak
PeP2	Ovate	Acute	white	Green	slightly red edged	weak
PeP3	Elliptic	Rounded	white	Green	red edged	strong
PeP4	Elliptic	Rounded	white	Green	red edged	strong
PeP5	Ovate	Acute	white	Green	red edged	medium
PeP6	Ovate	Acute	white	Green	slightly red edged	weak
PeP7	Ovate	Acute	white	Green	red edged	medium
PeP8	Ovate	Acute	white	Green	red edged	medium
PeP9	Ovate	Acute	white	Green	red edged	medium
PeP10	Ovate	Acute	white	Green	red edged	medium
AdP1	Ovate	Acute	white	Green	red edged	medium
AdP2	Ovate	Acute	white	Green	slightly red edged	weak
AdP3	Ovate	Acute	white	Green	red edged	medium
AdP4	Ovate	Acute	white	Green	red edged	medium
AdP5	Elliptic	Rounded	white	Green	red edged	strong
AdP6	Ovate	Acute	white	Green	red edged	medium
AdP7	Elliptic	Rounded	white	Green	red edged	strong
AdP8	Ovate	Acute	White	Green	red edged	medium
AdP9	Ovate	Acute	White	Green	red edged	medium
AdP10	Ovate	Acute	White	Green	red edged	medium

4.3 Phenological parameters

The phenological characters such as flowering season, duration of flowering, days taken from flowering to fruit set, days taken from fruit set to harvest, days taken from flowering to harvest and the fruiting season were observed and location wise data were recorded in Table 5.

4.3.1 Flowering season

The plants (AtP1-AtP10) from the first location and those from the sixth location (VaP1-VaP10) exhibited an early season of flowering which started from March and continued till October. In all the other locations, the flowering commenced in plants from the month of April and ended in September-October.

4.3.2 Duration of flowering (days)

The plants, irrespective of the location followed a general pattern of 12-15 days duration from bud initiation to anthesis. Rain and cloudy weather were found to unfavourably affect anthesis resulting in bud drop.

4.3.3 Flowering to fruit set (days)

Fruit set could be visually observed within 5 to 7 days after anthesis but the rains caused a delay in fruit set when compared to full sunny days.

4.3.4 Fruit set to harvest (days)

Harvest was possible in 23 to 25 days from fruit set when the plants received ample sunlight, but it was delayed to 26 to 28 days when there was continuous rain.

4.3.5 Flowering to harvest (days)

Fruits could be harvested exactly one month from the day of anthesis from the plants which received abundant sunlight but occurrence of heavy downpour was found to slow down the pace of fruit maturity.

4.3.6 Fruiting season

In the case of the plants, grown in the first location (AtP1-AtP10), fruits were harvested from the month of April onwards *i.e.,* the fruiting season got started in April

whereas in the remaining plants from the other locations, harvesting of fruits started only in May, and then the fruiting season continued till October to November.

4.4 Yield characters

Findings regarding the yield characters are recorded in Table 6a to 6e and 8a to 8e. The descriptive statistics of the quantitative parameters relating to yield characters are depicted in Table 7. Frequency distribution of the qualitative characters of dragon fruit is presented in Table 9.

4.4.1 Fruit weight (g)

Weight of individual fruits when recorded ranged from 84 g to 896 g. The highest fruit weight was observed in MuP1 and the lowest in KeP3. The average fruit weight was found to be 381.10 g with a CV of 46%.

4.4.2 Length of fruit (cm)

Maximum fruit length was found to be 10.40 cm in MuP6 and minimum value was 4.60 cm recorded in PeP9. The average length of fruit was 7.94 cm and showed a CV of 19%.

4.4.3 Width of fruit (cm)

The widest point of the cross-section of fruits when measured showed a maximum value of 10.40 cm in MuP6 and the minimum value of 4.40 in PeP9. The mean width of the fruits was found to be 7.83 cm with a CV of 20%.

4.4.4 Length/width ratio of fruit

The length/width ratio of the fruits lied between 1.00 and 1.21 with an average value of 1.02, which explained the appearance of the fruits to be moderately elongated or medium.

4.4.5 Number of bracts

The number and spread of bracts over the surface of fruits varied widely between 18 and 50 with the mean number of bracts to be 29.24. The maximum value of 50 was

shown by AiP6 and the minimum value of 18 was shown by ThP5, VaP2, VaP3 and KeP4.

4.4.6 Length of apical bract (cm)

The length of the bract at the apex of the fruits ranged from 3.0 cm (AiP10, MuP3 and AdP5) to 6.30 cm (KoP6). The mean length of apical bract was 4.68 cm with a co-efficient of variation 17%.

4.4.7 Width of the base of the bract (cm)

The width of the base of the bract at the middle portion of the fruits showed values ranging between 1.40 cm in MuP5 to 5.70 cm in VaP3, with an average base width of 3.35 cm and CV 25%.

4.4.8 Position of bracts towards the peel

The arrangement of bracts on the surface of 12 fruits were adpressed, that of 58 fruits were slightly held out and in 30 fruits strongly held out (Plate 10).

4.4.9 Fruit weight without peel (g)

The fruits when weighed after peeling showed minimum and maximum weight of 52 g (AiP9, KeP10) and 598 g (AtP1) respectively, with a mean weight of 269.60 g and CV of 49%.

4.4.10 Fruit shape

Fruits were either oval (37) or spherical (63) in shape, majority being spherical in shape.

4.4.11 Colour of peel (excluding bract)

The main colour of the fruit peel was found to be dark pink in 63 plants and medium pink in 37 plants (Plate 11).

4.4.12 Flesh colour

Flesh colour of the fruits were dark pink in 88 plants and purple in 12 plants (Plate 12).

4.4.13 Yield per post (kg/year)

The yield per post recorded ranged from 5 to 20 kg per year in the different locations. The yield showed an increasing trend with the age of the plants almost up to 5 years and thereafter the yield was found to remain steady.

Table 5. Location-wise phenological parameters observed in pink-purple fleshed dragon fruit

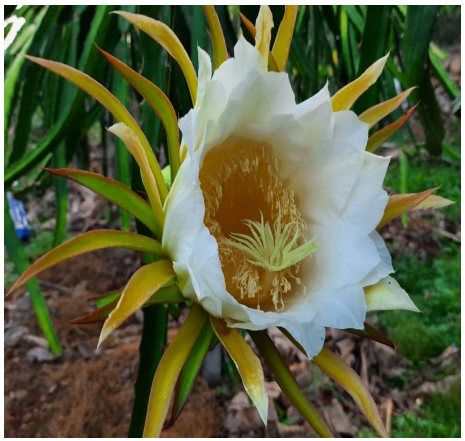
Location	Flowering season	Duration of flowering (days)	Flowering to fruit set (days)	Fruitset to harvest (days)	Flowering to harvest (days	Fruiting season
Athikkayam	March-October	15	5	29	32	April-November
Thatta	April-September	12	5	27	30	May-October
Karette	April-October	15	5	27	30	May-November
Kozhenchery	April-September	12	5	25	28	May-October
Aikkad	April-October	15	5	27	30	May-November
Muvattupuzha	April-September	15	5	25	28	May-October
Vaniyampara	March-October	15	5	29	32	April-November
Keerukuzhy	April-September	12	5	27	30	May-October
Perumbavoor	April-September	12	5	27	30	May-October
Adoor	April-October	15	5	27	30	May-November

Ovate bud with acute apex **Elliptic bud with rounded apex**

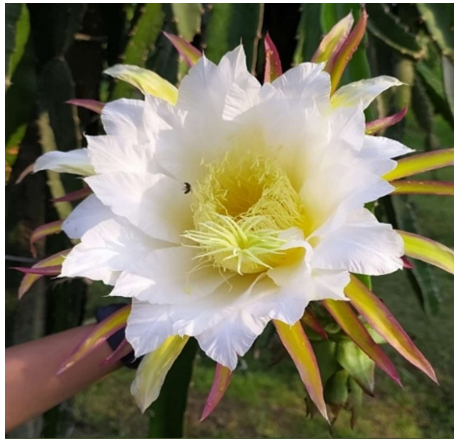
Plate 5. Shape of flower bud and bud apex in dragon fruit

White petals **Green sepals**

Plate 6. Opened flower of dragon fruit

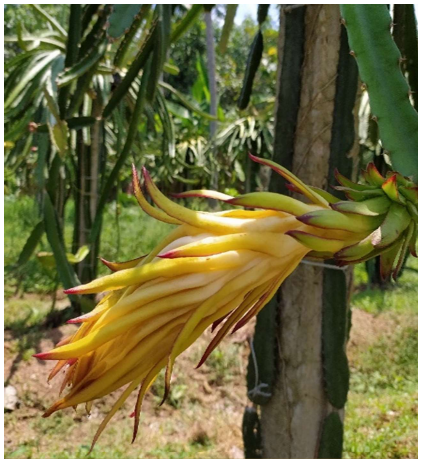


Slightly red edged



Red edged

Plate 7. Secondary colour of sepal in dragon fruit



Weak

Medium

Strong

Plate 8. Intensity of red colour of bract

Stamen and style

Style

Plate 9. Flower stamen and style

Table 6a. Quantitative characters of flower and fruit of dragon fruit plants AtP1-ThP10

Plants	Length of style (cm)	Number of stigma lobes	Fruit weight (g)	Length of fruit (cm)	Width of fruit (cm)	Length/width ratio of fruit	Number of bracts	Length of apical bract	Width of the base of bract	Fruit weight without peel (g)
AtP1	28.00	30.00	715.00	10.20	10.20	1.00	34.00	5.60	4.20	598.00
AtP2	29.80	27.00	575.00	9.80	9.80	1.00	34.00	5.80	4.00	454.00
AtP3	30.00	28.00	545.00	9.60	9.60	1.00	34.00	5.60	4.00	416.00
AtP4	31.0	28.00	450.00	8.70	8.70	1.00	38.00	5.20	3.80	326.00
AtP5	30.80	28.00	586.00	9.80	9.80	1.00	36.00	5.80	4.10	463.00
AtP6	31.00	29.00	457.00	8.70	8.70	1.00	35.00	5.20	3.90	334.00
AtP7	30.00	28.00	523.00	9.20	9.20	1.00	34.00	5.10	3.80	399.00
AtP8	29.00	28.00	518.00	9.20	9.20	1.00	32.00	5.00	3.80	392.00
AtP9	30.00	28.00	448.00	8.50	8.50	1.00	32.00	5.00	3.70	321.00
AtP10	31.00	28.00	452.00	8.80	8.80	1.00	32.00	5.20	3.80	328.00
ThP1	26.50	28.00	395.00	8.60	7.90	1.08	37.00	4.20	3.00	291.00
ThP2	29.00	29.00	407.00	9.00	8.20	1.09	32.00	4.00	3.00	299.00
ThP3	30.00	31.00	247.00	6.70	6.60	1.02	32.00	5.20	3.20	135.00
ThP4	28.00	30.00	178.00	6.00	5.90	1.02	35.00	4.50	2.60	123.00
ThP5	27.50	29.00	420.00	8.80	8.20	1.07	18.00	4.00	3.50	341.00
ThP6	26.50	28.00	652.00	8.50	8.50	1.00	38.00	3.50	2.20	398.00
ThP7	26.00	28.00	668.00	8.70	8.70	1.00	42.00	4.00	2.20	402.00
ThP8	28.00	30.00	320.00	7.80	7.80	1.00	24.00	4.20	3.20	264.00
ThP9	28.00	29.00	437.00	8.70	8.50	1.02	24.00	4.50	3.00	355.00
ThP10	26.50	30.00	242.00	6.40	6.40	1.00	22.00	5.00	2.50	151.00

Table 6b. Quantitative characters of flower and fruit of dragon fruit plants KaP1-KoP10

Plants	Length of style (cm)	Number of stigma lobes	Fruit weight (g)	Length of fruit (cm)	Width of fruit (cm)	Length/width ratio of fruit	Number of bracts	Length of apical bract	Width of the base of bract	Fruit weight without peel (g)
KaP1	29.00	30.00	353.00	7.70	7.70	1.00	25.00	6.00	4.50	248.00
KaP2	28.00	28.00	449.00	9.00	9.00	1.00	33.00	5.20	4.10	342.00
KaP3	31.00	29.00	303.00	7.40	7.40	1.00	27.00	5.00	3.70	224.00
KaP4	30.80	27.00	351.00	7.70	7.70	1.00	25.00	6.00	4.50	246.00
KaP5	31.00	27.00	520.00	9.20	9.20	1.00	34.00	5.00	3.50	443.00
KaP6	30.00	28.00	468.00	8.80	8.80	1.00	32.00	5.00	3.70	386.00
KaP7	30.00	27.00	578.00	9.70	9.70	1.00	32.00	5.50	4.20	474.00
KaP8	29.50	29.00	580.00	9.80	9.80	1.00	28.00	5.60	4.00	473.00
KaP9	28.70	30.00	526.00	9.30	9.30	1.00	35.00	5.20	4.80	293.00
KaP10	30.00	27.00	383.00	8.40	8.40	1.00	24.00	5.90	4.30	154.00
KoP1	29.00	30.00	505.00	9.70	9.70	1.00	33.00	5.50	4.00	410.00
KoP2	28.00	29.00	309.00	7.60	7.60	1.00	37.00	6.10	3.40	226.00
KoP3	30.00	28.00	351.00	7.60	7.60	1.00	25.00	6.00	4.30	248.00
KoP4	31.00	29.00	384.00	8.40	8.40	1.00	24.00	6.20	4.30	269.00
KoP5	29.00	28.00	450.00	8.60	8.60	1.00	32.00	5.80	3.80	349.00
KoP6	31.00	28.00	312.00	7.40	7.40	1.00	27.00	6.30	4.50	208.00
KoP7	30.60	27.00	445.00	8.60	8.60	1.00	35.00	5.10	3.80	342.00
KoP8	29.50	27.00	433.00	8.50	8.50	1.00	34.00	5.20	3.70	327.00
KoP9	28.00	30.00	323.00	7.60	7.60	1.00	25.00	5.90	4.50	218.00
KoP10	29.70	29.00	525.00	9.50	9.50	1.00	32.00	6.00	3.90	418.00

Table 6c. Quantitative characters of flower and fruit of dragon fruit plants AiP1-MuP10

Plants	Length of style (cm)	Number of stigma lobes	Fruit weight (g)	Length of fruit (cm)	Width of fruit (cm)	Length/width ratio of fruit	Number of bracts	Length of apical bract	Width of the base of bract	Fruit weight without peel (g)
AiP1	26.00	30.00	322.00	8.20	8.20	1.00	26.00	5.50	4.00	213.00
AiP2	25.50	32.00	433.00	9.20	9.20	1.00	23.00	4.50	3.60	318.00
AiP3	26.00	33.00	408.00	9.00	8.80	1.16	30.00	4.80	3.50	305.00
AiP4	24.50	36.00	138.00	5.60	5.30	1.06	30.00	4.50	3.00	68.00
AiP5	26.30	32.00	291.00	7.10	6.70	1.05	27.00	3.50	3.00	189.00
AiP6	28.00	30.00	401.00	9.70	8.00	1.21	50.00	4.50	2.50	298.00
AiP7	29.00	30.00	273.00	7.00	7.00	1.00	23.00	3.50	3.00	201.00
AiP8	28.30	33.00	100.00	5.50	5.30	1.03	41.00	3.50	2.50	59.00
AiP9	29.50	29.00	91.00	5.30	5.30	1.00	26.00	3.80	2.50	52.00
AiP10	26.00	28.00	628.00	9.30	9.30	1.00	40.00	3.00	2.60	303.00
MuP1	25.50	28.00	896.00	9.80	9.80	1.00	46.00	3.40	2.20	411.00
MuP2	26.00	27.00	720.00	9.50	9.50	1.00	44.00	3.20	2.50	403.00
MuP3	26.50	28.00	673.00	9.30	9.30	1.00	46.00	3.00	2.20	327.00
MuP4	26.00	29.00	358.00	8.40	8.40	1.00	30.00	3.60	2.30	253.00
MuP5	25.00	28.00	197.00	6.10	5.90	1.03	34.00	3.20	1.40	125.00
MuP6	27.50	28.00	578.00	10.40	10.40	1.00	26.00	4.50	3.60	467.00
MuP7	27.50	30.00	524.00	10.10	10.10	1.00	25.00	4.60	3.60	410.00
MuP8	27.30	27.00	408.00	9.00	8.80	1.02	24.00	4.50	2.30	286.00
MuP9	27.50	31.00	392.00	9.50	9.30	1.02	30.00	4.00	2.30	259.00
MuP10	26.80	30.00	134.00	5.50	5.20	1.06	23.00	4.50	3.00	65.00

Table 6d. Quantitative characters of flower and fruit of dragon fruit plants VaP1-KeP10

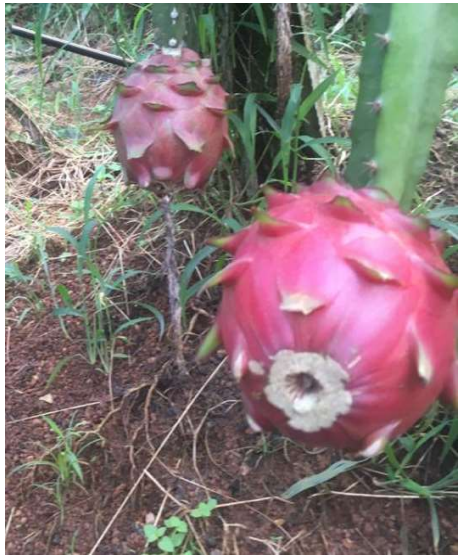
Plants	Length of style (cm)	Number of stigma lobes	Fruit weight (g)	Length of fruit (cm)	Width of fruit (cm)	Length/width ratio of fruit	Number of bracts	Length of apical bract	Width of the base of bract	Fruit weight without peel (g)
VaP1	23.50	35.00	230.00	7.20	6.90	1.04	24.00	5.00	2.50	139.00
VaP2	29.00	30.00	455.00	8.80	8.80	1.00	18.00	4.50	5.50	378.00
VaP3	30.00	32.00	430.00	8.90	8.90	1.00	18.00	4.80	5.70	352.00
VaP4	26.00	30.00	280.00	7.30	7.30	1.00	22.00	4.50	2.80	198.00
VaP5	25.80	30.00	510.00	9.10	9.10	1.00	20.00	4.00	4.00	428.00
VaP6	29.00	29.00	508.00	8.90	8.90	1.00	22.00	4.00	3.20	422.00
VaP7	28.00	33.00	250.00	7.20	6.80	1.06	23.00	5.00	2.30	164.00
VaP8	26.50	28.00	638.00	8.80	8.80	1.00	38.00	5.00	2.20	390.00
VaP9	28.50	29.00	476.00	9.00	8.80	1.02	20.00	4.20	3.00	372.00
VaP10	28.00	29.00	522.00	9.20	8.90	1.03	22.00	4.70	3.80	448.00
KeP1	28.00	33.00	115.00	5.20	4.80	1.08	28.00	4.60	3.00	63.00
KeP2	29.00	32.00	99.00	5.20	5.00	1.04	22.00	4.50	3.20	62.00
KeP3	28.00	29.00	84.00	4.90	4.80	1.02	20.00	4.60	3.20	67.00
KeP4	25.50	30.00	412.00	8.30	8.10	1.02	18.00	4.80	5.60	323.00
KeP5	27.00	28.00	526.00	8.40	8.40	1.00	40.00	4.00	2.30	289.00
KeP6	29.00	29.00	210.00	7.20	7.00	1.03	24.00	5.00	3.00	138.00
KeP7	29.00	30.00	117.00	4.80	4.60	1.04	28.00	4.50	3.00	66.00
KeP8	30.00	32.00	94.00	5.20	5.00	1.04	24.00	4.80	3.20	62.00
KeP9	27.50	29.00	89.00	4.80	4.60	1.04	22.00	4.60	2.80	54.00
KeP10	28.00	29.00	87.00	4.80	4.70	1.02	24.00	5.00	3.00	52.00

Table 6e. Quantitative characters of flower and fruit of dragon fruit plants PeP1-AdP10

Plants	Length of style (cm)	Number of stigma lobes	Fruit weight (g)	Length of fruit (cm)	Width of fruit (cm)	Length/width ratio of fruit	Number of bracts	Length of apical bract	Width of the base of bract	Fruit weight without peel (g)
PeP1	24.50	34.00	460.00	8.90	8.90	1.00	20.00	4.50	5.00	382.00
PeP2	25.20	32.00	225.00	7.10	7.10	1.00	22.00	4.80	3.50	112.00
PeP3	24.00	33.00	512.00	8.90	8.90	1.00	38.00	4.00	2.30	382.00
PeP4	26.20	32.00	554.00	9.10	9.10	1.00	42.00	3.50	2.20	394.00
PeP5	28.50	29.00	248.00	7.20	6.90	1.04	24.00	5.00	2.30	161.00
PeP6	27.00	32.00	310.00	7.50	7.50	1.00	24.00	4.80	2.30	178.00
PeP7	29.00	28.00	136.00	5.50	5.20	1.06	32.00	4.30	2.80	72.00
PeP8	28.00	29.00	99.00	5.20	5.10	1.02	22.00	4.50	3.20	59.00
PeP9	28.50	30.00	122.00	4.60	4.40	1.05	24.00	4.60	3.00	64.00
PeP10	28.00	29.00	88.00	4.80	4.60	1.04	24.00	4.50	3.00	58.00
AdP1	26.00	33.00	280.00	7.60	7.50	1.01	26.00	3.80	4.10	224.00
AdP2	25.00	30.00	228.00	7.00	7.00	1.00	22.00	4.00	3.60	212.00
AdP3	27.00	26.00	302.00	7.40	7.20	1.03	28.00	3.50	4.30	197.00
AdP4	28.00	32.00	480.00	8.60	8.50	1.01	30.00	4.80	3.50	392.00
AdP5	29.00	30.00	558.00	8.80	8.80	1.00	38.00	3.00	2.10	335.00
AdP6	29.00	33.00	428.00	8.90	8.70	1.02	28.00	4.70	3.90	333.00
AdP7	28.50	33.00	594.00	8.90	8.90	1.00	41.00	4.00	2.20	373.00
AdP8	26.50	29.00	112.00	5.40	5.30	1.02	24.00	4.50	3.30	74.00
AdP9	29.50	33.00	234.00	6.90	6.80	1.01	26.00	5.60	3.00	189.00
AdP10	28.00	29.00	256.00	7.20	7.10	1.01	24.00	5.20	3.20	204.00

Table 7. Descriptive statistics of fruit characters and quality attributes in dragon fruit

Descriptives	Fruit weight (g)	Length of fruit (cm)	Width of fruit (cm)	Length /width ratio of fruit	Number of bracts	Length of apical bract (cm)	Width of base of the bract (cm)	Fruit weight without peel (g)	TSS (°Brix)	Titrable acidity (%)	TSS/acid ratio
Range	812.00	5.80	6.00	0.21	32.00	3.30	4.30	546.00	7.00	0.00	58.33
Minimum	84.00	4.60	4.40	1.00	18.00	3.00	1.40	52.00	11.00	0.12	91.67
Maximum	896.00	10.40	10.40	1.21	50.00	6.30	5.70	598.00	18.00	0.12	150.00
Average	381.10	7.94	7.83	1.02	29.24	4.68	3.35	269.60	15.17	0.12	126.42
Standard error of mean	35.01	0.31	0.31	0.01	1.42	0.15	0.17	26.08	0.38	0.00	3.12
Standard deviation	176.46	1.54	1.58	0.03	7.14	0.79	0.84	131.42	1.94	0.00	16.12
Co-efficient of variation (%)	46	19	20	03	24	17	25	49	13	00	13

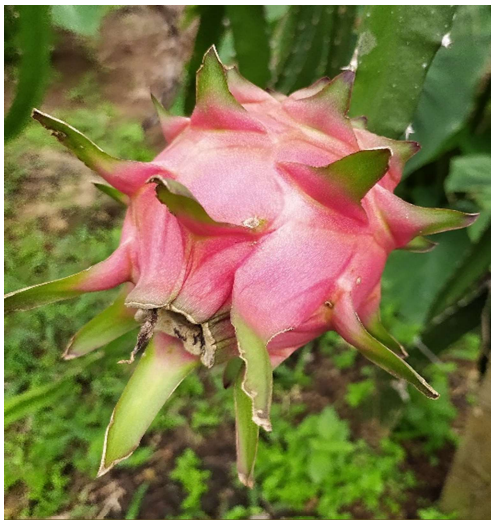


Adpressed, spherical

Slightly held out, oval

strongly held out, spherical

Plate 10. Position of bract towards the peel and fruit shape



Medium pink **Dark pink**

Plate 11. Peel colour of dragon fruit

Dark pink **Purple**

Plate 12. Flesh colour of dragon fruit

Table 8a. Qualitative characters of fruits and quality attributes of dragon fruit plants AtP1-ThP10

Plants	Position of bracts towards the peel	Fruit shape	Colour of peel	Flesh colour	TSS outer (°Brix)	TSS core (°Brix)	Titrable acidity (%)	TSS/acid ratio
AtP1	strongly held out	spherical	Dark pink	Dark pink	9.00	16.00	0.12	133.33
AtP2	strongly held out	spherical	Medium pink	Dark pink	9.50	16.00	0.12	133.33
AtP3	strongly held out	spherical	Dark pink	Dark pink	10.00	16.50	0.12	137.50
AtP4	strongly held out	spherical	Medium pink	Dark pink	9.00	16.00	0.12	133.33
AtP5	strongly held out	spherical	Medium pink	Dark pink	9.50	16.50	0.12	137.50
AtP6	strongly held out	spherical	Dark pink	Dark pink	8.00	15.50	0.12	129.17
AtP7	strongly held out	spherical	Medium pink	Dark pink	8.00	16.00	0.12	133.33
AtP8	strongly held out	spherical	Dark pink	Dark pink	9.50	16.00	0.12	133.33
AtP9	strongly held out	spherical	Medium pink	Dark pink	11.00	16.00	0.12	133.33
AtP10	strongly held out	spherical	Medium pink	Dark pink	10.00	16.50	0.12	137.50
ThP1	slightly held out	Oval	Dark pink	Dark pink	10.00	17.00	0.12	141.67
ThP2	slightly held out	Oval	Dark pink	Dark pink	11.00	17.00	0.12	141.67
ThP3	slightly held out	Oval	Dark pink	Dark pink	10.00	17.50	0.12	145.83
ThP4	slightly held out	oval	Dark pink	Dark pink	8.50	17.50	0.12	145.83
ThP5	slightly held out	oval	Dark pink	Dark pink	9.00	17.00	0.12	141.67
ThP6	Adpressed	spherical	Dark pink	Purple	7.00	14.00	0.12	116.67
ThP7	Adpressed	spherical	Dark pink	Purple	7.00	14.50	0.12	120.83
ThP8	slightly held out	spherical	Medium pink	Dark pink	10.00	17.00	0.12	141.67
ThP9	slightly held out	oval	Dark pink	Dark pink	8.00	17.00	0.12	141.67
ThP10	slightly held out	spherical	Medium pink	Dark pink	8.00	17.50	0.12	145.83

Table 8b. Qualitative characters of fruits and quality attributes of dragon fruit plants KaP1-KoP10

Plants	Position of bracts towards the peel	Fruit shape	Colour of peel	Flesh colour	TSS outer (°Brix)	TSS core (°Brix)	Titrable acidity (%)	TSS/acid ratio
KaP1	strongly held out	spherical	Medium pink	Dark pink	9.00	14.00	0.12	116.67
KaP2	strongly held out	spherical	Dark pink	Dark pink	10.00	15.00	0.12	125.00
KaP3	strongly held out	spherical	Dark pink	Dark pink	9.00	15.00	0.12	125.00
KaP4	strongly held out	spherical	Dark pink	Dark pink	8.00	14.00	0.12	116.67
KaP5	strongly held out	spherical	Medium pink	Dark pink	8.00	14.50	0.12	120.83
KaP6	strongly held out	spherical	Medium pink	Dark pink	9.00	15.00	0.12	125.00
KaP7	strongly held out	spherical	Dark pink	Dark pink	10.00	15.50	0.12	129.17
KaP8	strongly held out	spherical	Medium pink	Dark pink	10.00	15.00	0.12	125.00
KaP9	strongly held out	spherical	Dark pink	Dark pink	9.00	14.00	0.12	116.67
KaP10	strongly held out	spherical	Dark pink	Dark pink	8.00	15.00	0.12	125.00
KoP1	strongly held out	spherical	Medium pink	Dark pink	11.00	18.00	0.12	150.00
KoP2	strongly held out	spherical	Medium pink	Dark pink	11.00	18.00	0.12	150.00
KoP3	strongly held out	spherical	Medium pink	Dark pink	10.50	18.00	0.12	150.00
KoP4	strongly held out	spherical	Dark pink	Dark pink	11.00	17.50	0.12	145.83
KoP5	strongly held out	spherical	Dark pink	Dark pink	12.00	18.00	0.12	150.00
KoP6	strongly held out	spherical	Dark pink	Dark pink	12.00	17.00	0.12	141.67
KoP7	strongly held out	spherical	Medium pink	Dark pink	11.00	17.50	0.12	145.83
KoP8	strongly held out	spherical	Medium pink	Dark pink	10.50	17.00	0.12	141.67
KoP9	strongly held out	spherical	Dark pink	Dark pink	11.00	17.00	0.12	141.67
KoP10	strongly held out	spherical	Medium pink	Dark pink	11.00	18.00	0.12	150.00

Table 8c. Qualitative characters of fruits and quality attributes of dragon fruit plants AiP1-MuP10

Plants	Position of bracts towards the peel	Fruit shape	Colour of peel	Flesh colour	TSS outer (°Brix)	TSS core (°Brix)	Titrable acidity (%)	TSS/acid ratio
AiP1	slightly held out	spherical	Medium pink	Dark pink	7.00	14.00	0.12	116.67
AiP2	slightly held out	spherical	Medium pink	Dark pink	6.00	14.50	0.12	120.83
AiP3	slightly held out	oval	Dark pink	Dark pink	9.00	15.00	0.12	125.00
AiP4	slightly held out	oval	Dark pink	Dark pink	9.00	15.50	0.12	129.17
AiP5	slightly held out	oval	Dark pink	Dark pink	9.50	15.00	0.12	125.00
AiP6	slightly held out	oval	Dark pink	Dark pink	9.50	15.00	0.12	125.00
AiP7	slightly held out	spherical	Medium pink	Dark pink	6.00	14.00	0.12	116.67
AiP8	slightly held out	oval	Dark pink	Dark pink	7.00	14.00	0.12	116.67
AiP9	slightly held out	spherical	Medium pink	Dark pink	9.50	15.00	0.12	125.00
AiP10	Adpressed	spherical	Dark pink	Purple	7.00	14.00	0.12	116.67
MuP1	Adpressed	spherical	Dark pink	Purple	7.00	11.00	0.12	91.67
MuP2	Adpressed	spherical	Dark pink	Purple	7.50	12.00	0.12	100.00
MuP3	Adpressed	spherical	Dark pink	Purple	6.50	11.50	0.12	95.83
MuP4	slightly held out	spherical	Medium pink	Dark pink	9.00	15.00	0.12	125.00
MuP5	slightly held out	oval	Dark pink	Dark pink	10.00	16.00	0.12	133.33
MuP6	slightly held out	spherical	Medium pink	Dark pink	10.50	17.00	0.12	141.67
MuP7	slightly held out	spherical	Medium pink	Dark pink	12.50	16.00	0.12	133.33
MuP8	slightly held out	oval	Dark pink	Dark pink	12.00	16.50	0.12	137.50
MuP9	slightly held out	oval	Dark pink	Dark pink	11.00	16.50	0.12	137.50
MuP10	slightly held out	oval	Dark pink	Dark pink	12.00	16.00	0.12	133.33

Table 8d. Qualitative characters of fruits and quality attributes of dragon fruit plants VaP1-KeP10

Plants	Position of bracts towards the peel	Fruit shape	Colour of peel	Flesh colour	TSS outer (°Brix)	TSS core (°Brix)	Titrable acidity (%)	TSS/acid ratio
VaP1	slightly held out	oval	Dark pink	Dark pink	7.00	12.00	0.12	100.00
VaP2	slightly held out	spherical	Medium pink	Dark pink	11.00	12.50	0.12	104.17
VaP3	slightly held out	spherical	Medium pink	Dark pink	8.00	12.00	0.12	100.00
VaP4	slightly held out	spherical	Medium pink	Dark pink	8.00	11.50	0.12	95.83
VaP5	slightly held out	spherical	Medium pink	Dark pink	9.00	14.00	0.12	116.67
VaP6	slightly held out	spherical	Medium pink	Dark pink	10.00	14.00	0.12	116.67
VaP7	slightly held out	oval	Dark pink	Dark pink	9.00	12.50	0.12	104.17
VaP8	Adpressed	spherical	Dark pink	Purple	6.50	11.00	0.12	91.67
VaP9	slightly held out	oval	Dark pink	Dark pink	11.00	13.00	0.12	108.33
VaP10	slightly held out	oval	Dark pink	Dark pink	9.00	12.00	0.12	100.00
KeP1	slightly held out	spherical	Medium pink	Dark pink	11.50	16.00	0.12	133.33
KeP2	slightly held out	oval	Dark pink	Dark pink	8.00	17.00	0.12	141.67
KeP3	slightly held out	oval	Dark pink	Dark pink	8.00	16.50	0.12	137.50
KeP4	slightly held out	spherical	Medium pink	Dark pink	7.00	14.00	0.12	116.67
KeP5	Adpressed	spherical	Dark pink	Purple	7.50	11.00	0.12	91.67
KeP6	slightly held out	oval	Dark pink	Dark pink	10.00	17.00	0.12	141.67
KeP7	slightly held out	spherical	Medium pink	Dark pink	8.50	15.00	0.12	125.00
KeP8	slightly held out	oval	Dark pink	Dark pink	9.00	16.00	0.12	133.33
KeP9	slightly held out	oval	Dark pink	Dark pink	8.00	16.00	0.12	133.33
KeP10	slightly held out	oval	Dark pink	Dark pink	8.00	16.50	0.12	137.50

Table 8e. Qualitative characters of fruits and quality attributes of dragon fruit plants PeP1-AdP10

Plants	Position of bracts towards the peel	Fruit shape	Colour of peel	Flesh colour	TSS outer (°Brix)	TSS core (°Brix)	Titrable acidity (%)	TSS/acid ratio
PeP1	slightly held out	spherical	Medium pink	Dark pink	9.50	16.00	0.12	133.33
PeP2	slightly held out	spherical	Medium pink	Dark pink	10.00	17.00	0.12	141.67
PeP3	Adpressed	spherical	Dark pink	Purple	7.00	11.00	0.12	91.67
PeP4	Adpressed	spherical	Dark pink	Purple	7.50	11.00	0.12	91.67
PeP5	slightly held out	oval	Dark pink	Dark pink	12.00	16.00	0.12	133.33
PeP6	slightly held out	spherical	Medium pink	Dark pink	8.00	12.00	0.12	100.00
PeP7	slightly held out	oval	Dark pink	Dark pink	9.00	15.00	0.12	125.00
PeP8	slightly held out	oval	Dark pink	Dark pink	8.00	15.00	0.12	125.00
PeP9	slightly held out	oval	Dark pink	Dark pink	8.00	16.00	0.12	133.33
PeP10	slightly held out	oval	Dark pink	Dark pink	9.00	14.00	0.12	116.67
AdP1	slightly held out	oval	Dark pink	Dark pink	8.00	16.50	0.12	137.50
AdP2	slightly held out	spherical	Medium pink	Dark pink	6.00	14.00	0.12	116.67
AdP3	slightly held out	oval	Dark pink	Dark pink	8.00	17.00	0.12	141.67
AdP4	slightly held out	oval	Dark pink	Dark pink	8.00	16.50	0.12	137.50
AdP5	Adpressed	spherical	Dark pink	Purple	6.50	12.00	0.12	100.00
AdP6	slightly held out	oval	Dark pink	Dark pink	10.00	16.50	0.12	137.50
AdP7	Adpressed	spherical	Dark pink	Purple	7.00	11.00	0.12	91.67
AdP8	slightly held out	oval	Dark pink	Dark pink	7.00	15.50	0.12	129.17
AdP9	slightly held out	oval	Dark pink	Dark pink	8.00	16.00	0.12	133.33
AdP10	slightly held out	oval	Dark pink	Dark pink	7.00	16.00	0.12	133.33

Table 9. Frequency distribution of qualitative characters of dragon fruit

Sl. No.	Character	Expression	Frequency (%)
1	**Stem waxiness**	Strong	88.00
		Weak	12.00
2	**Stem sturdiness**	High	12.00
		Low	88.00
3	**Margin of rib**	Convex	88.00
		Flat	12.00
4	**Spine colour**	Dark brown	12.00
		Medium brown	88.00
5	**Bud shape**	Ovate	88.00
		Elliptic	12.00
6	**Bud apex shape**	Acute	88.00
		Rounded	12.00
7	**Sepal pattern of secondary colour**	Red edged	58.00
		Slightly red edged	42.00
8	**Intensity of red colour of bract**	Strong	12.00
		Medium	46.00
		Weak	42.00
9	**Position of bracts towards the peel**	Adpressed	12.00
		Slightly held out	58.00
		Strongly held out	30.00
10	**Fruit shape**	Oval	37.00
		Spherical	63.00
11	**Peel colour**	Dark pink	63.00
		Medium pink	37.00
12	**Flesh colour**	Dark pink	88.00
		Purple	12.00

4.5 Quality attributes

Quality attributes like TSS content, titrable acidity and TSS/acid ratio of dragon fruits were estimated and the data pertaining to the values of quality attributes are given in Table 7a to 7e. Organoleptic scoring of the fruits collected from different locations were carried out and the data are presented location wise.

4.5.1 Total soluble solids (°Brix)

The flesh of the fruit in the core region recorded higher TSS compared to that of the flesh adjacent to skin. The TSS measured in different fruits was in the range of 11 to 18 °Brix in the core with the maximum value (18 °Brix) being shown by fruits from plants KoP1, KoP2, KoP3, KoP5 and KoP10, indicating the possibility of location specific climatic or soil factors in deciding the quality of the fruits. The TSS value was the lowest in fruits collected from MuP1, VaP8, KeP5, PeP3, PeP4 and AdP7. The mean TSS shown by the dark pink/purple fleshed dragon fruits in the four districts of Kerala was observed to be 15.17.

4.5.2 Titrable acidity (%)

All the fruits analysed from the plants collected from ten different locations were found to have only very low titrable acidity of 0.12%.

4.5.3 TSS/acid ratio

The ratio of TSS to acidity of the fruits ranged from 91.67 to 150.00 with an average of 126.42 and CV of 13%. The maximum ratio was seen in the fruits that had exhibited maximum TSS (KoP1, KoP2, KoP3, KoP5 and KoP10) and the minimum ratio was seen in fruits with minimum TSS (MuP1, VaP8, KeP5, PeP3, PeP4 and AdP7).

4.5.4 Organoleptic scoring of the fruit

Fruits from ten locations were taken as ten samples and the organoleptic scoring of the samples were done. The various parameters for judging the quality of the fruits included colour, appearance, texture, taste, flavour, after taste and overall acceptability. The scoring was based on a 9-point hedonic scale in which, a point of nine represented the highest score showing high preference for the fruits and a point of one was the least

score that represented least preference. The data pertaining to the scores are detailed in Table 10.

The highest (8.60) mean score for colour was obtained for the fruits from AiP1-AiP10, followed by MuP1-MuP10 (8.10) and VaP1-VaP10 (8.10). The least mean score for colour was recorded in fruits from AtP1-P10 (6.40). Fruits from KoP1-P10 stood first (8.20) in the mean score for appearance and second highest average score was seen in fruits from AtP1-AtP10 (8.00). In terms of texture, fruits from MuP1-MuP10 got the highest mean score (8.40) whereas the least (5.90) in VaP1-VaP10. With respect to taste, flavour, after taste and overall acceptability, highest mean score was obtained for the fruits from KoP1-P10 (8.30, 8.70, 8.80 and 8.40 respectively). The overall acceptability of fruits after KoP1-KoP10 was succeeded by the fruits from AdP1-AdP10 (8.00), KeP1-KeP10 (7.70) and ThP1-ThP10 (7.50).

Table 10. Mean score of sensory evaluation

Parameters	Mean Score						
	Colour	**Appearance**	**Texture**	**Taste**	**Flavour**	**After taste**	**Overall acceptability**
AtP1-P10	6.40	8.00	7.10	7.10	6.80	7.40	7.10
ThP1-P10	7.50	6.20	7.40	7.10	7.90	8.30	7.50
KaP1-P10	6.50	7.80	7.40	7.20	7.40	7.70	7.20
KoP1-P10	8.00	8.20	7.80	8.30	8.70	8.80	8.40
AiP1-P10	8.60	7.00	7.10	7.30	6.20	7.90	7.30
MuP1-P10	8.10	7.40	8.40	6.20	6.00	6.50	6.20
VaP1-P10	6.70	5.90	7.50	5.90	6.30	6.70	6.30
KeP1-P10	8.10	5.20	7.10	7.80	8.00	8.40	7.70
PeP1-P10	7.90	6.50	6.50	7.00	7.50	7.50	7.30
AdP1-P10	7.40	7.40	7.50	8.10	7.80	8.00	8.00
Kendall's W	0.41	0.37	0.20	0.34	0.49	0.41	0.36

4.6 Economic data

The details including the farm size, area under dragon fruit, age of the plants, cultivation practices, cost of cultivation, yield, marketing details, returns, constraints and source of planting material of orchards at the ten locations were collected.

4.6.1 Farm size

The total area utilized for cultivation purpose (different crops) by the farmers varied widely between 0.10 acres to 40 acres. The maximum farm size was 40 acres in Vaniyampara. The details of farm size of the 10 farmers are furnished in Table 11.

4.6.2 Area under dragon fruit

The area under dragon fruit cultivation increased each year as the farmers themselves started bringing more under-utilized lands under cultivation. The present status of area under dragon fruit cultivation by 10 farmers from the four districts are listed in Table 11.

4.6.3 Age of plants

Since dragon fruit is a perennial crop having a life span of around 20-25 years, the plant growth stages were divided into three phases based on their age and stage of growth namely, the establishment phase (0-2 years), yield increasing phase (2-4 years) and yield stabilizing phase (4 years and above) as mentioned in Table 12. Out of the ten locations, three locations each came under the establishment phase and yield stabilizing phase respectively and rest of the four locations came under yield increasing phase.

4.6.4 Cultivation practices

The cultivation practices followed by the farmers varied with each other. The major variations were observed in manure and fertilizer application, weeding, pruning and plant protection measures. Majority of them didn't have any proper irrigation schedule and the rest of them provided irrigation only during extreme summer. For the cultivation of dragon fruit, majority of the farmers used organic manures like farm yard manure, bone meal, neem cake, poultry manure and goat manure. One of the farmers reported the use of sulphate of potash along with other organic manures. Fertilizer

application was generally done four times per year with a time interval of 3 months. Approximately 10-15 kg organic manure was given per post at a time. Weeding was another important operation followed by the farmers. Manual or mechanical weeding was practiced several times a year. Pruning of new shoots/growth arising from the main stem was an operation done either along with weeding or separately. In age-old orchards, pruning of older stems were done and these were made use for producing planting material. Plant protection practices were not found to be common, except organic or chemical spray, against mainly ants and rarely bugs.

4.6.5 Cost of cultivation

4.6.5.1 Operation-wise establishment cost

The total establishment cost per hectare of dragon fruit was estimated as ₹26,98,617 (Table 13). The establishment cost included the cost incurred for primary operations like land preparation, construction of concrete post, cost of planting material, planting, manure and fertilizer application. Maximum share of the total cost was for planting material (42.15%) followed by the cost incurred for constructing and erecting the concrete posts (41.33%). Other operations such as application of manures and fertilizers, planting and land preparation contributed to 13.95%, 1.69% and 0.88% of the total cost respectively.

4.6.5.2 Maintenance cost incurred during yielding phase of dragon fruit

The annual maintenance cost (operation-wise) per hectare of dragon fruit was assessed for various phases as furnished in Table 14. The average cost was found to be ₹4,97,706. The major expense was for application of manures and fertilizers (51.31%). Other operations like harvesting and post-harvest handling and weeding, incurred 41.81% and 6.88% of the annual maintenance cost respectively.

4.6.5.3 Total cost of cultivation

The total expenditure for cultivating dragon fruit in one hectare was estimated and are presented in Table 15. In order to arrive at the total cost of cultivation, the establishment cost (₹26,98,617) was amortized to ₹2,96,848 per hectare per year. The amortized value was then added to the annual maintenance cost and interest on working

capital at seven per cent, and then finally arriving at a total cost of ₹8,29,393 per hectare of dragon fruit. The initial investment required for establishment of the orchard along with the requirement of good amount of organic manures ended up in high cultivation expense. Other operations like plant protection and irrigation requirements were least observed in dragon fruit compared to other perennial crops.

Table 11. Area-wise details and planting density of different locations

Location	Total farm size (acre)	Area under dragon fruit (acre)	Spacing (m)	Number of poles	Number of plants	Plants/ha
Athikkayam (At)	20.0	4.00	3.0 × 3.0	2100	8400	5187
Thatta (Th)	1.00	0.20	2.0 × 2.5	160	640	7904
Karette (Ka)	16.0	12.0	2.5 × 2.5	7770	31080	6397
Kozhenchery (Ko)	0.10	0.05	2.5 × 2.5	32	128	6323
Aikkad (Ai)	2.50	0.30	3.0 × 3.0	226	904	7975
Muvattupuzha (Mu)	7.00	0.50	2.0 × 2.5	200	800	3952
Vaniyampara (Va)	40.0	5.00	2.0 × 2.5	4047	16188	7997
Keerukuzhy (Ke)	1.35	0.20	2.5 × 2.5	120	480	5928
Perumbavoor (Pe)	38.0	0.50	2.5 × 2.5	324	1296	6402
Adoor (Ad)	10.5	4.00	2.0 × 2.5	3230	12920	7978

Note: In all the locations, number of plants = number of poles x 4.

Table 12. Dragon fruit orchards at different locations under three growth phases based on the age of the plants

Establishment phase		Yield increasing phase		Yield stabilizing phase	
Location	**Age (year)**	**Location**	**Age (year)**	**Location**	**Age (year)**
Kozhenchery	1.5	Athikkayam	3.0	Thatta	6.0
Keerukuzhy	1.5	Aikkad	3.0	Karette	6.0
Adoor	1.0	Vaniyampara	2.0	Muvattupuzha	5.0
		Perumbavoor	3.0		

Table 13. Operation-wise establishment cost of dragon fruit orchard

Sl. No.	Particulars	Average cost (₹)
1	Land preparation	23,833 (0.88)
2	Constructing and erecting post	11,15,250 (41.33)
3	Planting material	11,37,333 (42.15)
4	Planting	45,633 (1.69)
5	Manure and fertilizer application	3,76,567 (13.95)
	Total	26,98,617

Note: Figures given in parenthesis indicate the per cent to column total

Table 14. Operation-wise annual maintenance cost of dragon fruit orchard

Sl. No.	Particulars	Cost (₹)		Weighted mean
		Yield increasing phase	Yield stabilizing phase	
1	Weeding (and irrigation if done)	43,057 (12.48)	22,477 (3.20)	34,237 (6.88)
2	Manure and fertilizer application	1,42,308 (41.26)	4,06,136 (57.90)	2,55,377 (51.31)
3	Harvesting and post-harvest handling	1,59,522 (46.25)	2,72,853 (38.90)	2,08,092 (41.81)
	Total	3,44,886	7,01,466	4,97,706

Note: Figures given in parenthesis indicate the per cent to column total

Table 15. Cost of cultivation of dragon fruit (₹/ha)

Sl. No.	Particulars	Cost (₹/ha)
1	Establishment cost	26,98,617
2	Amortized value	2,96,848
3	Annual maintenance cost	4,97,706
4	Interest on working capital @ 7%	34,839
5	Total cost	8,29,393

4.6.6 Yield

The average yield per hectare per year was found to be 21 tonnes. The yield ranged from 7 tonnes to 32 tonnes per hectare per year (Table 16), depending on the age of the plants and cultivation practices adopted. The yield details are presented in Table 16.

4.6.7 Marketing details

Dragon fruit marketing involves the entire activities starting from transporting the produce from the orchards till it finally reaches the consumer. The marketing chain included various intermediaries like middlemen, wholesalers, local traders or retailers and online sellers. Dragon fruit export was not reported by any of the farmers but the possibilities have to be explored in the near future.

Marketing channels identified for dragon fruit in the districts of Trivandrum, Pathanamthitta, Ernakulam and Thrissur districts are:

Channel I: Producer - Consumer

Channel II: Producer - Local trader – Consumer

Channel III: Producer – Wholesaler – Retailer – Consumer

Channel IV: Producer – Online sellers – Consumer

Channel V: Producer – Middlemen – Wholesaler – Retailer – Consumer

Majority of the sale was found to take place through channel I, channel II and channel III which represented the domestic markets for dragon fruit. Consumers preferred the direct purchase of fresh produce directly from the farmers by giving order for the fruits before harvest. When wholesalers and retailers were involved, the fruits were ordered either before the harvest or were purchased immediately after the harvest. The involvement of middlemen was high in large orchards with bulk production compared to the smaller orchards.

4.6.8 Returns

The gross and net returns of dragon fruit cultivation per year were estimated from the data collected and were found to be ₹35,62,161 and ₹27,32,768 respectively (Table 17). The benefit cost ratio was worked out from the gross returns and the total cost of cultivation. Three situations of different possible returns were considered for arriving at the B:C ratio. The price per kg of fruit (₹174) was taken into account based on the average price received by different farmers in the first case. Whereas in the second and third cases, the least price obtained per kilogram and a medium price lying

in between the average and least price were considered respectively. The B:C ratio turned out to be 4.29, 3.04 and 3.54 in the first, second and third cases correspondingly (Table 18).

Table 16. Yield and returns obtained from dragon fruit

Location	Yield per post (kg)	Total yield per year (kg)	Yield per ha per year (tonnes)	Price per kg (₹)	Total returns per ha per year (₹)
Athikkayam	15	31500	19	140	27,23,175
Thatta	15	2400	30	200	59,28,000
Karette	20	155400	32	150	47,97,975
Kozhenchery	10	320	16	200	31,61,600
Aikkad	10	2260	20	200	39,87,286
Muvattupuzha	20	4000	20	200	39,52,000
Vaniyampara	15	60705	30	120	35,98,592
Keerukuzhy	5	600	7	200	14,82,000
Perumbavoor	10	3240	16	150	24,00,840
Adoor	10	32300	20	180	35,90,145
Average	13	29273	21	174	35,62,161

Note: Yield per post indicate the yield of four plants.

Table 17. Net returns from dragon fruit cultivation

Sl. No.	Particulars	Quantity/value
1	Average productivity (kg/ha)	21,000
2	Average price received by farmers (₹/kg)	174
3	Gross returns (₹/ha)	35,62,161
4	Total cost (₹/ha)	8,29,393
5	Net return (₹/ha)	27,32,768

Table 18. Benefit cost ratio of dragon fruit cultivation under three alternative price (per kg) conditions

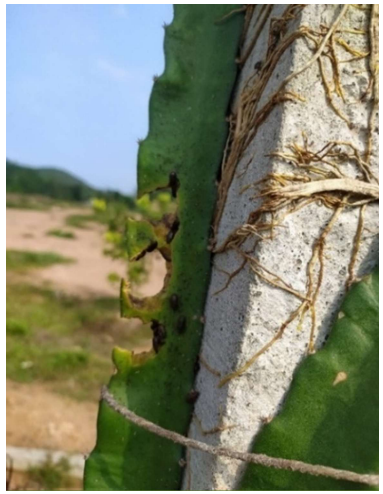
Sl. No.	Particulars of price received (₹/kg)	Value (₹/kg)	Gross return (₹/ha)	B:C ratio
1	Average	174	35,62,161	4.29
2	Least	120	25,19,160	3.04
3	Medium	140	29,39,020	3.54

4.6.9 Constraints

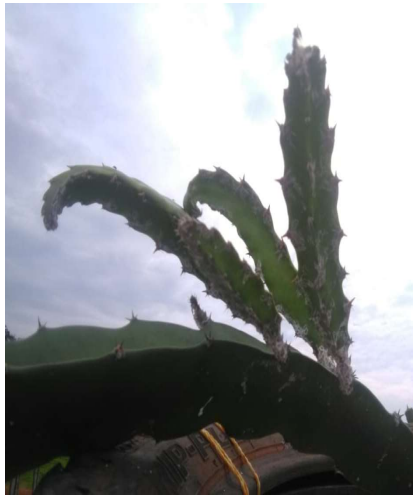
The constraints faced by farmers in dragon fruit cultivation were recorded and arranged according to a ranking method. The major constraints were identified based on the rank and frequency at which they occurred. The frequency distribution of the ranks for different constraints are mentioned in Table 19. Bud or flower drop was the major problem faced by farmers recently due to the heavy and continuous rainfall during the flowering period. Five out of ten farmers ranked this as the main constraint followed by weed menace which was the prime constraint for 4 farmers and disease incidence was the major problem for 1 farmer. Presence of pest was ranked as the second constraint by six farmers because of the common presence of ants in the orchards. Storage and marketing were not a big concern for the farmers as there was good demand for the produce.

Table 19. Frequency distribution of ranks obtained for different constraints

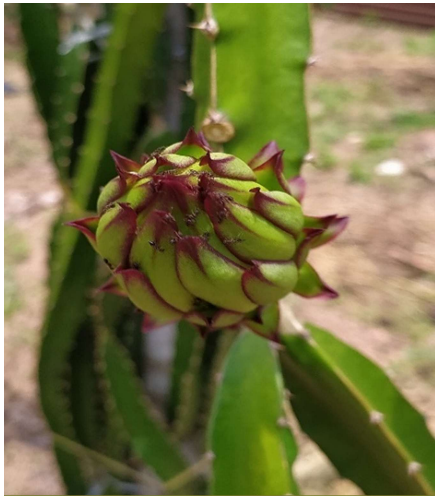
Constraints	Rank 1	Rank 2	Rank 3	Rank 4	Rank 5	Rank 6	Rank 7	Rank 8
Pests	-	6	-	1	3	-	1	-
Diseases	1	-	2	1	-	2	-	3
Weeds	4	2	2	2	-	-	-	-
Bud/flower drop	5	2	1	1	1	-	-	-
Availability of resources	-	-	4	3	1	3	2	-
Labour availability	-	-	1	1	4	1		-
Storage	-	-		1	1	2	3	3
Marketing	-	-	-	-	-	2	4	4



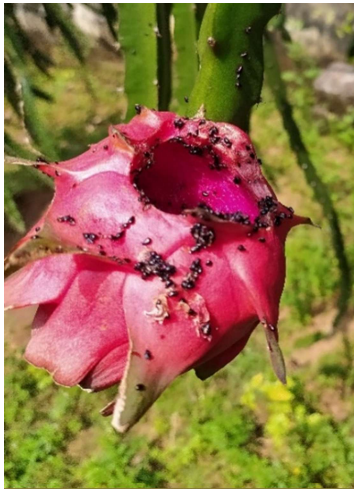
Beetle



Mealy bug



Ants



Damage by birds

Plate 13. Pest infestation in dragon fruit

(a)

(b)

Plate 14. Symptoms of canker (a) on stem (b) on fruit

4.6.10 Source of planting material

The source from where the planting material was procured by the farmers was recorded through the survey and it was found that the pink/purple fleshed dragon fruit cultivated in the districts under study were introduced to Kerala either from Malaysia/ Cambodia. Out of the ten orchards, three were cultivated with planting material brought from Malaysia and the rest of the orchards had dragon fruit which were brought from Cambodia (Table 20).

Table 20. Source of planting material in different orchards

Location	Source of planting material
Athikkayam	Malaysia (procured from Karette)
Thatta	Cambodia
Karette	Malaysia
Kozhenchery	Malaysia (procured from Kozhenchery)
Aikkad	Cambodia (procured from Thatta)
Muvattupuzha	Cambodia (procured from Thatta)
Vaniyampara	Cambodia (procured from Thatta)
Keerukuzhy	Cambodia (procured from Thatta)
Perumbavoor	Cambodia (procured from Thatta)
Adoor	Cambodia (procured from Thatta)

4.7 Incidence of pests and diseases

Dragon fruit was introduced to Kerala recently during the last decade. Since it is a new crop, the incidence of pests and diseases was less. Ants were common in dragon fruit but there was no significant yield loss. Recently infestation by different types of bugs were noticed. Fruit damage by birds was observed in some orchards (Plate 13).

Disease symptoms similar to canker (Plate 14) were observed in some of the orchards which were new to the farmers. Physiological disorder like yellowing during extreme summer was common in most of the orchards and these symptoms vanished immediately after a shower or with irrigation.

4.8 Statistical analysis

4.8.1 Factor analysis of mixed data (FAMD)

Factor analysis is a data reduction technique which analyses the similarity between individuals by considering the mixed type of variables (quantitative and qualitative). It works as principal component analysis (PCA) for the quantitative variables and as multiple correspondence analysis (MCA) for qualitative variables (Kassambara, 2017). FAMD was performed for stem and flower characters together and also for yield and quality attributes together.

4.8.1.1 FAMD for stem and flower characters

The results of FAMD based on 16 stem and flower characters are furnished in Table 21 and Table 22 represents the coordinates of the variables.

Based on the eigen value criteria (value >1), the first five dimensions were considered. The first two dimensions together explained 59.38% variability for the stem and flower characters (Fig. 14). The variance retained by dimensions 3, 4 and 5 were negligible. The variables that had significant and almost equal contribution in dimension 1 were intensity of red colour of bract, stem waxiness, stem sturdiness, margin of rib, spine colour, bud shape and bud apex shape as observed in Fig. 15, whereas the variables like intensity of red colour of bract, secondary colour of sepal, number of stigma lobes, length of style and distance between areoles had significant contribution to dimension 2, the maximum contribution being that of intensity of red colour of bract (Fig. 16).

The contribution of quantitative variables to the principal dimensions is explained by Fig. 17. The quadrant I showed stem segment length (length), stem segment width (width), arch height (AH) and number of spines per areole (NSA) which were explained by both the dimensions 1 and 2 whereas distance between areoles (DBL), number of stem segments (SSB) and length of style (LS) were explained by dimension 1 alone (quadrant II). The principal dimensions were not enough to explain the number of stigma lobes as the contribution of this variable was in the remaining dimensions.

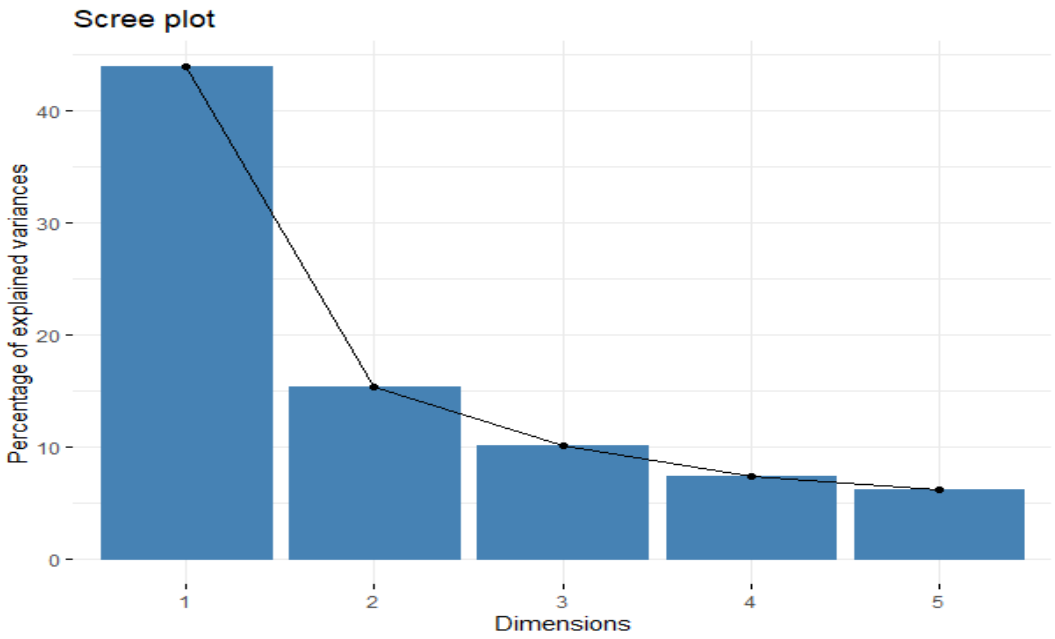


Fig. 14. Graph showing the variability explained by each dimension for stem and flower characters in dragon fruit

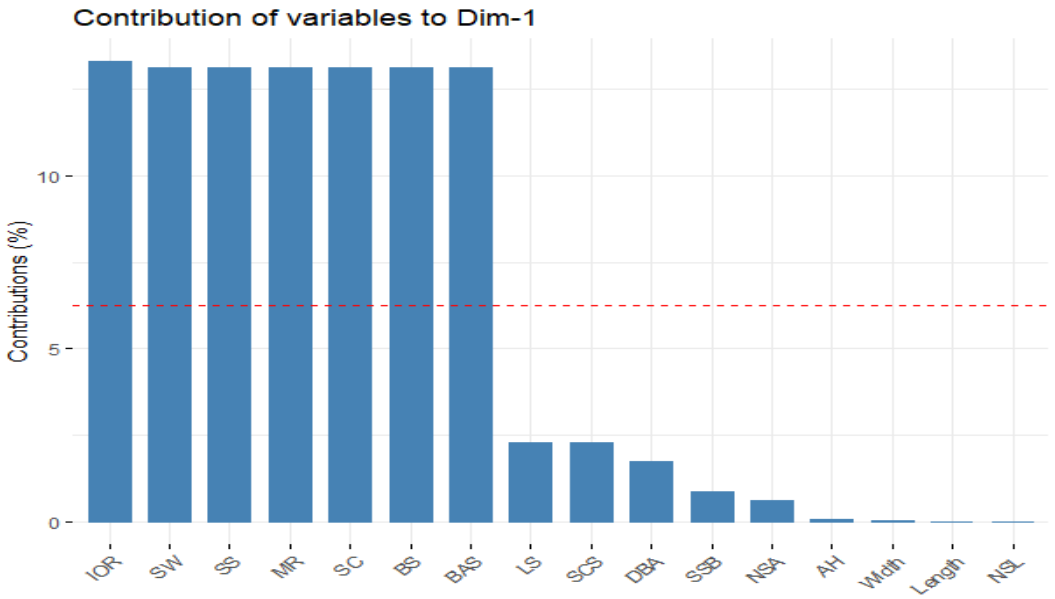


Fig. 15. Contribution of each variable in stem and flower characters to 1st dimension

(Length – Stem segment length; width – Stem segment width; DBA - Distance between areoles; AH – Arch height; NSA – Number of spines per areole; SSB – Number of stem segments per branch; LS – Length of style; NSL – Number of stigma lobes; SW – Stem waxiness; SS - Stem sturdiness; MR – Margin of rib; SC -Spine colour; BS – Bud shape; BAS – Bud apex shape; SCS – Sepal colour (secondary); IOR – Intensity of red colour of bract)

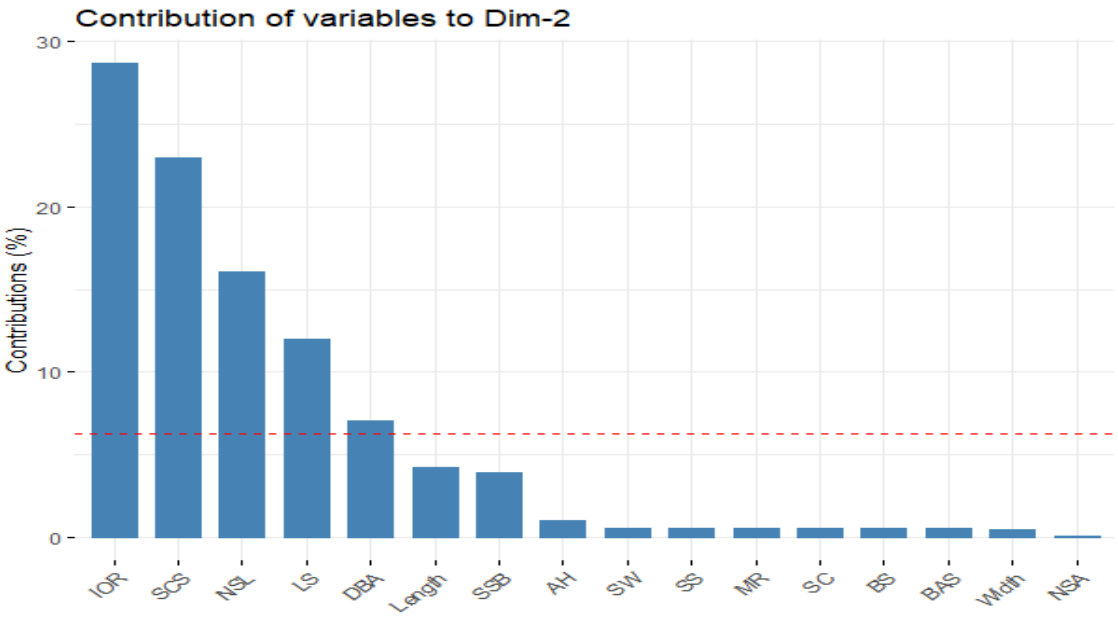


Fig. 16. Contribution of each variable in stem and flower characters to 2nd dimension

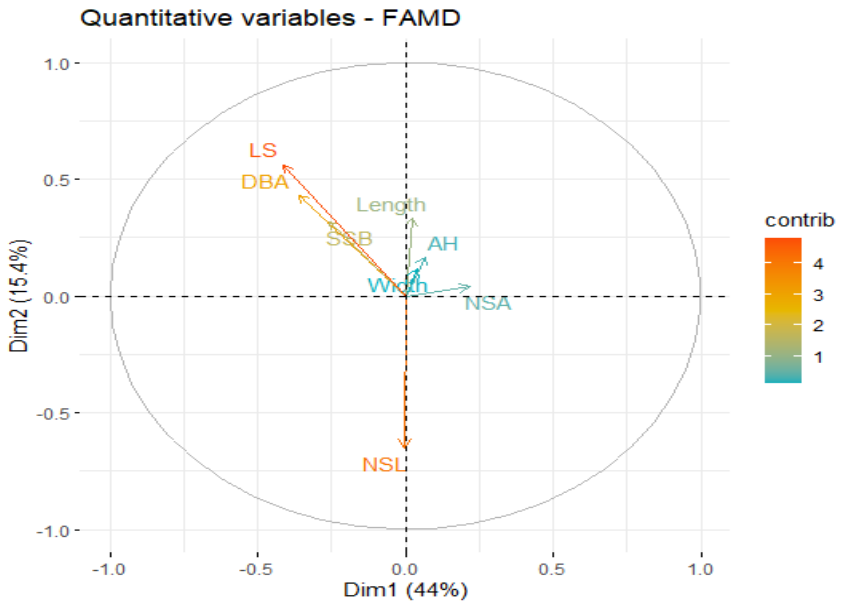


Fig. 17. FAMD of quantitative parameters of stem and flower characters

(Length – Stem segment length; width – Stem segment width; DBA - Distance between areoles; AH – Arch height; NSA – Number of spines per areole; SSB – Number of stem segments per branch; LS – Length of style; NSL – Number of stigma lobes; SW – Stem waxiness; SS - Stem sturdiness; MR – Margin of rib; SC -Spine colour; BS – Bud shape; BAS – Bud apex shape; SCS – Sepal colour (secondary); IOR – Intensity of red colour of bract)

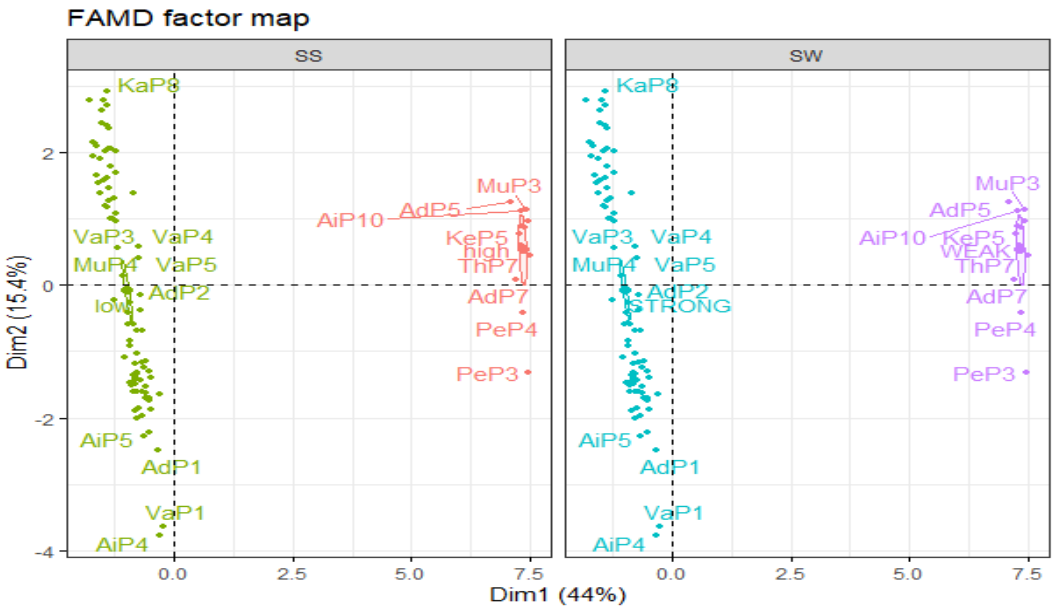


Fig. 18. FAMD factor map of stem sturdiness & stem waxiness

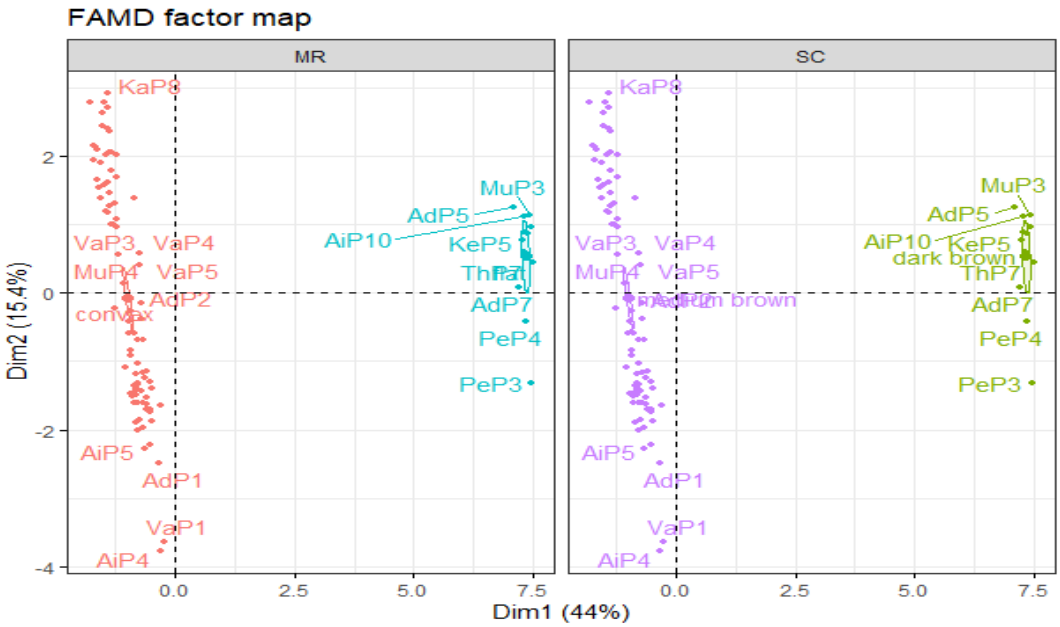


Fig. 19. FAMD factor map of margin of rib & spine colour

[At (P1-P10) from Athikkayam; Th (P1-P10) from Thatta; Ka (P1-P10) from Karette; Ko (P1-P10) from Kozhenchery; Ai (P1-P10) from Aikkad; Mu (P1-P10) from Muvattupuzha; Va (P1- P10) from Vaniyampara; Ke (P1-P10) from Keerukuzhy), Pe (P1-P10) from Perumbavoor; Ad (P1-P10) from Adoor)]

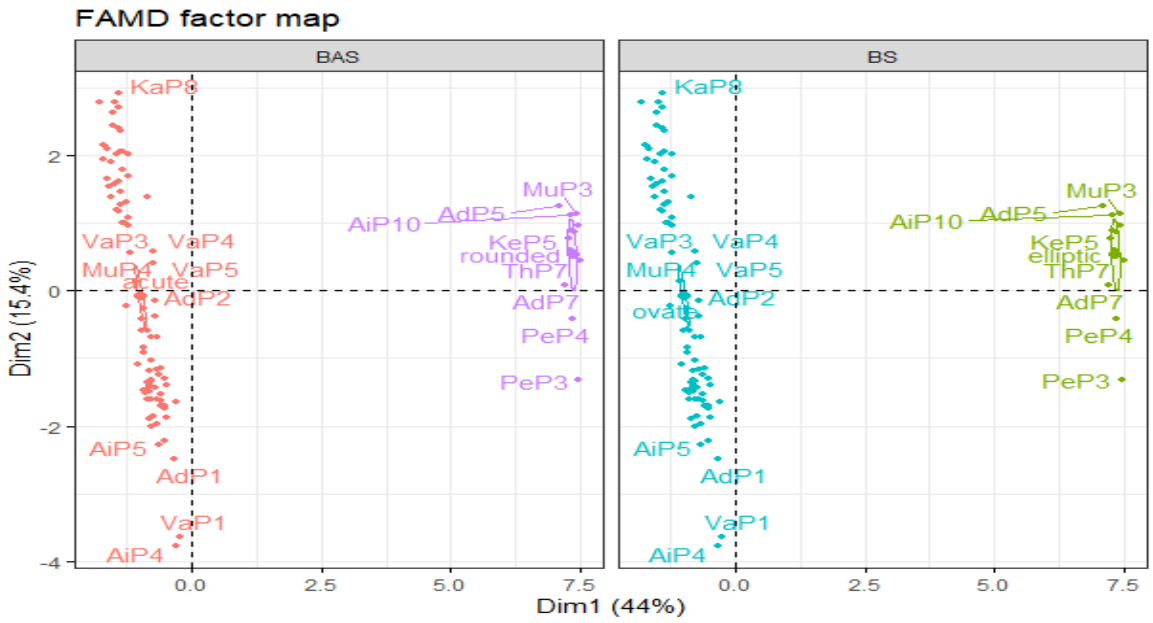


Fig. 20. FAMD factor map of bud apex shape & bud shape

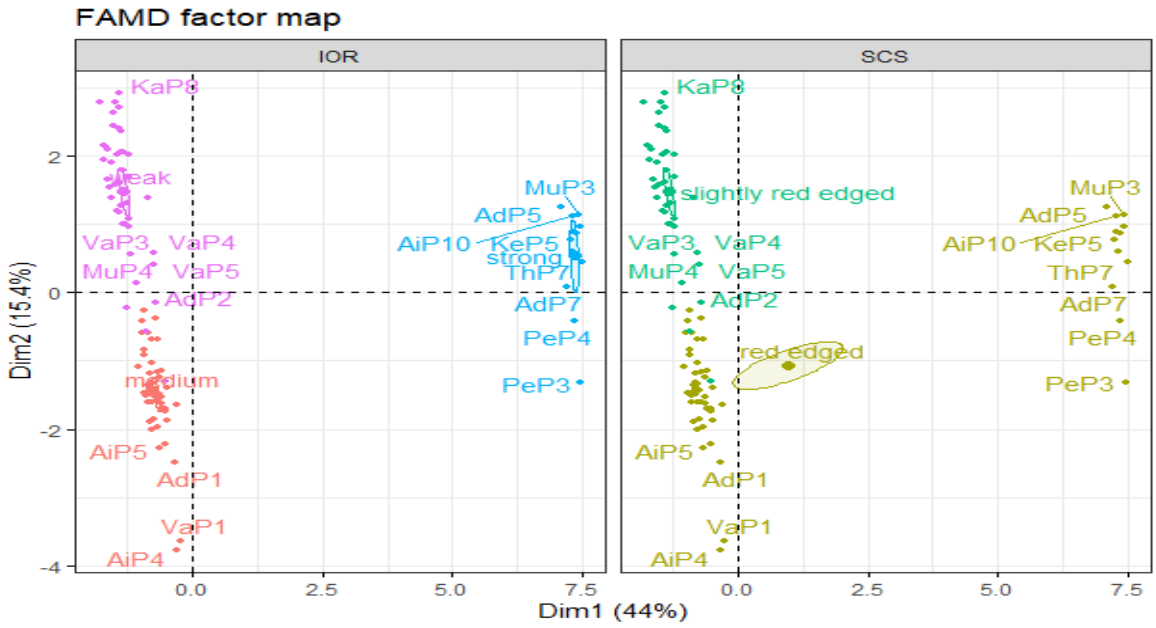


Fig. 21. FAMD factor map of intensity of red colour of bract & sepal colour (secondary)

[At (P1-P10) from Athikkayam; Th (P1-P10) from Thatta; Ka (P1-P10) from Karette; Ko (P1-P10) from Kozhenchery; Ai (P1-P10) from Aikkad; Mu (P1-P10) from Muvattupuzha; Va (P1- P10) from Vaniyampara; Ke (P1-P10) from Keerukuzhy), Pe (P1-P10) from Perumbavoor; Ad (P1-P10) from Adoor)]

Further, the contribution of individual qualitative variables to the dimensions 1 and 2 are depicted in the factor maps (Fig. 18 to Fig. 21). From the maps, it was inferred that the individuals which were lying close to each other had similar profiles when explained in dimension 1 and dimension 2.

Table 21. Eigen values/variances retained by each dimension

Dimensions	Eigen value	Variance percent	Cumulative variance percent
Dimension 1	7.47	43.96	43.96
Dimension 2	2.62	15.41	59.38
Dimension 3	1.72	10.13	69.51
Dimension 4	1.25	7.37	76.88
Dimension 5	1.05	6.18	83.05

Table 22. Coordinates of variables (stem and flower characters)

Characters	Dimension 1	Dimension 2	Dimension 3	Dimension 4	Dimension 5
Length	4.46e-04	1.11e-01	5.80e-04	5.23e-01	2.21e-02
Width	1.54e-03	1.33e-02	5.76e-01	1.39e-01	1.41e-03
DBA	1.30e-01	1.85e-01	1.01e-02	6.16e-02	2.62e-01
AH	4.64e-03	2.75e-02	6.24e-01	1.92e-02	6.02e-02
NSA	4.70e-02	1.62e-03	2.68e-01	1.79e-01	1.36e-01
SSB	6.56e-02	1.02e-01	1.80e-01	2.33e-01	3.80e-02
LS	1.71e-01	3.15e-01	9.81e-04	7.88e-02	4.51e-02
NSL	1.17e-05	4.22e-01	8.39e-05	2.49e-03	2.15e-01
SW	9.82e-01	1.49e-02	1.00e-03	1.64e-04	2.56e-05
SS	9.82e-01	1.49e-02	1.00e-03	1.64e-04	2.56e-05
MR	9.82e-01	1.49e-02	1.00e-03	1.64e-04	2.56e-05
SC	9.82e-01	1.49e-02	1.00e-03	1.64e-04	2.56e-05
BS	9.82e-01	1.49e-02	1.00e-03	1.64e-04	2.56e-05
BAS	9.82e-01	1.49e-02	1.00e-03	1.64e-04	2.56e-05
SCS	1.71e-01	6.03e-01	2.46e-02	6.92e-03	1.28e-01
IOR	9.93e-01	7.51e-01	3.19e-02	8.60e-03	1.43e-01

(DBA - Distance between areoles; AH – Arch height; NSA – Number of spines per areole; SSB – Number of stem segments per branch; LS – Length of style; NSL – Number of stigma lobes; SW – Stem waxiness; SS - Stem sturdiness; MR – Margin of rib; SC – Spine colour; BS – Bud shape; BAS – Bud apex shape; SCS – Sepal colour (secondary); IOR – Intensity of red colour of bract)

4.8.1.2 FAMD for yield and quality attributes

The findings from FAMD with respect to 15 characters of stem and flower are presented in Table 23 and the coordinates of the variables are depicted in Table 24.

Four dimensions explained the variability in yield and quality attributes of the plants wherein maximum variation (62.74%) was explained by dimension 1 and dimension 2 (Fig. 22). The variance shown by dimensions 3 and 4 were negligible when compared to that of dimension 1 and 2. The variables that had significant contribution in dimension 1 were fruit weight, position of bract towards peel, fruit width, fruit weight without peel, fruit length, flesh colour and fruit shape in a decreasing order. Position of bract towards peel, width of base of bract, length of apical bract, outer TSS, TSS-acid ratio, core TSS and flesh colour contributed towards dimension 2, maximum being contributed by position of bract towards peel.

The contribution of the quantitative variables in different dimensions are mentioned in Fig. 23. The variables like fruit weight (FW), fruit length (length), fruit width (width) and fruit weight without peel (FWP) were explained by both the dimensions (1st quadrant) and the set of variables including length of apical bract (LAB), width of base of the bract (WBB), TSS and TSS-acid ratio (SAR) lied in 2nd quadrant revealing their contribution to dimension 1. Number of bracts was explained by dimension 2 (quadrant 4) and length to width ratio of fruit was explained by the dimensions other than 1 and 2 (quadrant 3).

The role of individual qualitative characters in dimension 1 and dimension 2 becomes evident from factor maps (Fig. 26 and Fig. 27). The individual plants that lied adjacent exhibited identical features.

Table 23. Eigen values/variances retained by each dimension

Dimensions	Eigen value	Variance percent	Cumulative variance percent
Dimension 1	5.66	35.40	35.40
Dimension 2	4.37	27.34	62.74
Dimension 3	1.73	10.83	73.57
Dimension 4	1.23	7.70	81.27

Table 24. Coordinates of variables (yield and quality attributes)

Characters	Dimension 1	Dimension 2	Dimension 3	Dimension 4	Dimension 5
FW	0.866	0.043	0.039	0.021	0.000
Length	0.633	0.170	0.060	0.112	0.000
Width	0.678	0.191	0.026	0.074	0.000
LWR	0.181	0.084	0.269	0.123	0.011
NOB	0.356	0.049	0.238	0.151	0.007
LAB	0.028	0.556	0.002	0.071	0.178
WBB	0.000	0.566	0.076	0.028	0.124
FWP	0.652	0.173	0.029	0.083	0.000
TSS.O.	0.065	0.358	0.151	0.003	0.046
TSS.C.	0.291	0.352	0.157	0.046	0.068
SAR	0.291	0.352	0.157	0.046	0.068
POB	0.681	0.745	0.010	0.327	0.067
FS	0.422	0.155	0.198	0.074	0.038
PC	0.008	0.241	0.315	0.011	0.286
FC	0.513	0.339	0.005	0.062	0.002
FW	0.866	0.043	0.039	0.021	0.000

(FW- Fruit weight; LWR- L/W ratio; NOB- Number of bracts; LAB- Length of apical bract; WBB- Width of base of bract; POB- Position of bracts; FWP- Fruit weight without peel, FS-Fruit shape; PC- Peel colour; FC- Flesh colour; TSSO- TSS outer; TSSC- TSS core; SAR- TSS-acid ratio)

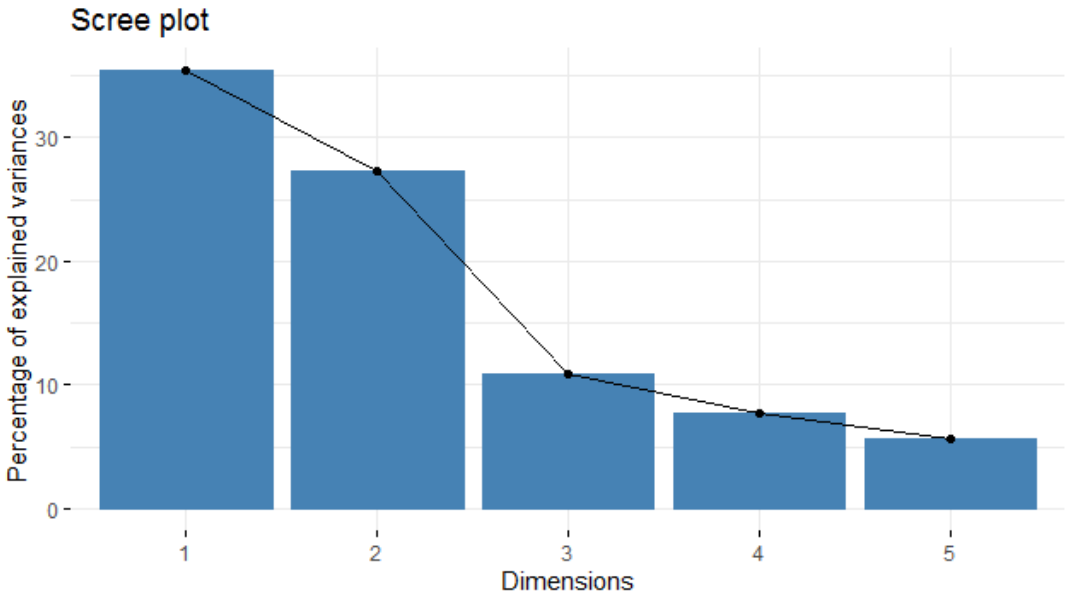


Fig.22. Graph showing the variability explained by each dimension for yield and quality attributes in dragon fruit

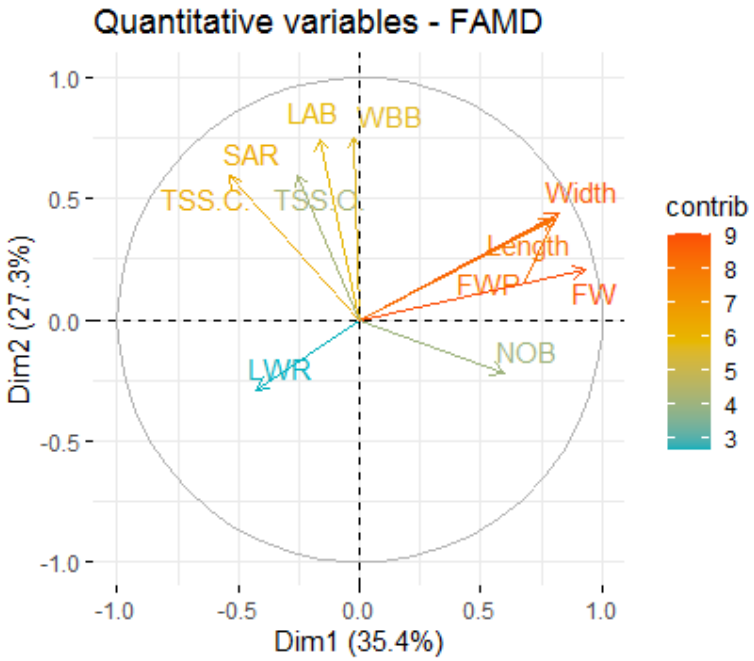


Fig. 23. FAMD of quantitative characters of yield and quality attributes

(FW- Fruit weight; LWR- L/W ratio; NOB- Number of bracts; LAB- Length of apical bract; WBB- Width of base of bract; POB- Position of bracts; FWP- Fruit weight without peel, FS-Fruit shape; PC- Peel colour; FC- Flesh colour; TSSO- TSS outer; TSSC- TSS core; SAR- TSS-acid ratio)

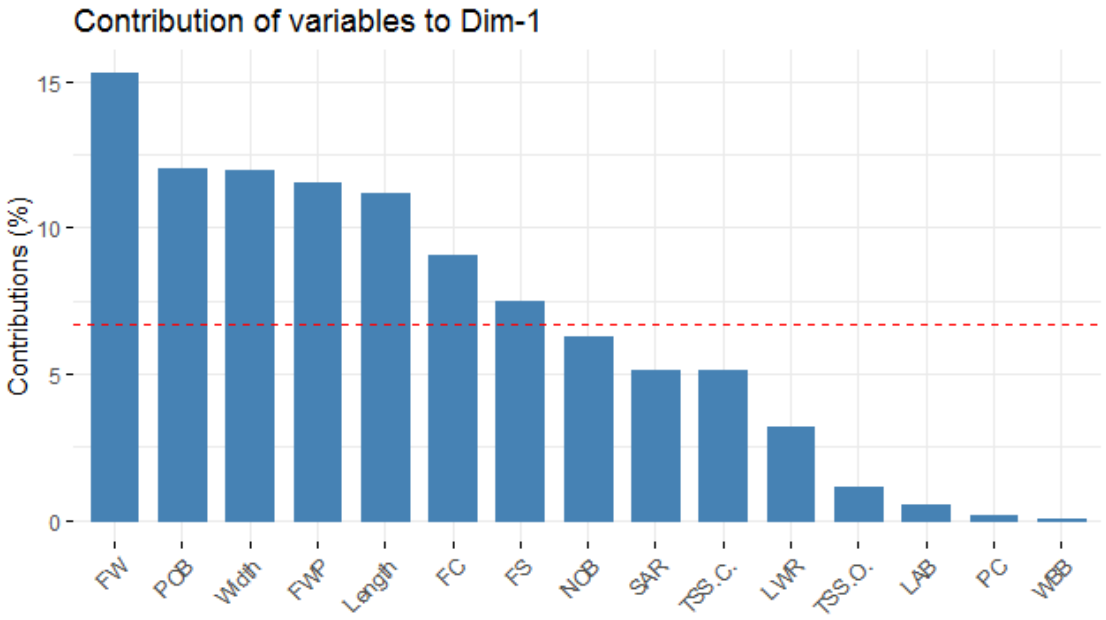


Fig. 24. Contribution of each variable in yield and quality attributes to 1st dimension

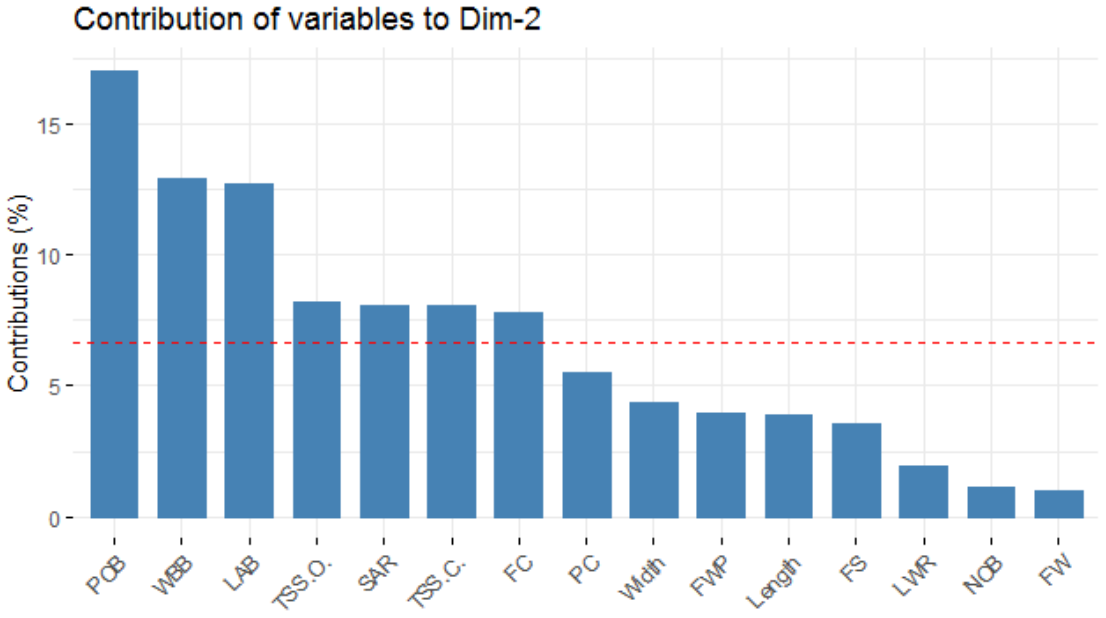


Fig. 25. Contribution of each variable in yield and quality attributes to 2nd dimension

(FW- Fruit weight; LWR- L/W ratio; NOB- Number of bracts; LAB- Length of apical bract; WBB- Width of base of bract; POB- Position of bracts; FWP- Fruit weight without peel, FS-Fruit shape; PC- Peel colour; FC- Flesh colour; TSSO- TSS outer; TSSC- TSS core; SAR- TSS-acid ratio)

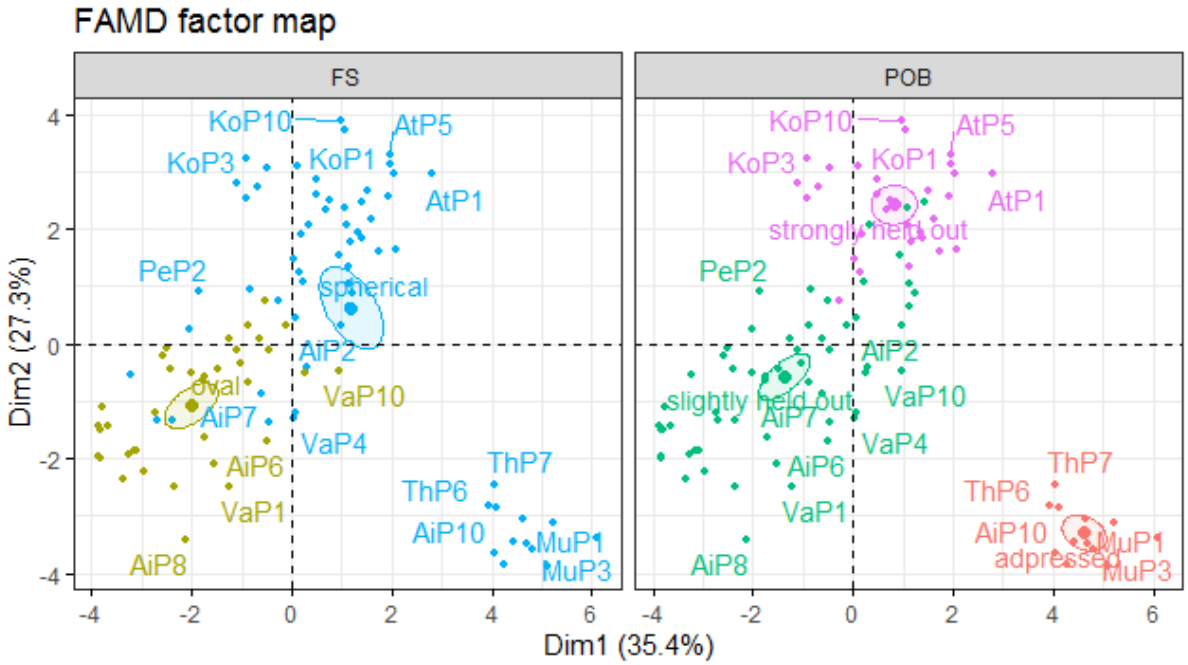


Fig. 26. FAMD factor map of fruit shape and position of bracts

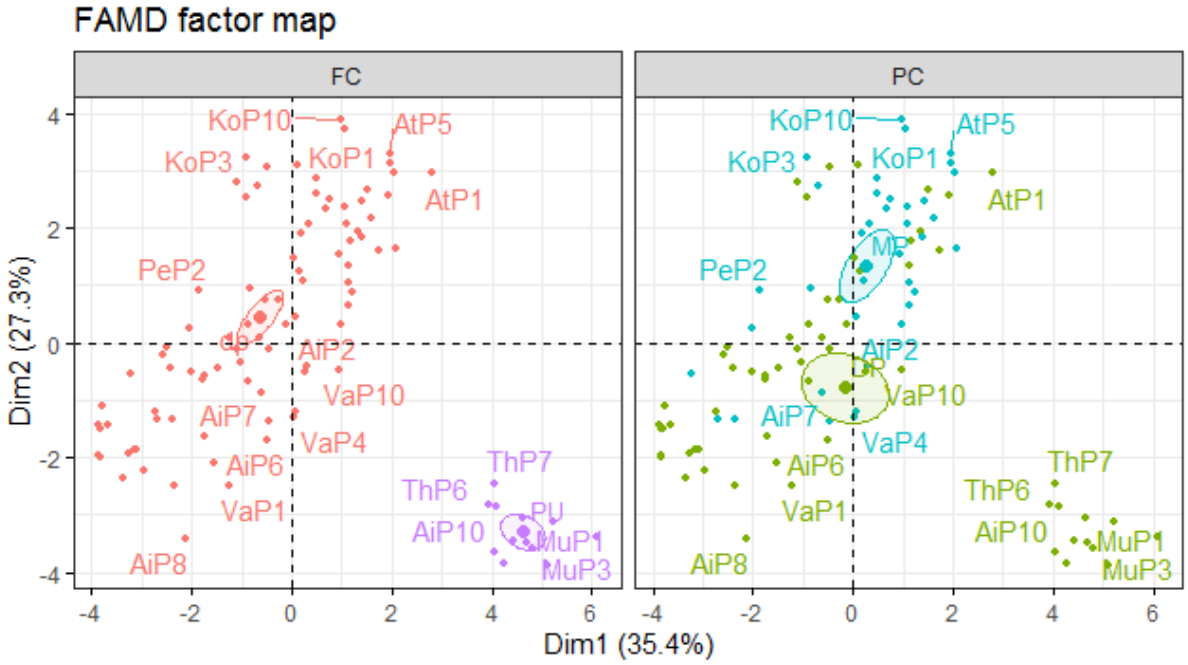


Fig. 27. FAMD factor map of flesh colour and peel colour

[At (P1-P10) from Athikkayam; Th (P1-P10) from Thatta; Ka (P1-P10) from Karette; Ko (P1-P10) from Kozhenchery; Ai (P1-P10) from Aikkad; Mu (P1-P10) from Muvattupuzha; Va (P1- P10) from Vaniyampara; Ke (P1-P10) from Keerukuzhy), Pe (P1-P10) from Perumbavoor; Ad (P1-P10) from Adoor)

4.8.2 Cluster analysis

The qualitative data was clustered with the single linkage method using Jaccard's similarity coefficients. Based on the analysis, similarity matrix was computed and the dendrogram was created. Clustering was also done for mixed data (qualitative and quantitative) using Gower distance and the cluster plots were plotted accordingly. The variables were clustered separately for stem-flower characters and yield-quality attributes. All the analysis were done in R 4.1.0 software.

4.8.2.1 Cluster analysis for qualitative data

The hierarchical cluster analysis of 100 dragon fruit collections for the 12 qualitative characters were carried out. The collections were grouped into six clusters based on 'Jaccard coefficient' and the linkage method used was 'single'. Cluster two had maximum plants (37), followed by cluster six with 16 plants, cluster five had 14 plants, cluster one and four with 12 plants each and the least number of plants were in cluster three (9) as presented in Table 25 and Fig.28. The cluster wise summary with respect to the qualitative characters are shown in Table 26.

Table 25. Hierarchical clusters of 100 dragon fruit collections

Cluster I	ThP6 ThP7 AiP10 MuP1 MuP2 MuP3 VaP8 KeP5 PeP3 PeP4 AdP5 AdP7
Cluster II	ThP1 ThP2 ThP3 ThP4 ThP5 ThP9 AiP3 AiP4 AiP5 AiP6 AiP8 MuP5 MuP8 MuP9 MuP10 VaP1 VaP7 VaP9 VaP10 KeP2 KeP3 KeP6 KeP8 KeP9 KeP10 PeP5 PeP7 PeP8 PeP9 PeP10 AdP1 AdP3 AdP4 AdP6 AdP8 AdP9 AdP10
Cluster III	ThP8 ThP10 AiP1 AiP2 AiP7 AiP9 KeP1 KeP4 KeP7
Cluster IV	MuP4 MuP6 MuP7 VaP2 VaP3 VaP4 VaP5 VaP6 PeP1 PeP2 PeP6 AdP2
Cluster V	AtP1 AtP3 AtP6 AtP8 KaP2 KaP3 KaP4 KaP7 KaP9 KaP10 KoP4 KoP5 KoP6 KoP9
Cluster VI	AtP2 AtP4 AtP5 AtP7 AtP9 AtP10 KaP1 KaP5 KaP6 KaP8 KoP1 KoP2 KoP3 KoP7 KoP8 KoP10

[At (P1-P10) from **Athikkayam; Th (P1-P10)** from **Thatta; Ka (P1-P10)** from **Karette; Ko (P1-P10)** from **Kozhenchery; Ai (P1-P10)** from **Aikkad; Mu (P1-P10)** from **Muvattupuzha; Va (P1- P10)** from **Vaniyampara; Ke (P1-P10)** from **Keerukuzhy), Pe (P1-P10)** from **Perumbavoor; Ad (P1-P10)** from **Adoor)]**

Table 26. Cluster wise summary of qualitative characters

Characters	Cluster I	Cluster II	Cluster III	Cluster IV	Cluster V	Cluster VI
Stem waxiness	Weak	Strong	Strong	Strong	Strong	Strong
Stem sturdiness	High	Low	Low	Low	Low	Low
Margin of rib	Flat	Convex	Convex	Convex	Convex	Convex
Spine colour	Dark brown	Medium brown	Medium brown	Medium brown	Medium brown	Medium brown
Bud shape	Elliptic	Ovate	Ovate	Ovate	Ovate	Ovate
Bud apex shape	Rounded	Acute	Acute	Acute	Acute	Acute
Sepal secondary colour	Red edged	Red edged	Red edged	Slightly red edged	Slightly red edged	Slightly red edged
Intensity of red colour of bract	Strong	Medium	Medium	Weak	Weak	Weak
Position of bract towards peel	Adpressed	Slightly held out	Slightly held out	Slightly held out	Strongly held out	Strongly held out
Fruit shape	Spherical	Oval	Spherical	Spherical	Spherical	Spherical
Peel colour	Dark pink	Dark pink	Medium pink	Medium pink	Dark pink	Medium pink
Flesh colour	Purple	Dark pink	Dark pink	Dark pink	Dark pink	Dark pink

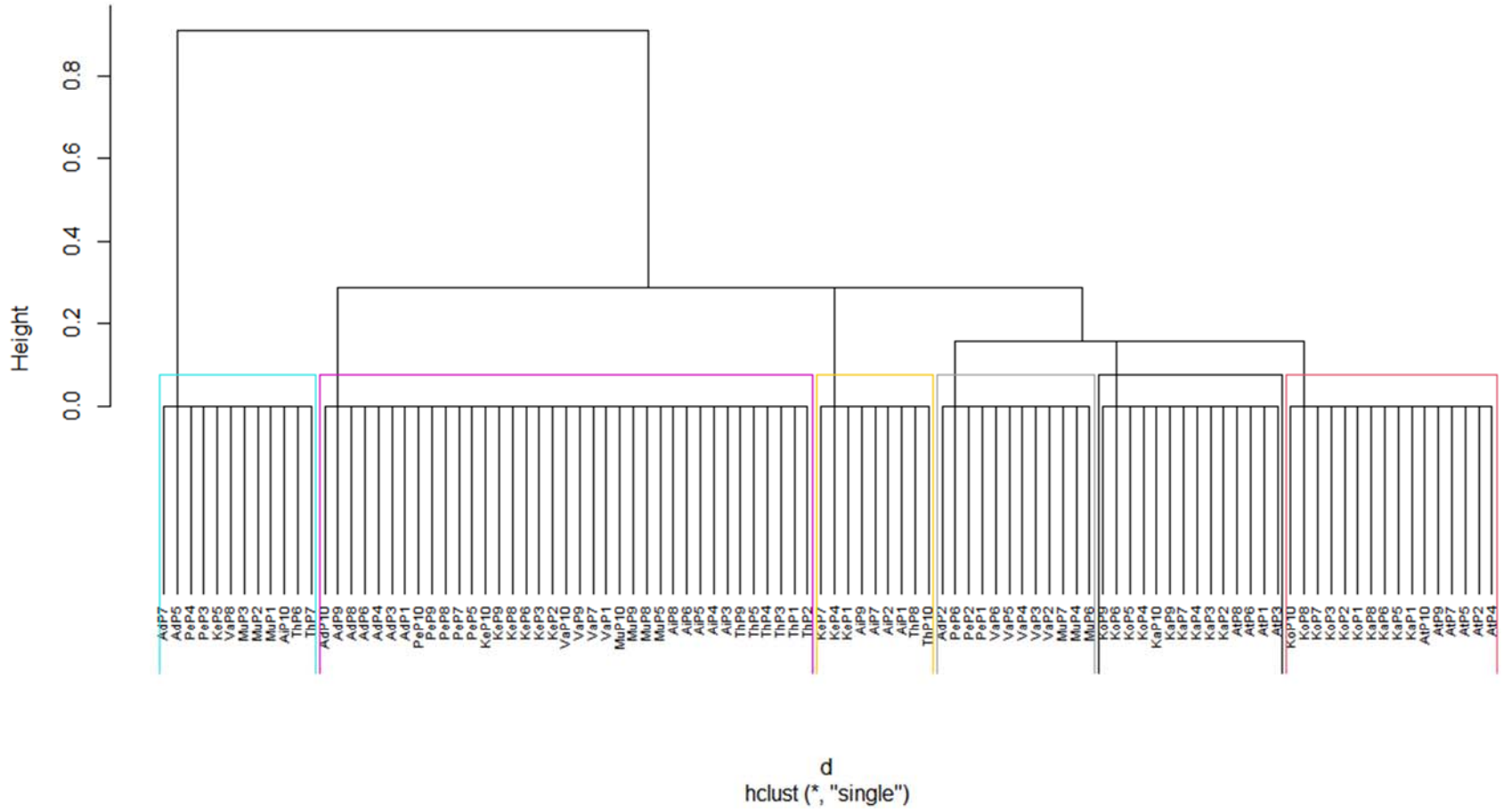


Fig. 28. Dendrogram on the basis of qualitative characters of dragon fruit

Cluster I alone had weak waxy stem, highly sturdy nature, flat margin of ribs, dark brown spines, elliptic flower bud with round apex, strong and intense red colour of flower bract, adpressed bracts and purple skin. Thus, Cluster I was highly distinguishable from other clusters. Cluster II and III varied only in the fruit shape and peel colour. Cluster II had oval shape and dark pink peel whereas Cluster III had spherical fruits with medium pink peel. Cluster III and IV were alike except in the secondary colour of sepal and intensity of red colour of bract. Cluster III had red edged sepal and medium intense red colour on bract whereas in Cluster IV, there was slightly red edged sepal and also the intensity of red colour on bract was weak. Cluster IV and V differed from each other in position of bracts towards the peel and the peel colour. Cluster IV possessed fruits with slightly held out bracts and medium pink peel. Cluster V fruits were with strongly held out bracts and dark pink peel. Cluster VI deviated from Cluster V only due to the medium pink peel of fruits in Cluster VI.

4.8.2.2 Cluster analysis of mixed data

Variables were considered as two different groups and clustering was done separately for the two groups using Gower distance. The first group contained stem and flower traits. The yield and quality attributes were confined in the second group. Partitioning around medoids (PAM) algorithm was followed and the number of clusters were based on the silhoutte width, which is an aggregate measure to see how an observation was analogous to its own cluster when compared to the adjacent cluster.

4.8.2.2.1 Clustering mixed data of stem and flower characters

When the mixed data was clustered for stem and flower characters, three clusters were formed based on the silhouette width (Fig. 29). Visualisation of the clustering of mixed data regarding stem and flower characters (Fig. 30) showed three well-separated clusters with the individuals listed under each cluster which facilitated in assessing the analogy of an observation with its own cluster when compared to neighbouring clusters. The clusters are enlisted in Table 25. The most similar pair of plants were AtP1 and KoP2 and the most dissimilar pair was found to be PeP4 and KaP8 (Table 28).

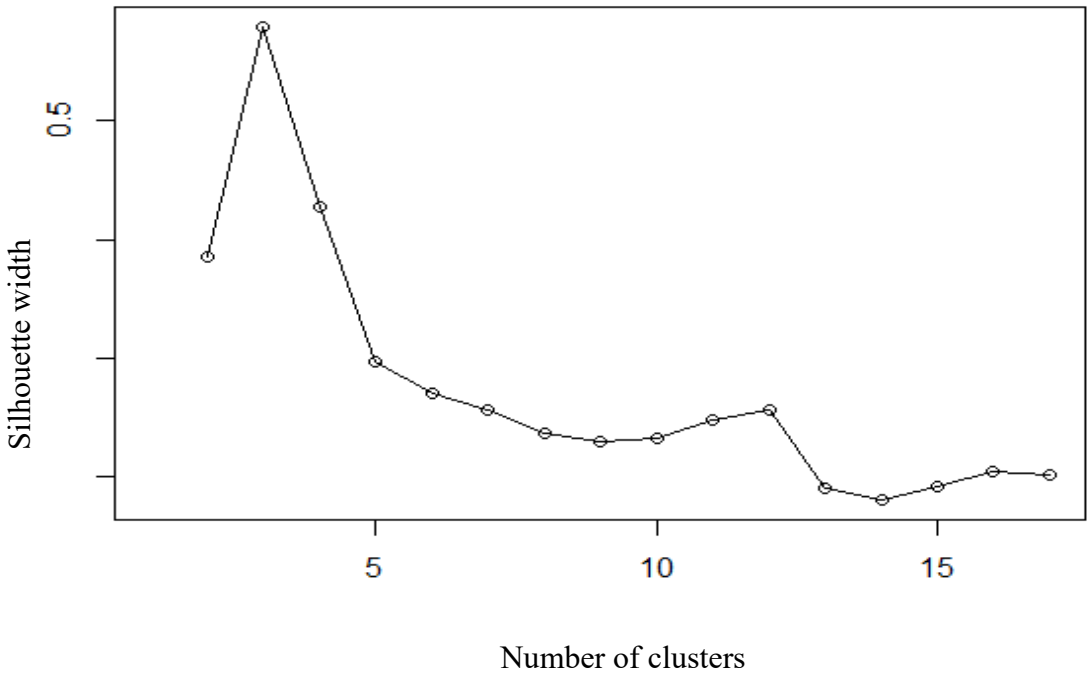


Fig. 29. Silhouette-width plot determining the optimum number of clusters for mixed data of stem and flower characters

Table 27. Clusters formed based on the mixed data from stem and flower characters

Cluster I	AtP1 AtP2 AtP3 AtP4 AtP5 AtP6 AtP7 AtP8 AtP9 AtP10 KaP1 KaP2 KaP3 KaP4 KaP5 KaP6 KaP7 KaP8 KaP9 KaP10 KoP1 KoP2 KoP3 KoP4 KoP5 KoP6 KoP7 KoP8 KoP9 KoP10 MuP4 MuP6 MuP7 VaP2 VaP3 VaP4 VaP5 VaP6 PeP1 PeP2 PeP6 AdP2
Cluster II	ThP1 ThP2 ThP3 ThP4 ThP5 ThP6 ThP7 ThP8 ThP9 ThP10 AiP1 AiP2 AiP3 AiP4 AiP5 AiP6 AiP7 AiP8 AiP9 MuP5 MuP8 MuP9 MuP10 VaP1 VaP7 VaP9 VaP10 KeP1 KeP2 KeP3 KeP4 KeP5 KeP6 KeP7 KeP8 KeP9 KeP10 PeP5 PeP7 PeP8 PeP9 PeP10 AdP1 AdP3 AdP4 AdP6 AdP8 AdP9 AdP10
Cluster III	AiP10 MuP1 MuP2 MuP3 VaP8 PeP3 PeP4 AdP5 AdP7

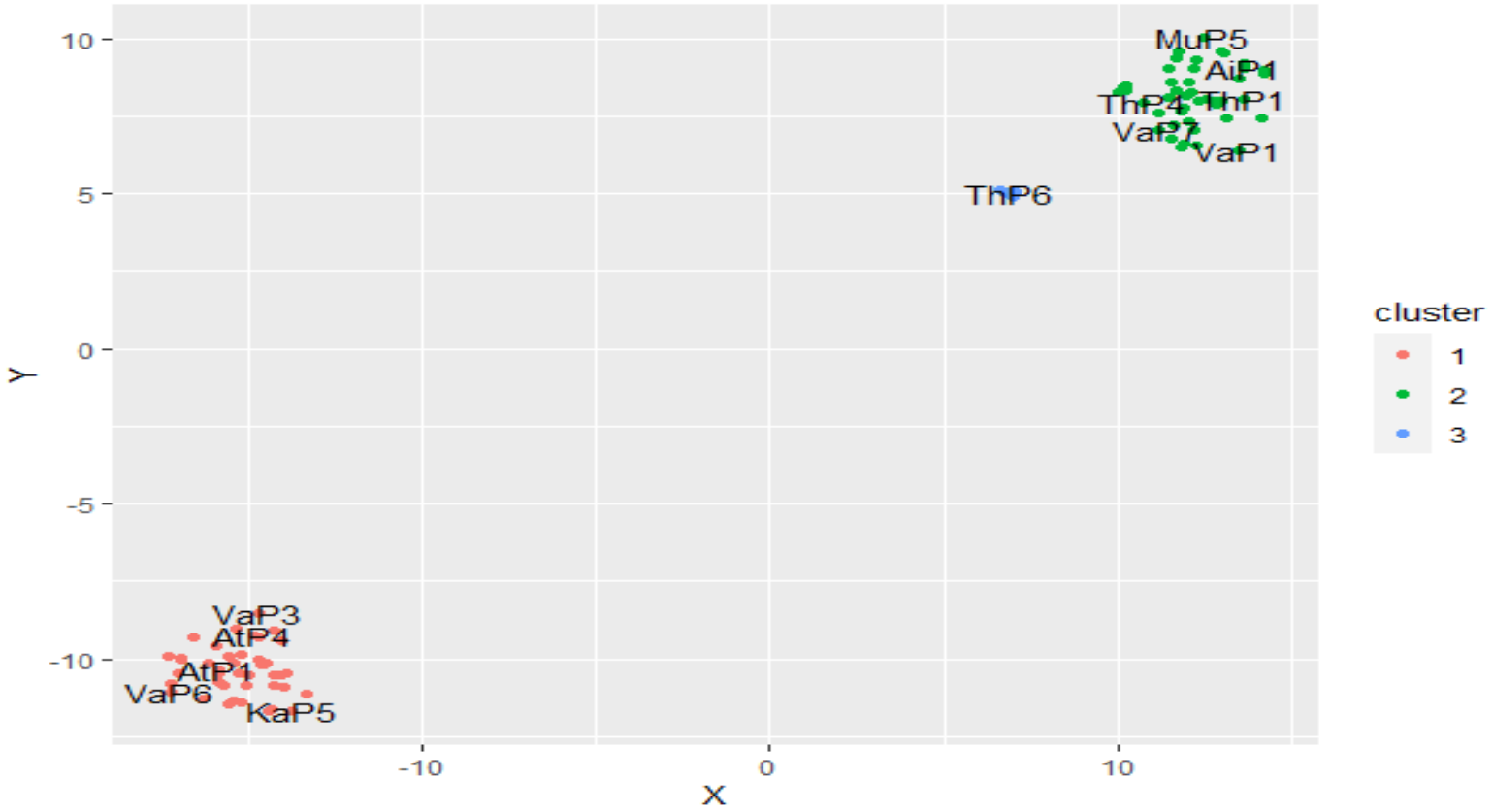


Fig. 30. Cluster plot with mixed data for stem and flower traits

Table 28. Most similar and dissimilar pairs of plants with respect to stem and flower characters

Characters	Most similar pairs		Most dissimilar pairs	
	AtP1	KoP2	KaP8	PeP4
Length	130.00	123.00	200.00	113.00
Width	3.10	3.00	6.30	2.90
DBA	4.00	4.30	4.00	3.00
AH	1.20	1.20	4.20	1.60
NSA	4.00	4.00	4.00	4.00
SSB	3.00	3.00	5.00	1.00
LS	28.00	28.00	29.50	26.20
NSL	30.00	29.00	29.00	32.00
SW	Strong	Strong	Strong	Weak
SS	Low	Low	Low	High
MR	Convex	Convex	Convex	Flat
SC	Medium brown	Medium brown	Medium brown	Dark brown
BS	Ovate	Ovate	Elliptic	Ovate
BAS	Acute	Acute	Acute	Rounded
SCS	Slightly red edged	Slightly red edged	Slightly red edged	Red edged
IOR	Weak	Weak	Weak	Strong

(DBA - Distance between areoles; AH – Arch height; NSA – Number of spines per areole; SSB – Number of stem segments per branch; LS – Length of style; NSL – Number of stigma lobes; SW – Stem waxiness; SS - Stem sturdiness; MR – Margin of rib; SC – Spine colour; BS – Bud shape; BAS – Bud apex shape; SCS – Sepal colour (secondary); IOR – intensity of red colour of bract)

4.8.2.2.1 Clustering mixed data of yield characters and quality attributes

Clustering of mixed data for yield and quality attributes gave four clusters according to the silhouette width (Fig. 31). Cluster plot (Fig. 32) clearly distinguished four clusters which are represented in Table 29. PeP3 and AdP7 were the most similar pair whereas MuP1 and MuP10 were most dissimilar (Table 30).

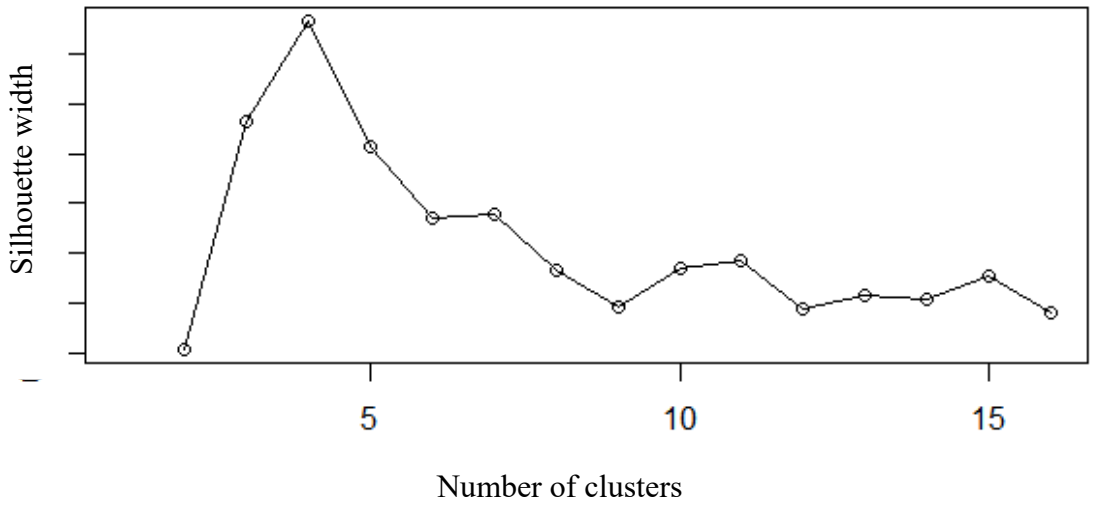


Fig. 31. Silhouette-width plot determining the optimum number of clusters for mixed data of yield and quality characters

Table 29. Clusters formed based on the mixed data from yield and quality attributes

Cluster I	AtP1 AtP2 AtP3 AtP4 AtP5 AtP6 AtP7 AtP8 AtP9 AtP10 KaP1 KaP2 KaP3 KaP4 KaP5 KaP6 KaP7 KaP8 KaP9 KaP10 KoP1 KoP2 KoP3 KoP4 KoP5 KoP6 KoP7 KoP8 KoP9 KoP10 MuP6 MuP7 PeP1
Cluster II	ThP1 ThP2 ThP3 ThP4 ThP5 ThP6 ThP7 ThP8 ThP9 AiP3 AiP4 AiP5 AiP6 AiP7 AiP8 AiP9 MuP5 MuP8 MuP9 MuP10 VaP1 VaP7 VaP9 VaP10 KeP2 KeP3 KeP5 KeP6 KeP8 KeP9 KeP10 PeP5 PeP7 PeP8 PeP9 PeP10 AdP1 AdP3 AdP4 AdP6 AdP8 AdP9 AdP10
Cluster III	AiP10 MuP1 MuP2 MuP3 VaP8 PeP3 PeP4 AdP5 AdP7
Cluster IV	ThP10 AiP1 AiP2 MuP4 VaP2 VaP3 VaP4 VaP5 VaP6 KeP1 KeP4 KeP7 PeP2 PeP6 AdP2

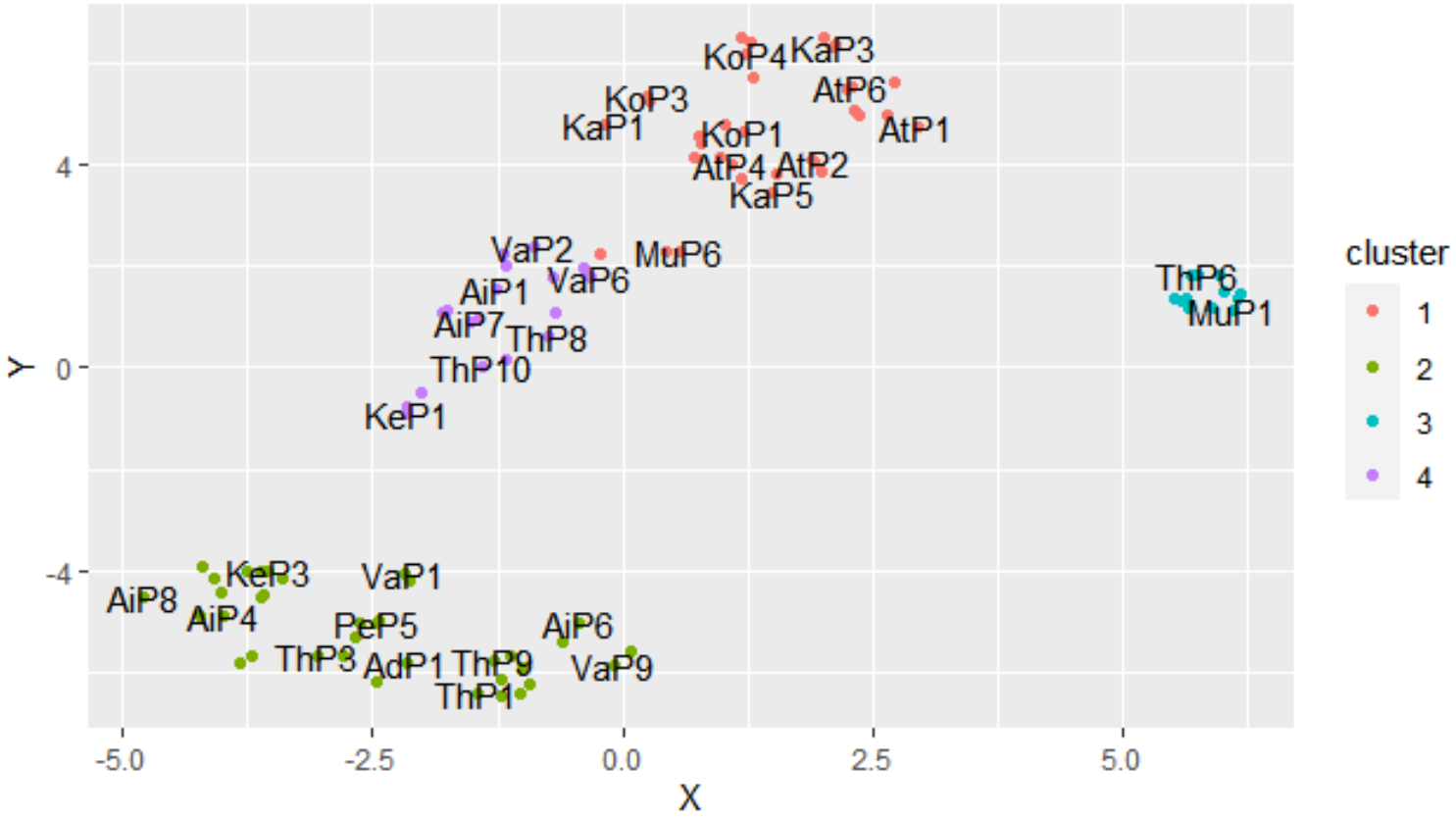


Fig. 32. Cluster plot with mixed data for yield and quality attributes

Table 30. Most similar and dissimilar pairs of plants with respect to yield and quality attributes

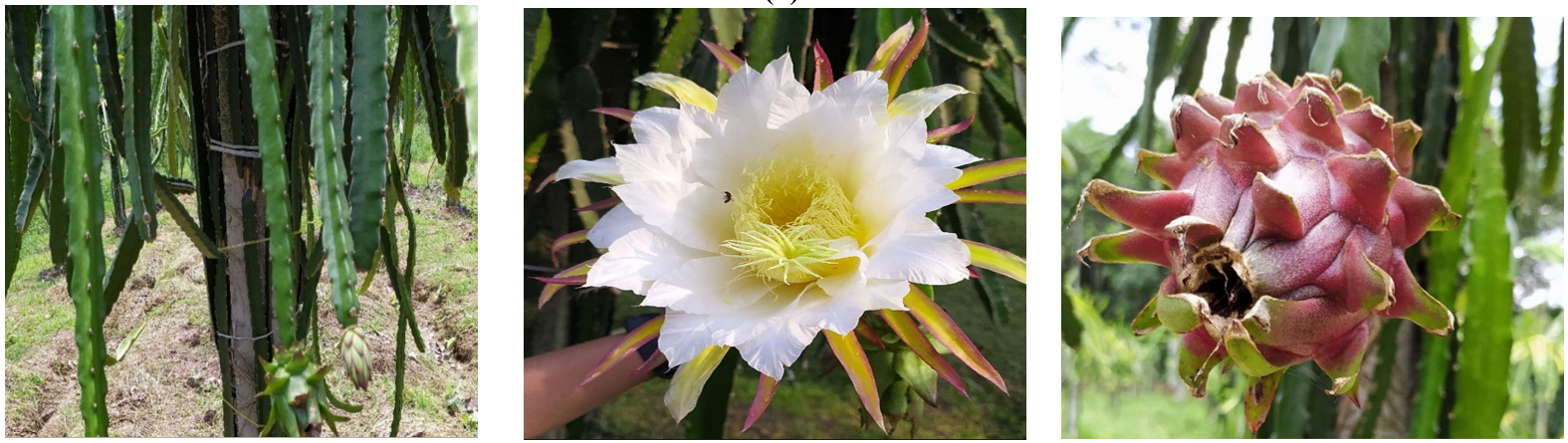
Characters	Most similar pairs		Most dissimilar pairs	
	PeP3	AdP7	MuP1	MuP10
FW	512.00	594.00	896.00	134.00
Length	8.90	8.90	9.80	5.50
Width	8.90	8.90	9.80	5.20
LWR	1.00	1.00	1.00	1.06
NOB	38.00	41.00	46.00	23.00
LAB	4.00	4.00	3.40	4.50
WBB	2.30	2.20	2.20	3.00
FWP	382.00	373.00	411.00	65.00
TSS.O.	7.00	7.00	7.00	12.00
TSS.C.	11.00	11.00	11.00	16.00
SAR	91.67	91.67	91.67	133.33
POB	Adpressed	Adpressed	Adpressed	Slightly held out
FS	Spherical	Spherical	Spherical	Oval
PC	Dark pink	Dark pink	Dark pink	Dark pink
FC	Purple	Purple	Purple	Dark pink

(FW- Fruit weight; LWR- L/W ratio; NOB- Number of bracts; LAB- Length of apical bract; WBB- Width of base of bract; POB- Position of bracts; FWP- Fruit weight without peel, FS-Fruit shape; PC- Peel colour; FC- Flesh colour; TSSO- TSS outer; TSSC- TSS core; SAR- TSS-acid ratio)

[At (P1-P10) from **Athikkayam; Th (P1-P10)** from **Thatta; Ka (P1-P10)** from **Karette; Ko (P1-P10)** from **Kozhenchery; Ai (P1-P10)** from **Aikkad; Mu (P1-P10)** from **Muvattupuzha; Va (P1- P10)** from **Vaniyampara; Ke (P1-P10)** from **Keerukuzhy), Pe (P1-P10)** from **Perumbavoor; Ad (P1-P10)** from **Adoor)]**

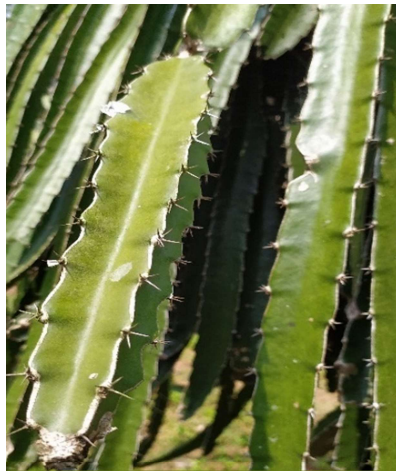
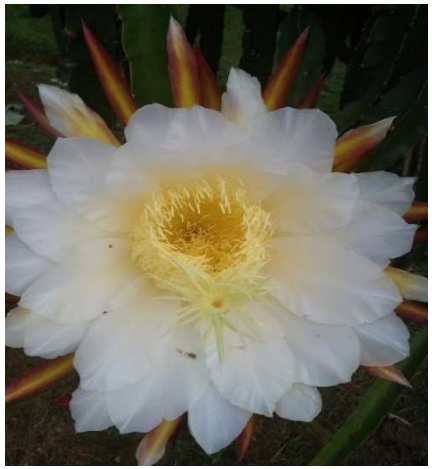
From the factor analysis and cluster analysis of qualitative and mixed data it was observed that the plants AtP1-P10, KaP1-P10 and KoP1-P10 were having close relation with each other which could probably be attributed to their common source of planting material (Malaysian). Hence, all the plants from this source of planting material formed a genotype. The rest of the plants showed variations among them even though the source of planting material was same (Cambodian), indicating more than one genotype from the same source. The plants AiP10, MuP1, MuP2, MuP3, VaP8, PeP3, PeP4, AdP5 and AdP7 were the most visually distinguishable from all the other plants under study with respect to their qualitative traits. Based on the qualitative traits, there were 6 clusters and through the clustering of mixed data, there were 3 clusters for stem and flower characters and 4 clusters for yield and qualitative characters. These results depicted the variations in the plants under study revealing the presence of different genotypes within the pink/purple fleshed dragon fruit (Plate 15A and 15B).

(a)

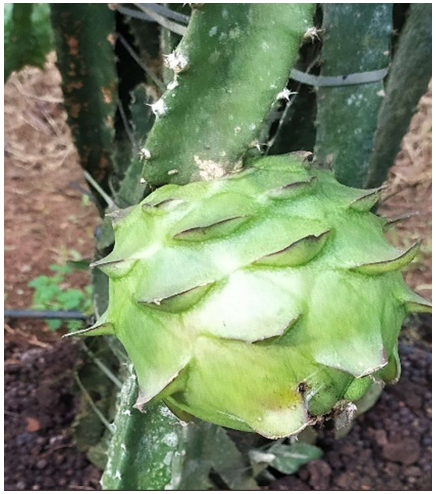
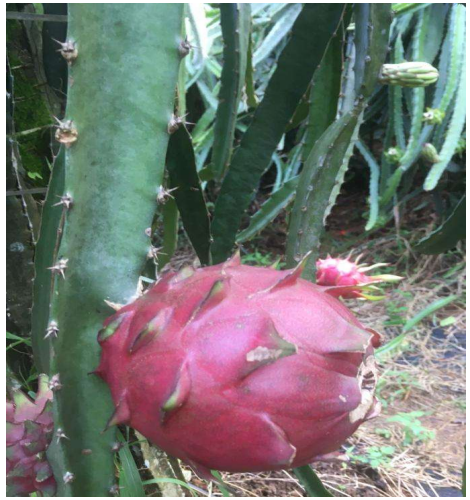


(b)

Plate 15A (a) and (b): Stem, flower and fruit characters of two different genotypes observed


(c)

(d)

Plate 15B (c) and (d): Stem, flower and fruit characters of two different genotypes observed

4.9 Species other than the pink/purple fleshed dragon fruit

Even though the pink or purple fleshed types (*H. costaricensis*) had the mainstay in commercial cultivation of dragon fruit in Kerala, farmers cultivated other types of dragon fruit in households and for ornamental purposes. These included mainly the yellow skinned dragon fruit with white flesh (*H. megalanthus*) (Plate 17) and pink skinned dragon fruit with white flesh (*H. undatus*) (Plate 16). The yellow skinned dragon fruits were further known to be of several types including the Columbian and Israel types. Various other exotic dragon fruits were found to be introduced from countries like Thailand and Vietnam which are getting popular now in different parts of Kerala. These types included the ones with pink flower and fruits with light green coloured peel and white flesh (referred to as Bruni by farmers), fruits with orange coloured peel and whitish pink flesh (referred to as Frankis Red by farmers) (Plate 18). The colour of seeds in all the above-mentioned species were black, however the size of seeds and seed density varied.

The yellow skinned type took nearly three months from flowering to harvest whereas the pink skin with white fleshed types performed almost similar to that of the commercially cultivated type in phenological aspects. The major identification criteria for plants of *H. undatus*, *H.costaricensis* and *H. megalanthus* were the appearance of the cladodes. The margin of rib in *H. megalanthus* were exactly concave, whereas it was clear convex in *H. undatus* and slightly convex to flat in *H. costaricensis*.

Plant with fruits

Flesh

Plate 16. ***Hylocereus undatus***

Stem with immature fruit

Flower

Ripe fruit

Flesh

Plate 17. ***Hylocereus megalanthus***

Flower

Fruit

Flesh

(a)

Flower about to open

Fruit and flesh

(b)

Plate 18 (a) and (b): Other species observed

DISCUSSION

5. DISCUSSION

Dragon fruit (*Hylocereus* spp.) is an exotic fruit crop, the cultivation of which is getting popular in India as well as in Kerala. Though the cultivation of this crop has now spread to a greater extent in our state, no scientific study has been taken up so far in KAU in this crop regarding its morphology, flowering, cultivation aspects and so on. So, it is under this circumstance, the present work was taken up with the aim of studying the morphology, flowering, yield and quality attributes of dragon fruit (*Hylocereus* spp.) genotypes grown in Kerala. This study will also help to throw some light on its cost of cultivation and economics. The information gathered from the study are discussed in a comprehensive manner in this chapter.

The two species of dragon fruit namely *H. costaricensis* and *H. polyrhizus* which are dark pink and purple fleshed respectively, are dominating the commercial cultivation of dragon fruit in Kerala. A lot of variations could be observed among the plants belonging to these species. This variability observed among the species of *Hylocereus* can be attributed due to cross pollination, resulting in inter and intra-specific hybridization (Tel-zur *et al*., 2004). A number of genotypes are present within this genus creating wide variability among the species of *Hylocereus* (Tel-zur *et al*., 2011). Similarly, Betancur *et al*., (2020) reported that in *H. undatus* high variability was observed within the species with respect to cladode, flower and fruit characters of certain accessions.

5.1 Stem characters

When the stem characters were studied, the qualitative characters like stem waxiness, stem sturdiness, margin of rib and spine colour contributed to maximum variability within the species. The plants which were sturdy in appearance possessed cladodes with weak stem waxiness and flat margin of ribs, whereas those with waxy stems exhibited lower sturdiness with convex to slightly flat margins. The number of spines per areole were found to be in the range of 3 to 5 in all the plants studied. These observations were in accordance with the report of Abirami *et al*., (2021). According to them, the stem characters such as number of spines (3-5), margin of ribs of cladode

(convex in *H. costaricensis*) and stem waxiness (weak or strong) could be effectively utilised for the identification of different *Hylocereus* spp.

The spine varied in colour from medium to dark brown. The spine colour was also seen to change to grey colour with ageing of plants. The distance between areoles and arch height (when measured from the middle part of the cladode) also varied and were in the range of 2.0 cm to 5.5 cm and 1.0 cm to 4.2 cm respectively within the species. Abirami *et al*., (2021) also reported a similar value for the distance between areoles (3.4 cm-4.0 cm).

The other quantitative characters like stem segment length (33-210 cm), stem segment width (1.80-6.60 cm), number of branches (many) and number of stem segments per branch (1-6) didn't differ much among the genotypes observed. This could be attributed to a common lineage as stated by Chatarsingh in 2021. He opined that though the different dragon fruit genotypes showed significant variations, they all shared a common lineage.

In all the locations surveyed, the plants were supported on concrete poles on top of which concrete rings or used tyres were placed to train the plants. As the plant grew up, the stems were tied on to the support (concrete pole) with the help of plastic or jute threads and the pole height ranged from 5 to 6.5 feet above the ground. Warusawitharana *et al*., (2017) reported that the same training practice was being followed in Sri Lanka, where concrete poles and fixed frames were used for supporting the plants.

5.2 Flower characters

The qualitative characters of flower within the species showed wide variation. When the dark pink/purple fleshed species were observed for the bud shape and bud apex shape, plants belonging to all the other clusters except Cluster I had ovate buds with acute apex (88% plants) whereas Cluster I had elliptic buds with rounded apex (12% plants). The main colour of sepal and petal colour in all the plants were same *i.e.* green and white respectively. The secondary colour pattern of sepals differed within the species. Cluster I, II and III had red edged sepals and Cluster IV, V and VI had slightly

edged sepal in which the red colour persisted at the apex of sepals. Intensity of red colour of bract was strong in Cluster I, medium in Cluster II and III and weak in Cluster IV, V and VI. Similar observations on bud shape, shape of bud apex, petal and sepal colour and pattern of secondary colour were reported by Abirami *et al*., (2021) for *H. costaricensis*.

The quantitative characters like length of style was recorded as 23.5 cm to 31.0 cm and the number of stigma lobes as 26 to 36. Stamen and stigma were cream in colour. The stigma was single and was held above the level of stamens and stamens were arranged in groups in all the flowers of all the plants under study. The position of stigma was in accordance to Weiss *et al*., (1994) who reported that the stigma was held 2 cm above the level of anthers in *H. undatus*.

The pollination of dragon fruit flowers was aided by honey bees in all the locations under study. But Valiente- Banuet *et al*. (2007), in their study reported that insects and birds are the pollinating agents in dragon fruit. Almeida *et al*., (2013) described the structure of floral organs in dragon fruit and observed that the ovary was inferior with nectarial tissues secreting nectar attracting pollinating agents. They also reported that the stigma was single and branched while stamen was arranged as a group, which was in consonance with the observations recorded under the study.

5.3 Phenological parameters

The plants in all the locations came to bearing within two years of planting of the cuttings, which was in accordance with the work of Perween *et al*. (2018) who observed that dragon fruit started yielding within 14-16 months of planting the stem cuttings.

Flowering in dragon fruit commenced from March-April and continued till September-October in the four districts under study. Similar results were reported in Sri Lanka by Gunasena *et al*., (2007), wherein flowering started in April and extended up to November, and also in Taiwan, Tran and Yen, (2014), reported that the fruiting season started in May and extended till first week of September.

The duration from flower bud initiation to anthesis was two weeks in general and the anthesis took place during the night time after 10 p.m. If the pollination was successful, fruit could be visible after 5 to 7 days of anthesis and the harvest was possible in 23-25 days from fruit set *i.e.,* one month after anthesis. However, heavy rain and cloudy weather delayed the fruit set. Fruiting started from April-May and the season prevailed till October to November. Tripathi *et al*., (2014) reported that heavy rain resulted in flower and bud drop in dragon fruit. The duration from bud initiation to flower opening according to Tran and Yen (2014) was about 15-19 days and it took 30-32 days for the complete maturation of fruits after anthesis. Fruits of *Hylocereus* accessions from Mexico recorded 27-120 days for attaining maturity (Ramirez,1999).

Jiang *et al*. (2012) observed the long-day nature of dragon fruit and stated that the flower bud formation depended on the duration of light hours. Kishore (2016) observed that the flowering in dragon fruit relied upon the availability of favourable weather conditions like longer days (more than 13 hours), humidity (above 80%), moderate annual rainfall (100-150 cm) and temperature (around 28°C).

Yah *et al*. (2008) reported that 25-31 days were required for fruit maturation from anthesis in dragon fruit. Tel-zur *et al*. (2011) stated that *Hylocereus* spp. except *H. megalanthus* took only 28-41 DAA to mature into a fully ripe fruit when the experiment was done in Israel.

5.4 Yield characters

The fruit weight recorded were in the range of 84g to 896g and was found to be in accordance with the fruit weight (140g to 945 g) obtained in Sri Lanka by Warusawitharana *et al*., (2017). Similar results were also obtained by Ramirez (1999) in Mexican *Hylocereus* accessions as they recorded fruit weight varying from 100g to 1200g.

Maximum value for both fruit length and width obtained in the study was 10.40 cm, similar to the findings of Warusawitharana *et al*., (2017) where they recorded fruit length and width in the range of 11.30 cm-14.20 cm and 8.20 cm-9.50 cm respectively.

Based on the length to width ratio of fruits, the fruits were classified into moderately elongated or medium in appearance and the number of scales/bracts on the peel was recorded to be in the range of 18-50 which were both in confirmation with the observations for *H. costaricensis* (moderately rounded or medium elongated with 27-33 bracts on peel) by Abirami *et al*., (2021).

The width of the base of bracts varied from 1.40 cm to 5.70 cm. The Orejona dragon fruit with red flesh and skin, recorded 27 bracts per fruit and the width of the base of bracts were 2.40 ± 0.50 cm (Tran and Yen, 2014).

The position of bract towards the peel showed three different arrangements namely, adpressed, slightly held out and strongly held out from the peel. The colour of the peel was observed to be dark pink or medium pink and flesh colour was either dark pink or purple. These results were in agreement with the findings of Abirami *et al*., (2021) for *H. costaricensis*.

The yield obtained from a single post per year varied from 5 kg to 20 kg in various locations under study depending upon the age of the plants. Tel-zur *et al*., (2011) stated that a yield of 15.4 kg and 14.8 kg were obtained from a post per year in *H. undatus* and *H. monocanthus* respectively.

5.5 Quality attributes

The fruits were found to have a higher TSS in flesh at the core than the flesh closer to peel. The TSS values obtained were in the range of 11°Brix to 18°Brix. Martinez Chavez (2011) obtained similar results from six Mexican genotypes in which the TSS varied from 14.5-17.6° Brix. Meija *et al*. (2013) also reported a TSS of 18°Brix in a group of wild species of *Hylocereus* and Abirami *et al*. (2021) also observed a TSS of 15.9°Brix for *H. costaricensis*.

Very low titrable acidity value (0.12%) was recorded for all the plants under study which was matching with the findings of Abirami *et al*., (2021) and Chatarsingh (2021) who reported the titrable acidity values ranging from 0.16-0.39% for different pitaya genotypes grown at various locations in India.

The TSS:acidity ratio was found to be very high in pitaya attributing to the low values of titrable acidity. The ratio obtained was between 91.67 and 150.00 with an average value of 126.42. Similar observation of high Brix-acid ratio in dragon fruit was reported by Yah *et al*., (2008).

5.6 Economic data

The major expense in dragon fruit cultivation was for the cost of planting material (₹11,37,333 per ha) when four stem cuttings were planted per post and for the supporting structures (₹11,15,250 per ha). This initial expense was similar to that cited by Mizrahi *et al*., (1997) in Israel (for erecting trellises for training the plants).

Nutrient management adopted by the farmers included organic fertilizer application and also integrated use of chemical fertilizers along with organic fertilizers. According to Kishore (2016), the best way to ensure quality of fruits is the use of composted cow dung and chemical fertilizers like urea, triple super phosphate and MOP as source of nutrients. Verma *et al*. (2019) reported that the incorporation of organic, inorganic and bio-fertilizers gave the best results with respect to the vegetative growth.

The average yield per ha was estimated to be 21 tonnes when 4 plants were planted per post. The yield relied upon the age of the orchards. Similar results were obtained for Tel-zur *et al*., (2011), as they got an yield above 2 tonnes per year from a two-year-old orchard when only one plant was planted per post and it reached more than 9 tonnes and 12 tonnes per year when the plants became three and four years old respectively.

The major constraint in dragon fruit cultivation as expressed by majority of the farmers in the four districts of Kerala were the bud and flower drop due to excess rainfall. Tripathi *et al*., (2014) stated the problem of flower and fruit drop was due to heavy rain. Raveh *et al*., (1998) stated that flower production observed in *H. polyrhizus* under 30% shade was more than double of which was seen when grown under 60% shade. Hernandez and Salazar (2012) reported that excessive downpour during the flowering season led to flower rot.

5.7 Pests and diseases

The incidence of pests and diseases was observed to be comparatively less during the study. Tripathi *et al*., (2014) reported that the disease and pest incidence in dragon fruit was low as it was a recent introduction to commercially cultivated fruit crops in India. Symptoms of canker was observed in one of the orchards. Hoa *et al*., (2016) reported diseases like fruit rot, yellow cladode and stem canker in dragon fruit.

Ants were the major pest in dragon fruit and rarely beetles and bugs. Barbeau (1990) reported the attack of dragon fruit by ants belonging to genera *Atta*. Other pests included beetles and bugs. The best example of beetle attack was that of *Cotinus mutabilis* which perforated the stem. Birds and rats were also reported as important pests which spoiled the fruits.

5.8 Statistical analysis

5.8.1 Factor analysis

Factor analysis was used to study the variability contributed by the traits in the dark pink/purple fleshed dragon fruit (*Hylocereus costaricensis*). Stem and flower characters were considered together for the analysis and based on the eigen values greater than 1, there were 5 dimensions out of which the first 2 dimensions together explained maximum variance (59.38%). The contributing variables were intensity of red colour of bract, stem waxiness, stem sturdiness, margin of rib, spine colour, bud shape, bud apex shape, secondary colour of sepal, number of stigma lobes, length of style and distance between areoles. Likewise, 4 dimensions resulted when yield and quality attributes were considered and among the four dimensions, first two dimensions explained maximum variance (62.74%). The significant variables were fruit weight, position of bract towards peel, fruit width, fruit weight without peel, fruit length, flesh colour, fruit shape, width of the base of the bract, length of apical bract, outer TSS, core TSS and TSS-acid ratio.

5.8.2 Cluster analysis

Clustering was done for qualitative data as well as for mixed data. Six clusters were formed based on the qualitative characters. Cluster I varied greatly from all other clusters with unique traits. The other clusters differed from each other in a few traits like peel colour, intensity of red colour of bract and position of bract towards peel. When mixed data including both qualitative and quantitative data were clustered, 3 clusters were formed with respect to stem and flower characters and 4 clusters with regard to yield and quality attributes, based on the silhouette width obtained. Clustering gave clear idea regarding the variation in genotypes present within the species commercially grown in Kerala.

SUMMARY

6. SUMMARY

The project entitled "Evaluation of dragon fruit (*Hylocereus* spp.) genotypes grown in Kerala" was carried out in the Department of Fruit Science, during the period 2019-21 to study the morphology, flowering, yield and quality attributes of dragon fruit grown in four districts of Kerala (Thiruvananthapuram, Pathanamthitta, Ernakulam and Thrissur). The preliminary study was done by selecting a total of 100 plants, 10 each from 10 different locations in the four districts and were evaluated based on the UPOV guidelines to identify the different genotypes that are being cultivated in Kerala. The plants were denoted as P1 to P10, prefixed with the first two letters of the location to which they belong, as follows.

KaP1-P10: Karette
ThP1-P10: Thatta
KeP1-P10: Keerukuzhy
KoP1-P10: Kozhenchery
AiP1-P10: Aikkad
AtP1-P10: Athikkayam
AdP1-P10: Adoor
MuP1-P10: Muvattupuzha
PeP1-P10: Perumbavoor
VaP1-P10: Vaniyampara

Various characters with respect to stem, flower, phenology, yield and quality were studied. In addition to that the economic details of cultivation were also calculated and the incidence of pests and diseases were noted. The meteorological data pertaining to the districts, during the period of study were also recorded.

The stem morphology included observations like stem segment length, stem segment width, distance between areoles, arch height, stem waxiness, stem sturdiness, margin of rib, number of spines per areole, spine colour, height of pole, number of branches and number of stem segments per branch.

Maximum stem segment length recorded was 210 cm and the minimum was 33cm with an average value of 116cm and CV 0.23%. The average value for stem segment width was 4.06 cm with CV 0.23%. The maximum and minimum width recorded were 6.60 cm and 1.80 cm respectively. The minimum value for distance between areoles observed was 2.0 cm and the maximum value was 5.50 cm with a mean

value of 3.50 cm and a coefficient of variation of 0.20%. The arch height varied from 1.0 cm to 4.2 cm with an average of 1.86 cm and CV of 0.31%.

Both strong and weak waxiness were observed in the plants studied. The plants showing weak waxiness had highly sturdy stem and those with strong waxiness had low sturdiness. The plants showed either flat or convex margin. The number of spines per areole ranged from 3 to 5 in all the plants under study. The spine colour was observed to be either medium brown or dark brown and the spine colour showed a trend of turning grey with ageing.

The height of the pole was within the range of 6.5 to 8 feet in different locations with 1 to 2 feet length buried underground. As the growth of the plant continued, they produced numerous branches that hung down from top of the pole. The number of stem segments per branch varied from 1 to 6 in different plants.

Flower buds were either ovate with acute apex or elliptic with rounded apex. The sepal main colour and petal colour in all the flowers were green and white respectively. However, the pattern of secondary colour in the sepals varied. Different flowers exhibited slightly red edged sepals and red edged sepals. The flowers were classified into three categories namely strong, medium and weak based on the intensity of the red colour of the bract. The style length ranged from 23.5 cm to 31.0 cm in various flowers. Similarly, the number of stigma lobes also varied (26 to 36) among the flowers.

The phenological parameters like flowering season, duration of flowering, days taken from flowering to fruit set, days taken from fruit set to harvest, days taken from flowering to harvest and the fruiting season were observed. The plants reached bearing stage within 1.5 to 2.0 years. Flowering commenced from March in two locations (Athikkayam and Vaniyampara) whereas in the other locations, it started in the month of April. The flowering continued till September to October. It took 12-15 days from the bud initiation to anthesis. Anthesis took place after 10 p.m and if the pollination was successful, fruit set was observed within 5 to 7 days. From fruit set to harvest, the duration was 25 to 29 days under favourable climatic conditions. The fruiting season started exactly one month after anthesis and ceased one month after flowering has stopped, *i.e.,* April to November.

Yield characters from each of the ten plants were recorded. Fruit weight, fruit length and width, length to width ratio of the fruits, number of bracts, length of apical bract, width of base of the bract, position of bracts towards the peel, fruit weight without peel, fruit shape, colour of peel excluding bract, flesh colour and yield per post per year were studied. Fruit weight varied from 84 g to 896 g with a mean weight of 381.10 g and CV 0.46%. The average values for length and width of the fruits were 7.94 cm and 7.83 cm with CV values of 0.19% and 0.20 % respectively. Length to width ratio of the fruits were in the range of 1.00 to 1.21 with mean value of 1.02, indicating moderately elongated or medium appearance of the fruits. The number of bracts on the fruits varied from 18 to 50. The length of apical bract in different fruits were in the range of 3.00 cm to 6.30 cm with a mean value of 4.68 cm and CV 0.17%. Width of the base of the bracts varied from 1.40 cm to 5.70 cm with average width of 3.35 cm and CV 0.25%.

Position of the fruit bracts with respect to the peel found to differ in fruits. The fruits had bracts which were adpressed, slightly held out or strongly held out. The fruit shape also varied from oval to spherical. The fruit weight without peel ranged from 52 g to 598 g with a mean value of 269.60 g and CV 0.49%. The peel colour was either medium pink or dark pink whereas the flesh colour was found to be dark pink or purple. The yield per post varied from 5 kg to 20 kg per year depending upon the age of the plants. The yield increased usually up to five years and gave steady yield after five years.

The total soluble solids (TSS), titrable acidity and TSS/acidity ratio were measured for the entire group of plants from the concerned locations. Sensory evaluation of the fruits from different locations were done based on a 9-point hedonic scale. The values ranged from 11 to 18 °Brix with respect to the TSS of the fruits whereas the titrable acidity was found to be 0.12% in all the fruits. The TSS: acidity ratio was found to be very high in pitaya attributing to the low values of titrable acidity. The ratio obtained was between 91.67 and 150.00 with an average value of 126.42. The plants KoP1 to KoP10 from Kozhenchery received the maximum score for appearance, taste, flavour, after taste and overall acceptance in the sensory evaluation.

Considering the perennial nature of dragon fruit, orchards in various locations were grouped into three phases based on the age of the plants. Orchards of age 0 to 2 years fell under establishment phase, those with 2-4 years of age came under yield increasing phase and yield stabilizing phase had orchards that were 4 years or older. Based on the phases, total cost of cultivation was estimated to be ₹8,29,393 per year per hectare. The maximum cost during establishment phase was incurred for the planting material and construction of posts. During the maintenance phase, maximum expenditure was for the manure and fertilizer application. Average yield per year per hectare was 21 tonnes and the average price received by farmers was ₹174 per kg.

Five channels were identified in the marketing of dragon fruit. Marketing was either direct from producer to consumer or the chain included middlemen, wholesalers, local traders or retailers and online sellers. The marketing channels identified were:

Channel I: Producer - Consumer
Channel II: Producer - Local trader – Consumer
Channel III: Producer – Wholesaler – Retailer – Consumer
Channel IV: Producer – Online sellers – Consumer
Channel V: Producer – Middlemen – Wholesaler – Retailer – Consumer

Out of these, the first three channels were more prominent. The involvement of middlemen was high in large orchards with bulk production compared to the smaller orchards. Dragon fruit export was not reported by any of the farmers but the possibilities have to be explored in the near future.

Net return of ₹27,32,768 was obtained from one hectare. The B:C ratio was 4.29 when the farmers received ₹174 per kg fruit. The B:C ratio obtained with the least price (₹120 per kg) was 3.04. When a medium price (₹140) lying between the least and average value was considered, a B:C ratio of 3.54 was obtained. Being a highly remunerative crop, area under dragon fruit cultivation was found to be expanding year after year, as more under-utilized lands are being brought under this crop.

Major constraint in dragon fruit cultivation was the bud and flower drop due to heavy and continuous rainfall during the flowering season. Weed growth was the second

major constraint reported by farmers. The source of planting material in all the locations under study was either Malaysia or Cambodia. Owing to the fact that dragon fruit was a recently introduced crop to India, pest and disease incidence were less compared to other fruit crops. But the menace caused by ants was common. Rarely, attack by mealy bugs, beetles and birds were observed. Disease symptoms similar to canker were observed on the fruits and stem in one of the locations. Physiological disorder like yellowing during extreme summer was common in most of the orchards and these symptoms disappeared immediately after a rain or with irrigation.

The variability within the species was analysed using statistical techniques like factor analysis and cluster analysis with the help of R 4.1.0 software. Maximum variability (59.38%) in the stem and flower characters was explained by two dimensions. The characters that contributed to the variability were intensity of red colour of bract, stem waxiness, stem sturdiness, margin of rib, spine colour, bud shape, bud apex shape, number of stigma lobes, length of style and distance between areoles. Similarly, maximum variability (62.74%) in the quality attributes were contributed by the first two dimensions out of four significant dimensions. The characters responsible for creating the variability were fruit weight, position of bract towards peel, fruit width, fruit weight without peel, fruit length, flesh colour, fruit shape, width of base of bract, length of apical bract, outer TSS, TSS-acid ratio and core TSS. Quantitative characters like stem segment length, stem segment width, arch height and number of spines per areole were explained by both the dimensions. Similarly, the quantitative characters like fruit weight, fruit weight without peel, fruit length and fruit width were explained by both the dimensions in yield and quality attributes, contributing to the variability.

From the factor analysis and cluster analysis of qualitative and mixed data it was inferred that the plants AtP1-P10, KaP1-P10 and KoP1-P10 were closely related with each other which could probably be attributed to their common source of planting material (Malaysian). Hence, all the plants from this source of planting material formed a genotype. The rest of the plants showed variations among them even though the source of planting material was same (Cambodian), which indicated that more than one genotype from the same source. The plants AiP10, MuP1, MuP2, MuP3, VaP8, PeP3, PeP4, AdP5 and AdP7 were distinguishable visually from all the other plants under

study with respect to their qualitative traits. Based on the qualitative traits, there were 6 clusters and through the clustering of mixed data, there were 3 clusters for stem and flower characters and 4 clusters for yield and qualitative characters. These results indicated the variations that existed among the plants under study revealing the presence of different genotypes within the dark pink/purple fleshed dragon fruit.

From the present work it was inferred that the commercially exploited species of dragon fruit in Kerala was the dark pink and purple fleshed ones with pink peel (*H. costaricensis*) and within this species different genotypes were present. In addition to *H. costaricensis*, other species of *Hylocereus* namely *H. undatus* and *H. megalanthus,* and other types known as Bruni and Frankis Red imported from countries like Thailand and Vietnam were also under cultivation by farmers and are getting popular in different parts of Kerala.

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APPENDIX I

Meteorological data during the period of study (January 2020-June 2021)

1. Thiruvananthapuram

Month	Maximum temperature (°C)	Minimum temperature (°C)	Relative humidity (%)	Rainfall (mm)
January ’20	33.0	23.5	76.5	79.80
February ’20	34.0	24.1	71.0	trace
March ’20	34.6	25.4	73.5	16.60
April ’20	34.7	25.7	75.5	215.1
May ’20	33.2	25.5	86.5	481.6
June ’20	31.7	24.4	85.0	363.7
July ’20	31.7	24.2	84.0	161.4
August ’20	31.3	24.5	83.0	213.4
September ’20	30.6	24.1	87.5	487.0
October ’20	31.5	23.9	82.5	235.8
November ’20	32.6	24.4	81.0	109.1
December ’20	32.4	23.9	79.5	43.90
January ’21	32.0	23.4	81.0	97.90
February ’21	33.9	23.6	70.5	0.300
March ’21	32.7	24.8	68.9	52.70
April ’21	31.4	26.7	76.3	158.2
May ’21	29.4	26.6	84.6	537.9
June ’21	28.4	25.9	87.5	232.0

2. Pathanamthitta

Month	Maximum temperature (°C)	Minimum temperature (°C)	Relative humidity (%)	Rainfall (mm)
January ’20	19.7	29.2	76.9	5.300
February ’20	20.4	33.5	63.6	10.50
March ’20	22.6	35.3	63.0	36.90
April ’20	23.4	34.7	68.3	63.30
May ’20	24.0	30.3	83.6	263.6
June ’20	22.7	27.3	88.4	274.2
July ’20	22.0	26.6	90.5	326.9
August ’20	22.2	26.6	91.0	247.8
September ’20	21.8	26.5	91.0	363.9
October ’20	21.7	26.9	89.4	295.3
November ’20	21.3	27.9	86.6	158.2
December ’20	20.0	27.1	85.4	84.40
January ’21	19.9	27.2	85.6	184.6
February ’21	18.7	29.4	74.4	0.000
March ’21	20.7	33.1	66.4	68.50
April ’21	23.1	31.5	79.2	210.9
May ’21	23.1	28.3	89.3	696.1
June ’21	22.8	27.0	91.3	416.5

3. Ernakulam

Month	Maximum temperature (°C)	Minimum temperature (°C)	Relative humidity (%)	Rainfall (mm)
January ’20	32.3	24.4	68.0	30.60
February ’20	32.7	25.0	67.5	65.40
March ’20	32.7	26.1	74.5	94.60
April ’20	33.2	26.0	74.0	171.6
May ’20	32.9	25.7	79.0	281.2
June ’20	30.5	24.5	84.5	500.2
July ’20	30.2	24.3	84.5	601.7
August ’20	30.0	24.8	85.0	566.2
September ’20	29.6	24.3	88.0	528.0
October ’20	30.4	24.3	81.0	249.6
November ’20	31.7	24.6	76.5	136.0
December ’20	31.6	24.0	71.5	15.20
January ’21	31.3	23.8	71.5	89.20
February ’21	31.9	24.1	64.5	0.200
March ’21	34.0	26.6	64.9	63.30
April ’21	31.6	27.1	77.5	189.8
May ’21	29.9	26.6	84.0	501.0
June ’21	28.9	26.2	85.7	268.9

4. Thrissur

Month	Maximum temperature (°C)	Minimum temperature (°C)	Relative humidity (%)	Rainfall (mm)
January ’20	34.1	22.4	60.0	0.000
February ’20	35.5	23.2	56.0	0.000
March ’20	36.4	24.4	68.0	33.40
April ’20	36.4	24.7	70.0	44.70
May ’20	35.0	25.2	78.0	59.60
June ’20	31.1	23.4	86.0	427.2
July ’20	30.5	23.1	87.0	563.0
August ’20	30.2	23.1	86.0	607.7
September ’20	30.0	22.4	89.0	587.6
October ’20	31.0	21.5	84.0	310.3
November ’20	33.0	22.0	73.0	56.10
December ’20	31.9	21.8	66.0	7.700
January ’21	32.5	21.3	64.5	45.70
February ’21	34.6	21.6	55.0	0.000
March ’21	35.6	25.1	62.6	42.20
April ’21	33.1	26.4	76.0	152.9
May ’21	30.3	25.8	84.6	353.3
June ’21	29.0	25.2	87.5	284.8

Light intensity (lux)

Location	Light intensity during vegetative growth period (lux)	Light intensity during flowering season (lux)
Athikkayam	767	405
Thatta	547	651
Karette	760	718
Kozhenchery	819	645
Aikkad	702	757
Muvattupuzha	520	417
Vaniyampara	652	760
Keerukuzhy	650	554
Perumbavoor	474	509
Adoor	545	574

*The values were measured in the range of 200000 (x100 lux).

APPENDIX II

Score card for organoleptic scoring of dragon fruits from different locations

Name of the judge:

Date:

Parameters	Score									
	Sample1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8	Sample 9	Sample 10
Colour										
Appearance										
Texture										
Taste										
Flavour										
After taste										
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

APPENDIX III

Constraints ranking card

Name of the farmer:

Date:

Constraints	Rank
Pests	
Diseases	
Weeds	
Bud/flower drop	
Availability of resources	
Labour availability	
Storage	
Marketing	

ABSTRACT

EVALUATION OF DRAGON FRUIT (*Hylocereus* spp.) GENOTYPES GROWN IN KERALA

By

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ABSTRACT OF THE THESIS

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Abstract

Dragon fruit (*Hylocereus* spp.) commonly known as the pitaya, is a perennial climbing vine belonging to the Cactaceae family. The present work carried out in the Department of Fruit Science during the period 2019-2021 to study the morphology, flowering, yield and quality attributes of dragon fruit grown in four districts of Kerala (Thiruvananthapuram, Pathanamthitta, Ernakulam and Thrissur) is of vital importance with respect to the popularity dragon fruit has gained within a very short span of time in Kerala. A total of 100 plants, 10 each from 10 different locations were evaluated based on the UPOV descriptor guidelines to characterise the different genotypes that are being cultivated in Kerala. The plants were denoted as P1 to P10, prefixed with the first two letters of the location to which they belong.

The commercial cultivation of dragon fruit in Kerala was found to be dominated by the dark pink/purple fleshed dragon fruit (*Hylocereus costaricensis*). Within this species, more than one genotype was identified. The stem, flower, yield and quality attributes were found to vary widely. The stem characters included stem segment length (33-210 cm), stem segment width ((1.80-6.60cm), distance between areoles (2.00-5.50 cm), arch height (1.00-4.20 cm), stem waxiness (strong and weak), stem sturdiness (high and low), margin of rib (convex and flat), number of spines per areole (3-5), spine colour (medium brown and dark brown), height of the pole (6.5-8 ft with 1-2 ft buried underground), number of branches (numerous) and number of stem segments per branch (1-6).

Variations were also observed for the flower characters such as bud shape (ovate and elliptic), shape of bud apex (acute and rounded), secondary colour pattern of sepal (slightly red edged and red edged), intensity of red colour on bracts (weak, medium and strong), length of style (23.50-31.00 cm) and number of stigma lobes (26-36). The yield characters studied were fruit weight (84-896g), length of fruit (4.60-10.40 cm), width of fruit (4.40-10.40 cm), length/width ratio of fruit (1.00-1.21), number of bracts (18-50), length of apical bract (3.00-6.30cm), width of base of the bract(1.40-5.70 cm), position of bracts towards the peel (adpressed, slightly held out and strongly held out), fruit weight without peel (52-592 g), fruit shape (oval or spherical), colour of peel

(medium pink and dark pink), flesh colour (dark pink and purple) and yield per post (5-20 kg per year based on the age of the plants). The values ranged from 11 to 18 °B with respect to the TSS of the fruits whereas the titrable acidity was found to be 0.12 per cent in all the fruits. The plants KoP1 to KoP10 from Kozhenchery received the maximum score for appearance, taste, flavour, after taste and overall acceptance.

Plants came into bearing within 1.5 to 2 years of planting when stem cuttings were used as the planting material. The duration from flower bud initiation to anthesis was 12-15 days in general and anthesis took place during the night time after 10 p.m. If the pollination was successful, fruit could be visible after 5 to 7 days of anthesis and the harvest was possible in 23-25 days from fruit set *i.e.,* one month after anthesis. When the phenology of the plants was studied, flowering started in the month of March in two locations (Athikkayam and Vaniyampara) whereas in all the other locations, it started in the month of April. The flowering season extended till September to October. The fruiting season started exactly one month after the anthesis and ceased one month after the flowering has stopped, *i.e.,* April to November.

As dragon fruit was a perennial crop, different orchards were grouped into three phases based on the age of the plants, namely the establishment phase (0-2 years), yield increasing phase (2-4 years) and yield stabilizing phase (4 years and above). Considering the phases, total cost of cultivation was calculated and it was found to be ₹8,29,393 per year per hectare. The maximum cost during establishment phase was incurred for the planting material and construction of posts. During the maintenance phase, maximum expenditure was for the manure and fertilizer application. Average yield per year per hectare was observed to be around 21 tonnes and the average price received by farmers was ₹174 per kg. Net return from one hectare was around ₹27,32,768. The B:C ratio was 4.29 when the farmers received ₹174 per kg fruit. The B:C ratio obtained with the least price (₹120 per kg) was 3.04. Being a highly remunerative crop, area under dragon fruit cultivation was found to be expanding year after year, as more under-utilized lands are being brought under this crop.

Major constraint identified in the cultivation of dragon fruit was the bud and flower drop due to excessive and continuous rainfall during the flowering season. Weed

growth was also found to be a major problem. The source of planting material in all the locations under study were found to be either from Malaysia or Cambodia. Since dragon fruit was a crop introduced recently to India, the incidence of pests and diseases were less compared to other fruit crops. But the menace caused by ants was common and rarely, mealy bugs and beetles were found. Fruits were found to be damaged by birds. Disease symptoms similar to canker were observed on the fruits and stem in one of the locations. Physiological disorder like yellowing during extreme summer was common in most of the orchards and these symptoms vanished immediately after a shower or with irrigation.

The variability within the species was analysed using statistical techniques like factor analysis and cluster analysis. Maximum variability (59.38%) in the stem and flower characters was explained by two dimensions. The characters that contributed to the variability were intensity of red colour of bract, stem waxiness, stem sturdiness, margin of rib, spine colour, bud shape, bud apex shape, number of stigma lobes, length of style and distance between areoles. Similarly, maximum variability (62.74%) in the quality attributes were contributed by the first two dimensions out of four significant dimensions. The characters responsible for creating the variability were fruit weight, position of bract towards peel, fruit width, fruit weight without peel, fruit length, flesh colour, fruit shape, width of base of bract, length of apical bract, outer TSS, TSS-acid ratio and core TSS.

Cluster analysis of the qualitative traits formed six different clusters. When the mixed data with both qualitative and quantitative characters were analysed through clustering, there were three clusters based on the stem and flower characters and four clusters based on the yield and quality attributes, which indicated variability within the species.

Other species of *Hylocereus* namely *H. undatus* and *H. megalanthus,* and other types known as Bruni and Frankis Red imported from countries like Thailand and Vietnam are also under cultivation by farmers and are getting popular in different parts of Kerala.