GENOTYPE EVALUATION AND PRODUCTION TECHNOLOGY DEVELOPMENT FOR HIGH DENSITY PLANTING SYSTEM IN PAPAYA *(Carica papaya* L.)

by

AMRITA MANOHAR
(2019-22-015)

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

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THESIS

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Faculty of Agriculture
Kerala Agricultural University

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

2023

DECLARATION

I, hereby declare that this thesis entitled **"Genotype evaluation and production technology development for high density planting system in papaya (*Carica papaya* L.)"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, associateship, diploma, fellowship or other similar title, of any other University or Society.

Amrita Manohar

(2019-22-015)

Vellanikkara,

Date: 21-07-2023

CERTIFICATE

Certified that this thesis entitled **"Genotype evaluation and production technology development for high density planting system in papaya (*Carica papaya* L.)"** is a record of research work done independently by **Ms. Amrita Manohar (2019-22-015)** 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.

Dr. Anu G. Krishnan
(Chairperson, Advisory committee)
Professor
Regional Agricultural Research Station
Kumarakom, Kottayam

Kumarakom
Date: 21/07/2023

CERTIFICATE

We, the undersigned members of advisory committee of **Ms. Amrita Manohar (2019-22-015)**, a candidate for the degree of **Doctor of Philosophy in Horticulture** with major in **Fruit Science**, agree that the thesis entitled **"Genotype evaluation and production technology development for high density planting system in papaya (*Carica papaya* L.)"** may be submitted by **Ms. Amrita Manohar (2019-22-015)**, in partial fulfilment of the requirement for the degree.

21/07/23

Dr. Anu G. Krishnan
(Chairperson, Advisory committee)
Professor
Regional Agricultural Research Station
Kumarakom, Kottayam

21/07/23

Dr. Jyothi Bhaskar
Professor and Head
Department of Fruit Science
College of Agriculture, Vellanikkara

21/7/23

Dr. Mary Regina F.
Professor and Head
Krishi Vigyan Kendra
Vellanikkara

21/7/23

Dr. Saji Gomez
Professor
Department of Post-Harvest Technology
College of Agriculture, Vellanikkara

21/7/23

Dr. Prameela P.
Professor and Head
Department of Agronomy
College of Agriculture, Vellanikkara

21/7/23

Dr. S. Praneetha, Professor (Horticulture)
Horticulture College and Research Institute,
TNAU, Coimbatore
(External Examiner)

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Amrita Manohar

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Introduction

1. INTRODUCTION

Papaya (*Carica papaya* L.), a popular and widely cultivated tropical fruit introduced from tropical America, is being cultivated in more than sixty countries across the globe. Internationally, papaya production has risen significantly in the past few years, owing primarily to increased production in India. Fruits of papaya have become an important agricultural commodity for export to developing countries, thus providing an income for thousands of people, particularly in Asia. It is a wonder fruit grown primarily for its exquisite flavour and has the potential to yield the proteolytic enzyme papain, in addition to its significant nutritional and therapeutic benefits. This fruit crop has gained popularity among farmers owing to its high production potential, precocious bearing habit, year-round fruiting nature, palatability, and multiple uses in medicinal, cosmetic, and food industries. Papaya is a powerhouse of vitamins and minerals. The mature green fruits of papaya contain a proteolytic enzyme called papain, which has numerous applications in pharmaceutical, cosmetic, and food industries. Due to its multiple uses, high returns and short juvenile period, many farmers in Kerala have started to grow this crop in their orchards.

India is the largest producer of papaya, accounting for about 59.49 lakh t from an area of 1.49 lakh ha (GOI, 2022). But the conventional system of cultivation practised in India has led to the low productivity of papaya orchards. This can be attributed to factors like the use of low yielding local varieties, lack of availability of high yielding released varieties/hybrids, lack of knowledge about promising local types, improper management practices, poor adoption of technologies, and low water and nutrient use efficiency. So, for improving this condition, identification of native genotypes best suited to the locality is a better option rather than the introduction of a new variety which may fail to exhibit its full production potential in the given location. In addition to this, the adoption of high-density planting (HDP) system and fertigation can improve productivity, nutrient use efficiency, and water use efficiency in papaya.

All living organisms are composed of genes whose expression is influenced by the environment. Under open field conditions, environmental factors, such as temperature, moisture, etc., are highly fluctuating resulting in a stronger environmental impact on phenotypic expression. Furthermore, the genotypic expression of a phenotype is environment dependant (Kang, 1998). So, under diverse environmental conditions, genotypes exhibit varying levels of phenotypic expression, resulting in crossover performance (Haldavankar *et al.,* 2009). Hence, a genotype that performs well in one region may not yield the same in another due to changes in environmental conditions. More studies are needed to identify the genotypes of papaya that can perform better in the climatic conditions of Kerala and produce quality fruits. So, in this project, an attempt was made to identify the genotypes, both local types and released varieties, best suited for Kerala conditions.

Planting more trees per unit area at a closer spacing is known as high-density planting (HDP) system. It not only provides higher yield and net returns but also facilitates optimal use of fertilizers, irrigation, and other inputs (Peter *et al.,* 1975; Goswami *et al.,* 1993). An increase in productivity was observed in papaya when planted under the HDP system, which accommodated about 6400 plants per hectare (Mishra and Goswami, 2016). To reap the full benefits ofHDP, cultivation of dwarf varieties and adoption of nutrient management techniques have to be practiced.

Various researchers across the globe have reported that the best method to manage nutrient supply is by the application of fertilizers through irrigation water, viz., fertigation. Chaudhri *et al.* (2001) reported that fertigation aided in the effective use of fertilizers for maximum output in papaya orchards. It also improved the morphological parameters, yield and fruit characters in papaya (Jeyakumar *et al.,* 2010; Deshmukh and Hardaha, 2014). The adoption offertigation system alone showed an improvement of 43 per cent in yield of papaya fruit over the conventional system of planting (Singh and Singh, 2006). This is due to the enhanced photosynthetic efficiency in fertigated plants, which resulted in larger fruit size and a higher yield when compared to plants fertilised through conventional methods (Jeyakumar *et al.*, 2001). So, it was imperative to conduct research on spacing and fertigation levels, which were important variables in **HDP**, to arrive at the optimum spacing and fertigation doses suitable for papaya under Kerala conditions.

In this context, the present study on 'Genotype evaluation and production technology development for high density planting system in papaya (*Carica papaya* L.)' was carried out with the following objectives:

Evaluation of papaya genotypes for table purpose and standardization of fertigation and spacing levels for growth, yield, and quality of papaya under high density planting system

Review of Literature

2. REVIEW OF LITERATURE

Papaya (*Carica papaya* L.) is an evergreen tropical herbaceous fruit crop well-known for both its medicinal and nutritional properties. Papaya is mostly planted as a backyard crop in Kerala, but due to its market demand, it has lately acquired popularity as a commercial crop in farmers' fields. Moreover, this crop comes to flowering and fruiting within a year, making it more profitable for farmers to get an early return. Papaya is not only valued for its ripe fruits, but also for the 'papain', the latex extracted from mature green fruits. The popular value-added product 'tutti-frutti' is made from unripe papaya fruits. Hence, papaya is both a valuable source of nutrient-rich food and a profitable crop for growers. It can be grown even in limited space because of its single-stemmed nature.

2.1 SCREENING OF GENOTYPES SUITABLE FOR TABLE PURPOSE UNDER KERALA CONDITION

The polygamous nature of this crop (Hofmeyr, 1936; Storey, 1937) led to considerable variation in the phenotypic and morphological characters of the papaya genotypes, which can be used in the hybridisation programme to develop a cultivar of our choice. A large number of varieties are released in the market, but the suitability of most of these varieties for Kerala conditions is yet unknown.

A variety that performs best in one location may not be the same in another. Furthermore, there are a lot oflocal genotypes available around us that may be best suited to Kerala conditions. So, identification and evaluation of such local types could help in papaya hybridisation programmes, paving the way for a new papaya variety that possesses good climatic adaptation, morphological and fruit characters. So, the present investigation on the identification of the best table purpose papaya genotype under Kerala conditions was proposed. The literature that is relevant to the current investigation is furnished in this chapter.

2.1.1. Evaluation of papaya genotypes

Asudi *et al.* (2010) investigated the variability of Kenyan papaya genotypes for their morphological, fruit and yield characters. They noticed significant variations among the 60 papaya accessions for the above characters and suggested that these variations could be used in the selection of parents in the papaya breeding programme. Thus, it would help in improving the genetic makeup of papaya, which helps in adapting to different conditions.

According to Reddy *et al.* (2011), the lowest disease incidence (8.33 %) and maximum days (26 days) for the expression of papaya ringspot virus were recorded in the papaya cv. Red Lady. Prakash and Singh (2013) evaluated 16 genotypes of papaya under open field conditions for resistance to papaya ring spot and leaf curl virus infections. They discovered that five genotypes (P-7-9, Sinta, Pune Selection 3, P-7-2, and RCTP-1) exhibited resistance to the papaya ring spot and leaf curl virus infections. The evaluation of selfed progenies of gynodioecious papaya cvs. Arka Surya and Arka Prabhath under Maharashtra conditions showed considerable variation in morphological and fruit parameters (Nirujogi and Dinesh, 2012). The variation in these characters can be attributed to the difference in the genetic makeup of female and hermaphrodite plants. Similarly, Das *et al.* (2014) evaluated the performance of papaya varieties Sunrise Solo and Washington and found that Sunrise Solo seems to be superior over Washington with respect to the days to fruit maturity (154 days) and percentage fruit set (76.09 %).

2.1.2. Biometric characters

a. Height of plant

Singh and Kumar (2010) report that there was a significant amount of variation in both plant height (138.4 to 240.6 cm) and girth (28.02 to 36.8 cm). Five papaya cultivars, including Pusa Nanha, Pusa Delicious, Pant Papaya 1, Madhu Bindu and Arka Surya, were assessed in North Gujarat by Meena *et al.* (2012).

According to them, the cultivar Pant Papaya-I produced the tallest plant throughout all stages of growth.

Under Bangalore conditions, Nirujogi and Dinesh (2012) assessed the papaya cvs. Arka Surya and Arka Prabhath. The plant height at first blooming ranged from 93.50 to 116.90 cm and 54.50 to 86.45 cm in Arka Surya and Arka Prabhath, respectively. Das (2013) examined eight papaya cultivars and hybrids in the Tripura condition, including Coorg Honey Dew, Pusa Dwarf, Pusa Majesty, Pusa Nanha, Washington, Arka Surya, and RCTP-1 varieties. The tallest and shortest plants were those of the new local dwarf gynodioecious type (91.33 cm) and the high yielding selection RCTP-1 (293.55 cm), both of which are high yielders.

In a field experiment conducted in Gujarat, Kumar *et al.* (2015) assessed 17 papaya genotypes. and found that environmental changes had a significant impact on the height of the plant, which varied from 120 to 185.33 cm. According to Reshma (2015), the plant height of 40 collections varied significantly from 2.1 to 6.6 m, with the lowest plant height recorded by Pusa Nanha (1.79 m). Similar findings were made by Akhil (2020) on the plant height of papaya accessions and found that the lowest plant height was observed in Pusa Nanha (1.70 m), followed by Red Lady (1.88 m) and CO2 (2.17 m). A study was conducted by Varu (2020) to study the variability of different varieties and selections on the morphological, flower and yield characters of papaya under Gujarat conditions. Among the genotypes, the papaya variety Pusa Dwarf recorded the lowest plant height (148.16 cm). The plant height of all nine genotypes under study ranged from 148.16 cm (Pusa Dwarf) to 224.98 cm (Selection-6).

b. Girth of plant

Meena *et al.* (2012) examined five papaya varieties: Pusa Delicious, Pusa Nanha, Pant Papaya-I, Madhu Bindu and Arka Surya. The stem girth was noted highest in Pusa Delicious at 60 (0.89 cm), 120 (2.21 cm) and 180 (3.85 cm) days after planting (DAP), whereas Pant Papaya-I had the highest stem girth after 240

DAP (6.92 cm). In the study to evaluate the performance of eight papaya varieties and hybrid under Tripura conditions, Das (2013) noticed that Arka Surya showed the highest stem girth among the treatments.

Another crucial factor that affects plant vigour is collar girth. Reshma (2015) discovered that towards the end of the monitoring period, CO 8 had the highest collar girth, measuring 94.62 cm. It was observed that during the first phases of growth, the rise in plant height and collar girth was higher and this increment decreased as growth progressed. Initial growth was noted at a higher pace, but as plants aged, their growth rate decreased. On evaluating the papaya genotypes, it was found that by the end of the observation period, Acc. 4 exhibited the highest collar girth of 70.30 cm, whereas papaya cv. Red Lady exhibited the smallest collar girth of 34.53 cm (Akhil, 2020).

c. Number of leaves

An investigation was carried out by Anh *et al.* (2011) to compare the biometric and fruit characters of 12 local papaya varieties in Vietnam. They observed that the plant height (94.00- 169.00 cm), stem diameter (6.50-8.60 cm) and number of leaves (17.60-21.80) varied significantly between the 12 papaya varieties. The number of leaves showed variations in different varieties of papaya, as reported by Nirujogi and Dinesh (2012). The papaya varieties Arka Prabhath and Arka Surya showed variation in the number of leaves that ranged from 20-33 and 18-31 respectively. These differences in their morphological parameters can be attributed to the differences in their genetic constitution.

The most crucial vegetative measures to assess photosynthetic capacity and predict fruit yield are the number ofleaves and leaf area. The quantity of completely grown leaves and the area of the leaves failed to increase steadily; rather, patterns of leaf production varied between accessions and varieties (Reshma, 2015). Varu (2020) reported that among the eight papaya selections and varieties evaluated, the number ofleaves varied from 41.44 in Pusa Dwarf to as little as 29.91 in Selection-2.

d. Length of leaf petiole

According to Reshma (2015), the length of the leaf petiole showed considerable variation among the 30 papaya genotypes under study. She noticed that the longest petiole was present in Ace 18 (120.30 cm), followed by Ace 25 (106.68 cm) at 12 months after planting (MAP). A similar trend was reported by Akhil (2020) after the evaluation of 12 papaya genotypes. He observed that the longest petiole was found in Ace 4 at 12 MAP and also suggested that throughout the growth phase of the plant, different accessions exhibited different rates of petiole growth.

e. Colour of leaf petiole

The investigation of 30 papaya genotypes for evaluating the differences **in** their morphological, fruit, yield and quality parameters was carried out by Reshma (2015). The leaf petiole of papaya genotypes varied significantly with respect to its colour, like pale green, dark green, normal green, green and shades of red purple, and red purple.

f. Height at first flowering

Chalak *et al.* (2016) assessed nine papaya cultivars for growth, yield and quality under Pune conditions. The papaya variety Pusa Nanha marked the lowest height at first flowering (53.30 cm), whereas variety CO 2 exhibited the highest value for height at first flowering (75.00 cm). Reshma (2015) evaluated 30 papaya genotypes, including both accessions and varieties, for growth and yield characters. She observed that early bloomers were Accession 4, Accession 2, Accession 17, and Accession 12. The height of the plant at first flowering ranged from 61.00 to 152.27 cm. Among the accessions and varieties examined, papaya cv. Pusa Nanha and CO 8 reported the lowest flowering heights (61.00 cm and 62.73 cm, respectively). According to the finding of Akhil (2020), first flowering height was recorded lowest in the papaya cv. Pusa Nanha (70.70 cm) followed by Ace 6 (91.17

cm), Arka Prabhath (99.73 cm) and Red Lady (100.50 cm). The highest value for first flowering height was observed in Ace 4 (140.80 cm).

g. Days to flowering

In an open field experiment with seventeen genotypes of papaya, Kumar *et al.* (2015) observed that flowering occurred between 230.83 and 242.27 days. The days to flowering were greatly affected by the changes in the environment. In order to assess the growth, yield, and quality of papaya, Chalak *et al.* (2016) examined nine papaya cultivars in Pune. It was noted that cv. Red Lady (70.40 DAP), displayed the earliest flowering, followed by cv. CO2 (73.50 DAP) whereas papaya cv. Pusa Giant took the maximum number of days to flower (85.40 DAP).

According to Reshma (2015), the early bloomers were Accession 4 (88.97 days), Accession 2 (89.00 days), Accession 17 (95.41 days), and Accession 12 (97.67 days) among the thirty papaya genotypes evaluated for their morphological and yield characters. Varu (2020) found that the least number of days to flowering was taken by papaya selection-I (87.03 days), followed by selection-8 (90.68 days). The days to first flowering of the papaya selections and cultivars ranged from 87.03 days to 106.86 days. The lowest number of days to flowering was observed in papaya Ace 2 (108.33 days) and CO 8 (112.00 days), while the highest number of days to flower was noted in Ace 3 (135.00 days). The papaya cv. Arka Prabhath took 129.00 days for first flowering, and it was on par with the cv. CO 2 (127.33 days) (Akhil, 2020).

h. Sex expression of plant

As a polygamous species, papayas have three fundamental sex types: staminate (male), hermaphrodite (bisexual), and pistillate (female). Only the female flowers are stable, while the male and hermaphrodite flowers change their sex forms depending on the prevailing climatic conditions. Papaya has 32 heritable sex forms, of which 31 alter its sex form, with the exception of the female form (Storey, 1937; Ram et al., 1994). The sex expression of papaya is strongly influenced by environmental as well as genetic variables. Comparing the female plant to the hermaphrodite and sex-reversing male plants, it was found that female plants were more stable and productive. Also, there is a considerable correlation between plant growth rate, minimum temperature and percentage of carpelloidic flowers (Awada, 1958).

The highest female fertility (8.17 %) was recorded in March when the temperature reached 29.5 °C, while the lowest fertility (0.22 %) was documented in the sex-reversing males during December when the minimum temperature was 12.2 °C (Ram *et al.*, 1994). The papaya plant developed rapidly throughout the summer season, but fruit production was halted during the winter season. These fruits then ripened during the following spring and summer. Allan (2002) reported that papaya performed poorly when the soil temperature and minimum air temperature were below 19 °C and 11 °C, respectively.

i. Number of flowers/cluster

According to Singh (1990), female papaya trees may have single flowers, racemose, or corymb-type inflorescences. In the latter scenario, 5 to 6 blooms can be seen in each cluster. The lower number of flowers per cluster was observed in the papaya cultivars CO 4 and CO 2, as reported by Lakshmi (2000).

Varu (2020) recorded the number of flowers per node of plants in his experiment on the evaluation of eight papaya selections and cultivar and observed that the number of flowers ranged from 3.94 (selection-6) to 5.73 (selection-4).

j. Fruit set percentage

Nair *et al.* (2010) studied the genetic characteristics of papaya hybrids at Kerala Agricultural University and found that the hybrids had shorter days to first flowering in Pusa Nanha x Pusa Dwarf and the highest percentage of fruit set in Pusa Nanha x Coorg Honey Dew.

k. Days for first harvest

Papaya plants begin to yield fruit in 6-12 months, and individual fruits typically reach maturity in 5-9 months, depending on the cultivar and temperature (Aravind *et al.*, 2013). According to Varu (2020), among the eight papaya selections and cultivars assessed, the least number of days to fruit maturity was observed in selection-4 (232 days), followed by selection-2 (234 days) and selection-I (235 days). The highest number of days were taken by selection-7, which took about 260 days for the fruit to mature.

2.1.3. Yield characters

a. Fruit weight, fruit length, fruit girth and fruit volume

According to Samson (1986), the fruit weight ranged from 0.5 to 2.0 kg. **Akhil** (2020) found that the fruit weight of the papaya varieties varied from 813 g to 1867 g.

Desikan (1972) examined the length of papaya fruits in the cultivars CO 1, Coorg Honey Dew, and Washington and discovered that the mean lengths were 17.50 cm, 26.57 cm, and 18.70 cm, respectively. According to Singh *et al.* (2006), fruit length (26.19 cm), fruit breadth (42.28 cm), and fruit cavity (15.34 cm) all showed considerable variation in papaya. Anh *et al.* (2011) assessed the length and diameter of the fruits of twelve local papaya types in Vietnam. The fruit length and diameter were found to be between 9.67 to 17.33 and 6.67 to 14.17, respectively.

Meena *et al.* (2012) recorded significant variation in fruit length, diameter and flesh thickness of five papaya varieties under Gujarat conditions. The papaya cv. Pusa Nanha had the higher fruit length, diameter and flesh thickness among the other varieties. A study carried out by Das (2013) to assess eight papaya cultivars and hybrids, including the Coorg Honey Dew, Pusa Dwarf, Pusa Majesty, Pusa Nanha, Washington, Arka Surya, RCTP-1, and native dwarf varieties cultivated in Tripura. The highest fruit length and breadth were measured in the cultivars RCTP-

1 (23.57 cm) and Pusa Dwarf (15.20 cm), respectively. The fruits with the highest weight (1830 g), length (29.00 cm), and volume (2060 ml) were identified in Ace 25. While highest fruit circumference was observed in papaya cv. CO 8 (48.00 cm) (Reshma, 2015). Varu (2020) evaluated eight papaya selections and a variety for their growth, yield and quality characters and concluded that fruit length, girth and weight ranged between 18.28-25.02 cm, 38.41-47.30 cm and 1142.51-1654.40 kg, respectively. According to Akhil (2020), among the 12 papaya genotypes evaluated, the fruit volume ranged between 733 ml-1754 ml in Ace 3 and Pusa Nanha, respectively.

b. Shape of fruit

According to Rao *et al.* (1974), the fruits of papaya variety CO 2 were medium to large with an oblong shape. Similar findings were drawn by Singh (1990), who found that the shape of papaya cv. CO 2 is oblong with ridges at the tip. Spherical fruits grow on female trees, but the shape of fruit on bisexual trees depends on environmental conditions, notably temperature, which alters floral morphology during the early stages of the inflorescence's development (Nakasone & Paull 1998).

When produced under identical agro-ecological settings, it was discovered that the weight, volume, and shape of a particular type of papaya fruit remained consistent. Fruit shape in papayas was a trait that was sex-linked. The fruit of female trees is spherical to ovoid in shape, whereas the fruit of hermaphrodite trees is long, cylindrical, or pear-shaped (Hofmeyr, 1936; Chan and Paull, 2008; Paull *et al.*, 2008).

c. Flesh thickness and colour

In papayas, yellow pulp colour was dominant over red pulp, as suggested by Storey (1937) and the flesh thickness ranged from 1.50 to 4.00 cm depending on the cultivar (Nakasone & Paull, 1998), whereas the flesh colour varies from pale yellowish to red (Villegas, 1997). Also, in the context of processing and table purposes, the demand for red pulp is higher than that for yellow pulp (Balamohan *et al.,* 2010). The ripe fruits and flesh of papayas ranged from yellow to salmon red (Aravind *et al.,* 2013).

The flesh thickness of papaya genotypes ranged from 1.86 cm to 3.37 cm. The highest flesh thickness was noted in Ace 5, while the lowest was noted in Ace 2 (Akhil, 2020).

d. Number of fruits per plant

Bose and Mitra (1985) reported that the number of fruits per plant was observed to be 11, 30-40, 35-40, 40, 50-60, 20 and 40 in the papaya cultivars Washington, CO 2, CO 3, CO 4, Solo, Coorg Honey Dew and Pusa Dwarf, respectively.

The fifteen papaya hybrids and selections that were grown in eastern India were assessed by Jana *et al.* (2010). They observed that the cultivar CO 3 produced the higher number of fruits/plant (51.00). An evaluation of local papaya varieties was carried out in Vietnam (Anh *et al.,* 2011). The results showed a significant difference among the varieties for the number of fruits, which ranged from 12 to 24 fruits per plant. Kumar *et al.* (2015) observed that, papaya genotypes showed a wide range of differences in the number of fruits per plant (19.67 to 60.73). They opined that the environmental factors had a significant impact on fruit production. Five papaya cultivars, Arka Surya, Madhu Bindu, Arka Prabhath, Pusa Dwarf and Red Lady, were evaluated by Tyagi *et al.* (2015) in Punjab. The findings showed that the fruit number (20.67-46.00) showed an observable variation, and in papaya cv. Red Lady (46.00) and Arka Prabhath (20.67), respectively, the higher and lower number of fruits were produced.

A study was conducted to evaluate the growth, yield and quality of different papaya types under northern Kerala condition (Akhil, 2020). The yield attributes, like number of fruits per plant and yield per plant, were found to be significantly different in all the papaya types. The higher number of fruits per plant and yield per plant were noticed in KAU Ace 1 (20.68 fruits planr^{1}) and Ace 5 (26.93 kg plant·

^{1}). He also opined that fruit yield has a positive correlation with fruit weight and the number of fruits in papaya.

e. Yield per plant and yield per hectare

Reni (1997) examined twelve papaya varieties under Vellanikkara conditions for yield, quality, and post-harvest characteristics. Papaya cv. CO-6 recorded the highest yield (52.5 kg), whereas Solo produced the maximum number of fruits. Lakshmi (2000) evaluated different papaya varieties in Kerala for their suitability for table purposes. The fruit yield of CO 2 was the highest of all the varieties. Out of fifteen papaya selection/hybrids examined, Jana *et al.* (2010) noticed that the papaya cv. Ranchi had the highest average fruit weight (2.04 kg) and yield per plant (34.92 kg). Tyagi *et al.* (2015) concluded that in terms of yield and fruit weight, there was a significant difference among the cultivars. On comparing the fruit weight and yield, the papaya cv. Red Lady recorded the maximum values for both characters (841.67 g and 38.84 kg, respectively).

Reshma *et al.* (2016) evaluated papaya varieties and accessions to identify the most promising ones that will grow well in Kerala. The papaya Acc. 15 recorded the highest value for fruit weight (1830 g), which was followed by CO-8 (1770 g). The highest yield per plant was recorded in Ace 25 (31.50 kg planr^{1}), followed by Acc. 6 (27.63 kg/plant) and Acc. 1 (26.57 kg/plant). The maximum number of fruits per plant (35.11) was produced by Acc. 25, followed by Acc. 1 (32.66), Acc. 5 (32.33), and Acc. 6 (30.11). According to Varu (2020), all the papaya selections and variety differed significantly in yield characters. The maximum number of fruits per plant, yield per plant and yield per hectare were produced by selection-4 (36.38, 33.81 kg planr^{1} and 84.52 kg ha-^{1}, respectively). The values of yield parameters ranged between 22.41-36.38 (number of fruits per plant), 18.97-33.81 kg planr^{1} (yield per plant) and 47.42-84.52 kg ha-^{1} (yield per hectare).

2.1.4. Fruit quality characters

a. Total soluble solids

According to Ram (1981), the total soluble solid (TSS) content of different papaya cultivars can vary from 6 to 13 °Brix. A study performed by Lakshmi (2000) on the evaluation of papaya varieties for table purposes noticed that the TSS of papaya varieties ranged from 11.60-14.78 °Brix. The highest TSS was recorded in the cv. Sunrise Solo (14.78 °Brix) followed by Thailand (13.95 °Brix), while the lowest TSS was recorded in the variety Pusa Dwarf (11.60 °Brix). Meena *et al.* (2012) assessed five cultivars of papaya, viz., Pusa Delicious, Pant Papaya-1, Pusa Nanha, Madhu Bindu and Arka Surya in Gujarat conditions. The highest TSS was reported by the variety Pusa Delicious (12.23 °Brix) followed by Pant Papaya-I (11.30 °Brix). The papaya genotypes Arka Surya and Arka Prabhath cultivated in Bangalore conditions were examined by Nirujogi and Dinesh (2012). After analysing the fruit quality parameter, the TSS of the fruits ranged from 8.64 to 13.94 ^{0}Brix in Arka Surya and 10.70 to 13.50 °Brix in Arka Prabhath.

In Punjab, five varieties of papaya, including Arka Surya, Madhu, Pusa Dwarf, Arka Prabhath, and Red Lady were assessed by Tyagi *et al.* (2015). Highest TSS (13.00 °Brix) and total sugars (7.90 °Brix) were reported in the cultivar Red Lady. Akhil (2020) evaluated the TSS content of 12 papaya genotypes and noticed that the TSS of papaya genotypes ranged between 8.97-14.71 °Brix.

b. Titrable acidity

Lakshmi (2000), on evaluating the papaya varieties to check their suitability for table purposes discovered that TNAU papaya variety CO2 recorded the highest acidity (0.23 %), whereas variety CO 4 recorded the lowest acidity (0.07 %) in their fruits. On the contrary, Akhil (2020) observed that the titrable acidity was lowest in the papaya cultivars CO2 (0.13 %) and Arka Prabhath (0.14 %).

In a field study, eight papaya cultivars and hybrids were assessed, including the Coorg Honey Dew, Pusa Dwarf, Pusa Majesty, Pusa Nanha, Washington, Arka

Surya, RCTP-1, and native dwarf varieties cultivated in Tripura (Das, 2013). The lowest acidity was recorded in the variety Arka Surya (0.13%), while the highest was noted in the variety Washington (0.22%).

c. Total carotenoid content

The findings of Lakshmi (2000) showed that the fruits of Sunrise Solo (2.48 mg 100 mg-^{1}) had the highest carotenoid content. The variety CO2 had the lowest carotenoid concentration (1.64 mg 100 mg-^{1}), followed by Pusa Dwarf (1.73 mg 100 mg-^{1}). Wall (2006) pointed out that the flesh colour of papaya fruits was governed by the carotenoids. All papaya cultivars that produce orange and yellow flesh contain carotenoids like p-cryptoxanthin and p-carotene. The concentration of esterified carotenoids was higher during ripening. So, they integrated into the membranes more quickly, thereby enhancing the fruit colour (Andersson *et al.*, 2008; Yahia and Ornelas-Paz, 2010).

Devitt *et al.* (2009) suggested that for plants to perform photosynthesis, carotenoid pigments are an important factor. In the chromoplasts of flowers, fruits, or seeds of many papaya species, carotenoids build up as secondary metabolites to produce distinctive coloration that ranges from yellow to orange and red. Also, the carotenoid content mostly affects the flesh colour of papaya fruits. The two main carotenoids identified in papaya fruits were lutein and alpha-carotene (peel) and lycopene (pulp). The rapid breakdown of chlorophyll and the presence of carotenoids like lutein and beta-carotene caused the colour change in the peel from green to yellow. Papaya varieties are of two types: red-fleshed and yellow-fleshed. Lycopene is the main carotenoid in the pulp of papayas with red flesh, whereas beta-carotene and beta-cryptoxanthin are the main carotenoids in papayas with yellow flesh (Saengmanee *et al.*, 2018).

Papaya is a fruit that contains a high proportion of carotenoid. Carotenoids can only be obtained from natural sources or dietary supplements since humans are unable to synthesise them. On account of their provitamin A and antioxidant percentage, carotenoids play an important role in human health (Shen *et al.*, 2019).

The carotenoid content in the papaya genotypes assessed by Akhil (2020) showed that the highest total carotenoid content was noted in the cv. CO 8 (3.18 mg/ 100 g^{-1}) followed by Arka Prabhath (3.14 mg/100 g^{-1}). The range of total carotenoid content falls between 1.58-3.18 mg/ 100 g^{-1}.

d. Ascorbic acid content

On an average, the vitamin C level of papaya fruit is 51.2 mg 100 g^{-1} (Charoensiri *et al.*, 2009; USDA, 2014). After anthesis, vitamin C levels were low between 91-133 days (21.2-36.9 mg 100 g^{-1}), then increased and reached a maximum at 161 DAA (77.8 mg 100 g^{-1}). Lycopene and beta-carotene contents were greater when grown in the shaded area compared to those grown in the sunlight-exposed area, whereas the sunlight had no effect on the TSS, dry matter, or vitamin C contents.

Das (2013) examined eight papaya varieties and hybrids, including the Coorg Honey Dew, Pusa Dwarf, Pusa Majesty, Pusa Nanha, Washington, Arka Surya, RCTP-1, and Local Dwarf types. Papaya cv. Coorg Honey Dew (67.37 mg 100 g^{-1}) had the highest ascorbic acid content, while cv. Arka Surya (59.63 mg 100 g^{-1}) had the lowest content. According to Lakshmi (2000), the highest content of ascorbic acid was recorded in the papaya cultivar CO 3 (131.26 mg 100 g^{-1}), whereas cultivar CO 5 (62.01 mg 100 g^{-1}) recorded the lowest value for ascorbic acid. Akhil (2020) observed that the ascorbic acid content of Arka Prabhath was found to be 83.93 mg 100 g^{-1}. The ascorbic acid content of these 12 papaya genotypes under study ranged from 44.03 to 93.37 mg 100 g^{-1}.

e. Sugar content

Reshma (2015) reported that a significant variation was noticed between the thirty papaya genotypes accessed for the fruit quality characters. The range of values observed for TSS, acidity, total sugars and reducing sugars were 9.90-15.17 ^{0}Brix, 0.133-0.285 %, 8.46-10.89 % and 7.57-10.49 %, respectively.

Reports from the study conducted by Akhil (2020) show that the highest percentage of total and reducing sugar was found in papaya cv. Red Lady (10.12 % and 9.46 %). The concentrations of total and reducing sugars in cv. Arka Prabhath were recorded to be 9.75 % and 9.13 %, respectively.

f. Shelf life

Two gynodioecious papaya varieties, Arka Surya and Arka Prabhath, were assessed by Nirujogi and Dinesh (2012) in Bangalore. The pulp of both Arka Surya and Arka Prabhath was deep pink in colour; however, Arka Surya had better keeping qualities, retaining fruit for 3.5-7.12 days as compared to 5.92-10.02 days in Arka Prabhath. Akhil (2020) recorded that the fruits of Arka Prabhath could retain their quality for 8.23 days.

2.2 EFFECT OF FERTIGATION AND SPACING LEVELS IN PAPAYA UNDER HIGH DENSITY PLANTING SYSTEM

The conventional system of water and fertilizer application was found to be less efficient in papaya, due to the increased leaching losses of water and fertilizer. This will make it unavailable for the plants to absorb an adequate quantity of water and fertilizer to meet the crop demand. Water is an essential resource for the sustainable development of fruit crops that requires careful monitoring and management in order to attain improved water use efficiency. The irrigated area under horticulture crops in India is expected to rise in the near future. So scientific management of water resources is required to optimally utilise available water for fruit crops. According to Bhardwaj *et al.* (1995), the uniform distribution of water to young fruit trees via drip irrigation had a positive influence on plant vegetative growth. Drip irrigation effectively boosted vegetative growth parameters over basin irrigation, and the positive influence on plant vegetative growth might be attributed to the continuous supply of water to the plants. This retains the soil moisture and prevents water stress in the plant, resulting in enhanced vigour (Subramanian *et al.*, 1997). This improved growth under drip could be attributed to the increased turgidity of cells, which leads to cell expansion and improved cell wall development

(Viers, 1972). Moreover, water supplied to the crops through drip irrigation is in the form of water droplets that wet the root zone of the plant alone, reducing leaching of water and surface evaporation. Drip irrigation will not only help in the efficient and judicious use of irrigation water but also reduce tillage, produce high quality fruits, increase crop yield, and increase fertiliser use efficiency (Qureshi *et al.,* 2001). Hence, drip irrigation reduced the water requirement (45-50 per cent), fertilizer usage (25-30 per cent) and human labour (40-50 per cent) according to the reports of INCID (1994).

While considering fertilizer losses, one of the best remedy to increase fertilizer use efficiency is to adopt fertigation. In this technique, optimum quantities of water and fertilizer will reach the root zone of the crop in the form of droplets through the drip irrigation system (Goldberg and Shmueli, 1970). As vegetative growth and flowering occur concurrently in papaya, it is critical to provide adequate nutrients at optimal levels during the active growth stage (Kumar *et al.,* 2008). According to Manohar *et al.* (2001), fertigation greatly enhanced fertiliser nutrient savings by up to 25 per cent without compromising crop yield when compared to the conventional technique of nutrient application. Fertigation decreases nutrient loss by delivering nutrients directly to the active root zone, thus increasing the quantity and quality of farm output. The split application of fertilisers, along with frequent supplies of water through drip, enhances fruit yield and quality due to increased uptake of nutrients compared to the traditional practise of fertiliser application. Fertigation enhanced the yield in papaya in addition to saving fertilizers and water by up to 50 and 53 per cent respectively (Chaudhri *et al.* 2001). Similar observations were made by Deshmukh and Hardaha (2014), wherein there was a 45 to 66 per cent water saving and a 21 to 36 per cent increase in yield by drip irrigation over the conventional method of papaya cultivation.

The cultivatable land area has been shrinking all these years, whereas the input costs of fertilizers, human labour, and irrigation have increased tremendously. It is high time to switch to a high-density planting system (HDP) which increases the number of plants accommodated per unit area of land. It makes use of both vertical and horizontal space to get the maximum possible output per unit area without impairing the soil fertility status. The HDP system coupled with fertigation helps reduce human labour by adding mechanised operations in the plot like fertilizer application, irrigation, weeding and harvesting. So, to fetch the maximum possible output from a unit area, it is a better idea to combine fertigation with an **HDP** system in our papaya orchards.

This chapter contains a variety of literature referring to the key works on the effect of spacing and fertigation on papaya. It has been divided into various subsections, as follows:

2.2.1 Effect of fertigation and spacing on biometric characters

a. Height of plant

The impact of different spacing levels on papaya variety CO 2 was assessed by Rajasekharan (1975). He observed that wider spacing reduced plant height in papaya. In the papaya cultivar Ranchi, it was observed that an increase in plant density increased the height of plant and number ofleaves, whereas it decreased the stem girth, plant spread and petiole length (Biswas *et al.*, 1989).

Shukla *et al.* (2001) reported that highest plant height was observed under the closer spacing of 1.25 x 1.25 m in the papaya variety Pusa Delicious, whereas higher stem girth was noticed in wider spacing. Split application of fertiliser through drip irrigation might have contributed to an increased uptake of nutrients during the growth phase, which contributed to enhanced protein and protoplasm synthesis, ultimately leading to better growth and development of the crop. (Sharma *et al.*, 2005; Sagvekar *et al.*, 2019). In an experiment conducted by Sadarunnisa *et al.* (2010) to evaluate the effect of fertigation on the growth and yield of the papaya variety Red Lady found that the plant height was highest in treatment with 100 % recommended dose of fertlizers (RDF) ofN and K (220.50 cm) followed by 75 % recommended dose of fertlizers (RDF) (217.50 cm) of N and K. Bhalerao *et al.* (2009) reported an increase in plant height of 185 cm in banana cv. Grand Naine, by the application of 100 % RDF of N and K through fertigation. Meanwhile, the plants subjected to soil application of 100 % RDF were observed to have a height of 180 cm.

According to Patel *et al.* (2017 b), the sapota plants of variety Kalipatti that received 100 % RDF of N, P and K through fertigation showed highest plant height, followed by 75 % RDF ofN, P and K. The lowest plant height was reported for the control plants.

Shashikant *et al.* (2022) reported that the papaya plants that received fertigation doses of 120 % RDF showed highest plant height followed by 100% RDF.

b. Girth of plant

Arango *et al.* (1986) observed that with the decrease in planting distance, the height of the plant and flowering height generally increased in papaya, whereas the stem diameter and number ofleaves generally decreased. Also, it was noted that planting distance had no influence on the number of nodes to the first flowering nor the number of days from transplanting to flowering. The increase in trunk diameter could be attributed to increased nutrient intake and storage in leaf tissues, which in tum ensure photosynthetic efficiency, resulting in increased carbohydrate synthesis, translocation, and accumulation (Ghanta *et al.*, 1995).

Fertigation in the papaya variety Red Lady receiving 100 % RDF ofN and K2O was observed to have highest stem girth at 180 DAP (28.33 cm), 270 DAP (42.21 cm) and 360 DAP (48.15 cm). The lowest stem girth was reported in the plants supplied with 60 % RDF of N and K2O at 180 DAP (22.39 cm), 270 DAP (36.50 cm) and 360 DAP (42.09 cm) (Babaji, 2013). In an experiment to study the effect of different levels of fertigation in banana (50 %, 60 % and 80 % RDF of NPK), Pramanik and Patra (2016) noted that vegetative growth parameters like plant height (304.30 cm) and pseudostem girth (75.48 cm) were highest in the plants subjected to 80 % RDF, followed by 60 % RDF with a plant height of 293.58 cm and a pseudostern girth of 70.53 cm. Prajapathi *et al.* (2017) revealed that at 270 days after transplanting in papaya, highest plant height (171.24 cm) and stern girth (36.85 cm) were observed in plants supplied with drip irrigation with 100% RDF ofN, P, and K. This may be attributed to the presence of sufficient doses of nutrients that boosted the synthesis of IAA, which in turn stimulated cell elongation and increased plant height and stern girth (Meena *et al.*, 2020). Sebastian (2021) reported that the stern girth of plants that received 100 per cent recommended doses of N2 and K2O through drip was found to be superior (37.01 cm) to 75 per cent recommended doses ofN2 and K2O (30.92 cm) in the papaya variety Arka Surya.

c. Number of leaves

Kawarkhe (2002) observed that the highest plant spread and number of leaves were noticed under wider spacing. Mathew (2005) reported that a spacing of up to 1.50 rn x 1.50 rn did not show any negative impact on the number of leaves in papaya. However, at a spacing of 1.25 rn x 1.25 rn, there was a notable reduction in the number of leaves per plant. Sadarunissa *et al.* (2010) evaluated the effects of fertigation on the vegetative characters of papaya cv. Red Lady. They had observed that the maximum number of functional leaves were recorded in the plants that received 100 % RDF ofN and K2O (45.50), followed by 75 % RDF (43.25) and 50 % RDF (34.75). The least number of functional leaves was reported in those plants supplied with conventional irrigation and 100% RDF of N and K2O through soil application (31.50).

According to Singh *et al.* (2008), it was apparent that the plant height of papaya plants was highest in closer spacing, whereas the number of leaves was higher in wider spacing. Similarly, when compared to the other spacings, papaya plants planted at a closer spacing of 1.0 x 1.0 rn were found to have the maximum number of flowers (64.00). On studying the effect of fertigation on papaya cv. CO.7, maximum plant height (268 cm), stern girth (43.2 cm) and number of leaves (34.2) were noted in 100% RDF ofN and K2O (Jeyakurnar *et al.*, 2010).

Babaji (2013) investigated the effect of fertigation and mulching on the yield of papaya cv. Red Lady and suggested that the highest number of functional leaves were noted in 100 % RDF of N and K2O on 180 (24.25), 270 (34.80), and 360 (44.97) DAP. Meanwhile, the lowest number ofleaves were observed in 60 % RDF ofN and K2O on 180 (21.28), 270 (30.89), and 360 DAP (39.62). According to Maneesha *et al.* (2019), the application of 100 % RDF of N and K2O through fertigation on a weekly basis resulted in an increase in the number ofleaves (17.82) in pineapple cv. Gaint Kew during the crop establishment stage. The lowest number of leaves was noted in plants supplied with conventional irrigation and soil application of fertilizers. The result from the experiment conducted by Sebastian (2021) suggested that the number of leaves increased with the increase in doses of N and K2O through drip. The number of leaves was higher (21.00) in plants of the papaya variety Arka Surya supplied with 100 % RDF of N and K2O than those subjected to 75 % RDF ofN and K2O (16.56).

d. Height at first flowering

Reddy et al. (1989) and Kumar (1995) proposed a relationship between elevated fertiliser levels and reduced flowering height in the treatment plants of papaya. Similarly, the first flowering height of fertigated papaya plants was low, according to Jeyakumar *et al.* (2010). Therefore, the CO 7 variety plants that received 100% RD ofN and K2O displayed a lower height of96.32 cm. The height at first flowering was highest in control plants (103.41 cm). This was most likely due to the effective and timely absorption of nutrients by the plants. According to the findings of Mathew (2005), the height at first flowering decreased as the plant-to-plant spacing increased. So, the wider spaced plants produced flowers at a lower height compared to the closely spaced plants.

Valji (2011) found significant changes in height at first flowering in papaya var. Madhu Bindu subjected to different fertigation treatments. The papaya plants that obtained 80 % RD of N and K20 by fertigation flowered at the lowest height (60.45 cm), followed by fertigation at 100% RD ofN and K20 (62.65 cm), whereas the plants that obtained 100% RD of N and K20 through soil application (control) registered a flowering height of 74.71 cm. Plants fertigated with 60% RD ofN and K20 had the highest value for height at first flowering (83.28 cm). Fertigation of papaya variety "Red Lady" in Navsari (Gujarat) conditions resulted in a lowest height at first flowering (76.57 cm) in 100% RD ofN and K20, while papaya plants that received 80% and 60% RD ofN and K20 flowered at 78.74 cm and 84.16 cm, respectively (Parag *et al.*, 2016).

e. Days to flowering

While carrying out spacing trials with papaya cv. Ranchi, Kumar *et al.* (1989) discovered that as plant density increased, flowering was delayed, flowers and fruits per plant and fruit weight per plant were reduced. They proposed that it might be due to increased competition between the closely spaced plants for nutrients and water and also due to the lesser availability of sunlight and water for photosynthesis. On studying the effect of different planting density on papaya, Mathew (2005) observed that the days taken for first flowering decreased as the plant spacing increased. Banana plants of cv. Grand Naine that received 100 % RDF of N and K2O through fertigation flowered in 282 days (Bhalerao *et al.*, 2009), whereas plants that received 100 % and 50% RDF of N and K20 through soil flowered in 291 days and 299 days, respectively.

Valji (2011) found that plants of papaya var. Madhu Bindu that received drip irrigation with 100 % RDF of N and K2O, flowered considerably earlier (69.10). While, the plants that received drip irrigation with 60 % RDF ofN and K20 recorded more days (91.27) for the initial appearance of the flowers after transplanting. Under Gujarat (Navsari) conditions, a study was conducted by Babaji *et al.* (2013) on the effect of fertigation on the papaya variety Red Lady. They observed that 100 % RDF of N and K20 exhibited the lowest number of days to flowering (108.58), while 60 % RDF ofN and K20 recorded the highest number of days to flowering (122.56).

An experiment on the effect of different levels of fertigation on papaya cv. Arka Surya revealed that the lowest number of days to first flowering was observed in 125 % RDF ofN and K (159.22), followed by 100 % RDF ofN and K (161.22) (Sebastian *et al.*, 2021).

f. Sex expression

The application of 50 % of RDF through fertigation has resulted in higher number of hermaphrodite (63.05) flowers per plant in pomegranate cv. Mridula, which was followed by 75 % RDF by fertigation (57.70) (Shanmugasundaram, 2013). The control plants, on the other hand, had fewer hermaphrodite flowers per plant (39.30). According to the study conducted by Thanari and Suma (2018), it was found that pomegranate plants getting 100 % RDF through fertigation produced more hermaphrodites (107.0) and male flowers (92.0), while treatments receiving 100 % RDF through soil application produced fewer hermaphrodites and male flowers (84.0 and 78.0).

g. Number of flowers/cluster

Highest number of flowers per plant, number of fruits per plant, fruit weight and yield per plant were recorded under the widest spacing treatment, whereas estimated yield per ha showed an increasing trend with increasing plant density in guava cv. L49 under ultra high density planting in Rajasthan conditions (Kumawat *et al.*, 2014).

Shanrnukhi *et al.* (2018) discovered that fertigation with higher doses of fertilizers increased the number of flowers per cluster of plant compared to fertigation with lower doses.

h. Fruit set percentage

In a study conducted to understand the effect of fertigation in ultra high-density planting of the mango variety Alphonso, Prakash *et al.* (2015) discovered that there was a strong relationship between fruit set percentage and the level of fertilizer applied. The higher the dose of RDF, the higher the percentage of fruit set.

The plants that received 100 % RDF of NPK exhibited a higher fruit set percentage (0.35 %) whereas 50 % RDF ofNPK gave the lowest fruit set percentage (0.29 %).

i. Days to first harvest

Bhalerao *et al.* (2009) opined that those plants of the banana cultivar Grand Naine that received 50% RD of N and K2O through fertigation took more days to harvest their fruits than those that received 100 % RD of N and K2O through fertigation. According to the findings of Valji (2011), there was a significant influence of various fertigation levels in papaya var. Madhu Bindu on the number of days from transplanting to fruit maturity. Hence, the minimum number of days (249 days) required for fruit maturity was recorded in the treatment that received drip irrigation at 0.8 PEF coupled with 100 % RD of N and K2O, while the maximum number of days (278 days) to fruit maturity was observed in drip irrigation at 60 % RD ofN and K2O and 0.4 PEF.

The pomegranate cv. Mridula supplied with fertigation@ 125 per cent RDN recorded the lowest number of days (141.85 days) from flowering to harvest, whereas plants supplied with fertigation @100 per cent RDN exhibited 142.73 days from flowering to harvest. The control treatment recorded the highest number of days (145.90 days) from flowering to harvest (Shanmugasundaram, 2013).

2.2.2. Effect of fertigation and spacing on yield characters

a. Fruit weight

According to Camejo and Alvarez (1983), the planting density did not show any significant effect on the fruit weight of papaya. The fruit weight of the papaya variety Ranchi increased with a wider spacing, while the lowest was recorded in closely spaced plants. This may be due to the increased competition for water and nutrients and the lesser availability of sunlight and carbon dioxide for photosynthesis among the closely spaced plants (Kumar *et al.*, 1989).

The effects of different fertigation levels (100, 80, and 60 % of RDF) on the fruit weight of papaya cv. Red Lady were assessed by Jadhav *et al.* (2016). The findings from their study indicated that plants receiving 100 % RDF produced fruits with the highest average weight (1.12 kg), while the lowest average fruit weight (0.83 kg) was noted in plants receiving 60 % RDF. According to Godi *et al.* (2020), the fruit weight of papaya cv. Red Lady increased as the level of fertigation dose increased. The highest fruit weight was observed in plants supplied with a fertigation dose of 125 per cent RDF (1.50 kg), followed by 100 per cent RDF (1.40 kg). Similar observations were made by Shashikant *et al.* (2022) in fertigated plants of papaya. The plants that received 120 % RDF recorded highest number of fruits per plant, fruit weight, per plant fruit yield and per hectare fruit yield followed by 100 % RDF treatment.

b. Fruit length and fruit girth

Thakur and Singh (2004) reported that application of 100% of the recommended dose through fertigation recorded the highest fruit weight, pulp weight, length and breadth of mango cv. Arnrapali. Similar conclusions were drawn by Chauhan and Chandel (2008) on the impact of fertilizer dose on yield and size of fertigated kiwi fruits. They noticed that 100 per cent of the recommended dose of N, **P,** and K fertilizers resulted in highest fruit weight, length and diameter, closely followed by 75 per cent of the recommended dose ofN, P, and K. These treatments were superior to the 50 per cent and 25 per cent recommended doses of N, P, and K, which might be due to the increase in the synthesis of metabolites and their translocation to fruits in relation to the higher nutrient level.

According to the findings from the experiment conducted by Mathew (2005), it was reported that increase in plant spacing increased the length, girth, and volume of papaya fruits. Deshmukh and Hardaha (2014) observed that the application of 100% CPE and 100% RDF increased the length and diameter of the fruits along with the yield in papaya cv. Red Lady. In papaya cv. Red Lady, adoption of 100% RDF (200 g N, 200 g P2O, and 250 g K2O) through fertigation resulted in significantly longer fruits (22.93 cm), whereas plants obtaining 60% RDF through fertigation had shorter fruits (18.63 cm) (Jadhav *et al.,* 2016).

Shashikant *et al.* (2022) opined that plants that received 100 % CPE + 120 % RDF through fertigation produced fruits with highest fruit length (42.00 cm) and fruit diameter (9.45 cm) in the papaya, followed by the fruits of plants fertigated with 100 % CPE + 100 % RDF for fruit length (40.00 cm) and fruit diameter (9.20 cm).

c. Fruit volume

Taking into consideration the effect of fertigation on the fruit volume of papaya var. Madhu Bindu, Valji (2011) observed that the highest fruit volume (1357.05 cc) was recorded by the plants receiving fertigation at 100 % RD ofN and K20. Meanwhile, the plants supplied with N and K20 at 60 % of RD were reported to have the lowest fruit volume (1027.44) among the other treatments.

Mounashree *et al.* (2018) observed the effect of different levels of fertigation doses on the yield of strawberry cv. Sabrina. Those plants supplied with 100 % RDF through fertigation recorded highest fruit weight, fruit volume, yield per plant, fruit length and diameter, immediately followed by 75 % RDF.

d. Flesh thickness

According to Biswas *et al.* (1989), the flesh thickness of papaya cv. Ranchi increased with closer spacing, accommodating more plants per hectare than the wider spaced ones. Jadhav *et al.* (2016) conducted research on Papaya cv. Red Lady to study the effect of fertigation on its pulp thickness. According to their findings, plants receiving 100% RDN through fertigation had the highest pulp thickness (3.33 cm), whereas plants receiving 60% RDN had the lowest pulp thickness (3.06 cm) among the other treatments.

e. Number of fruits per plant

Singh *et al.* (2008) studied the effect of spacing levels on the growth and yield of papaya. They observed that the number of fruits increased with an increase in plant spacing in papaya. This can be attributed to the increased availability of sunlight and an increase in the C:N ratio of widely spaced papaya plants.

Jayakumar *et al.* (2010) studied the effect of fertigation on yield characteristics of the papaya variety Red Lady. They found that fertigation with 100 per cent **RD** ofN and K2O produced the maximum number of fruits per plant (40.2), followed by 75 per cent RD of N and K2O (38.5). The least number of fruits were recorded in the plants receiving fertigation@ 50 per cent RD of N and K2O (33.5). According to research by Sadarunnisa *et al.* (2010), treatments receiving the recommended dose of nutrients through soil (54.88) produced fewer fruits per plant than those receiving fertigation applications of 75% RD of N and K2O (74.39).

The highest number of fruits per plant was noticed in the plants supplied with 100 per cent RDF of N and K2O through fertigation in the papaya variety Red Lady, while the lowest number of fruits per plant was recorded in the treatment plants receiving N and K2O at 60 per cent RDF (Babaji, 2013). The findings of Deshmukh and Hardaha (2014) on the effect of fertigation on the papaya cv. Red Lady suggests that fertigation with 100 % RDF gave the maximum number of fruits per plant (35.00), followed immediately by 80 % RDF (31.00). The lowest number of fruits per plant (22.00) was noticed in the control treatment receiving the conventional method of irrigation and fertiliser application. Sagvekar *et al.* (2019) opined that the number of fruits per plant, average fruit weight, and yield per hectare have a positive correlation with the increase in the RDF level applied through drip water in papaya cv. Red Lady.

A study was conducted by Sebastian *et al.* (2021) to evaluate the influence of fertigation and foliar sprays on the yield characters of papaya cv. Arka Surya. Among the water spray treatments, the maximum number of fruits per plant was observed in the treatment with 100 % RD ofN and K2O (37.22) followed by control (conventional method of irrigation and soil application of full dose of fertilizers). The least number of fruits per plant was recorded in the treatment plants receiving 75 % RD of N and K2O coupled with the water spray. The reports from the experiment conducted by Shashikant *et al.* (2022) on the impact of fertigation on the growth and yield of papaya suggest that fertigation with 100 per cent irrigation of CPE coupled with 120 per cent RDF produced the highest number of fruits (26.00), followed by the treatment supplying 100 per cent irrigation of CPE and 100 per cent RDF (24.00).

f. Seeds per fruit

Ghanta *et al.* (1994) observed that an increase in planting density increased the number of seeds per fruit of papaya plants.

g. Fruit yield

In the banana variety Robusta, the biomass production per plant was found to increase as the planting distance increased (Reddy, 1982). Anil (1994) stated that in tissue culture banana a wider plant spacing showed a higher biomass accumulation as compared to the closer spacing.

The report of the study conducted by Babaji (2013) suggested that there was a significant difference in yield per plant of papaya cv. Red Lady subjected to different fertigation treatments. The plants treated with 100% RDN of N and K2O via drip irrigation exhibited the highest yield per plant (31.03 kg), whereas those plants that received 60% RDN of N and K2O recorded the lowest yield per plant (16.60 kg). Deshmukh and Hardaha (2014) found that there was a significant difference in the yield of papaya cv. Red Lady subjected to different levels of fertigation. The highest yield per plant was observed in the plants that received 100 per cent RDF ofN and K2O (73.97 kg), followed by 75 per cent RDF ofN and K2O (62.21 kg) and control treatment with soil application of fertilizers (55.70 kg). The plants supplied with 50 per cent RDF of N and K2O (62.21 kg) marked the lowest yield per plant (45.56 kg) among the treatments.

Prajapati *et al.* (2017) investigated the effects of fertigation on papaya yield characteristics. In terms of fruit yield per plant, 100 % RDN produced the highest yield (22.38 kg), whereas conventional methods of soil application and irrigation produced the lowest yield (14.94 kg). Sebastian *et al.* (2021) studied the influence of fertigation levels along with different foliar sprays on the papaya variety Arka Surya. Among the fertigation treatments coupled with water sprays, the 100 per cent RD ofN and K20 was reported to have the highest yield per plant (23.62 kg), while the lowest yield per plant was noticed in the fertigation level of 75 per cent RD ofN and K20 (16.21 kg).

Shashikant *et al.* (2022) reported the highest yield per plant (57.20 kg) and yield per hectare (143 T ha^{-1}) in the papaya plants drip irrigated with 100 CPE coupled with 120 per cent RDF. It was followed by the treatment combination of 100 CPE and 100 per cent RDF (48.00 kg and 120.00 T ha^{-1}).

As the planting density of papaya increased from 1250 to 2500 plants ha^{-1}, yield per plant declined from 40.8 to 22.1 kg, according to the study by Camejo and Alvarez (1983). The highest yield (kg ha^{-1}) was obtained at a closer spacing with an intermediate planting density of 2500 plants ha^{-1}, while the lowest yield was obtained at a wider spacing with a planting density of 1250 plants ha^{-1}. The highest yield (27-28 t ha^{-1}) was recorded in trees planted at a wider spacing than closer ones (Arango *et al.,* 1986; Olalde *et al.,* 1986).

In papaya cv. Ranchi, Biswas *et al.* (1989) found that increasing the planting density delayed the time of flowering, decreased the number of fruits per plant, fruit weight, and yield per plant, but increased the yield per hectare of papaya orchard as the planting density increased. Similar conclusions were drawn by Ghanta et al. (1994) on the yield per hectare (98.73 t ha^{-1}) of papaya plants planted at a closer spacing with a plant population of 4444 plants ha^{-1}. According to the reports of Deshmukh and Hardaha (2014), the highest yield per hectare of papaya was reported in drip irrigation at 100 % CPE with 100 % RDF (225.10 T ha^{-1}), followed by 80 % and 60 % RDF (197.30 T ha^{-1} and 181.70 T ha^{-1}, respectively) at 100 %

CPE. An increase in yield was observed in the papaya variety Pusa Nanha planted under high density planting at a spacing of 1.25 m x 1.25 m accommodating about 6400 plants per ha (Mishra and Goswami, 2016). Papaya exhibited the highest fruit yield per hectare (75.94 t ha^{-1}) when 100 % RDN was applied by fertigation, whereas conventional irrigation systems produced the lowest fruit yield of 46.11 t ha^{-1} (Prajapati *et al.*, 2017).

Godi *et al.* (2020) investigated the influence of irrigation and fertilizer level through drip on the yield characters of papaya variety Red Lady. They concluded that the number of fruits per plant, yield per plant and yield per hectare increased directly proportional to the amount of fertilizer in all the treatment plants, with the highest value recorded by the fertigation level of 125 % RDF, followed by 100 % RDF.

i. Days to fruit maturity and ripening

In papaya cv. Madhu Bindu plants receiving drip irrigation at 0.8 PEF together with N and K20 at 100% RDF, fruits matured early for harvest (249.00 days). While in the treatments receiving drip irrigation at 0.4 PEF and N and K20 at 60% RDF, fruits matured late (278.00 days), as observed by Tank *et al.* (2011).

Jadhav *et al.* (2016) observed that plants supplied with a fertigation level of 100 % RDF took a lesser number of days to fruit maturity in the papaya cv. Red Lady. According to Parag *et al.* (2016), papaya cv. Red Lady took a minimum number of days to reach fruit maturity (260.99 days) after receiving 100% RDF through fertigation. Meanwhile, it took more days for fruit maturity (276.90 days) in those plants receiving 60 % RDF. The lesser number of days from transplanting to fruit maturity was recorded by plants fertigated with 100% RDF (299.56), while 75 % **RDF** treatment took the maximum number of days (327.56) for fruit maturity, as reported by Sebastian *et al.* (2021).

2.2.3. Fruit quality characters

a. Total soluble solids, titrable acidity and sugar content

Arango *et al.* (1986) observed that planting distance did not affect the fruit quality of papaya fruits, whereas Biswas *et al.* (1989) reported that total soluble solids and total sugar concentration in papaya fruits increased with a wider plant spacmg.

Jeyakumar *et al.* (2010) studied the effect of fertigation on quality attributes of papaya cv. CO 7 and noticed that drip irrigation with 100 per cent RDF ofN and K2O resulted in highest total soluble solid content (11.4 %), total sugars (8.85 %), and lowest titrable acidity (0.14 %) in the papaya fruits.

While a low total soluble solid and reducing sugar content (5.96 °Brix and 6.89 %, respectively) was recorded in plants receiving fertigation@ 60% RD ofN and K2O, application of N and K2O at 100% RD of N and K2O resulted in the highest total soluble solids (7.47 °Brix) and reducing sugar (8.44 %) in papaya cv. Red Lady (Babaji, 2013).

In the context of different fertigation levels, the use of 100 % RDF of N, P and K led to higher TSS, total sugars, carotenoids and ascorbic acid levels in mango var. Alphonso, whereas the use of 50 % RDF recorded the lowest value with respect to these parameters (Prakash *et al.*, 2015). Adequate doses ofN, P and K fertilizers are important to obtain better fruit quality in mango. Likewise, Colapietra (1987) and Sadarunnisa *et al.* (2010) observed similar behaviour with grapes and papaya, respectively.

According to Pramanik and Patra (2016), the highest total soluble solid concentration (23.51 °Brix) was recorded in the banana cv. Martaman fertigated with 100 % of RDF. The plants receiving 50 % of RDF through fertigation were reported to have the lowest value for total soluble solids (21.21 °Brix).

Patel *et al.* (2017 a) investigated the effects of fertigation on the biochemical characteristics of sapota cv. Kalipatti. The plants getting 100 % RDN had the highest TSS of 19.30 °Brix, whereas the plants receiving 50 % RDN had the lowest TSS of 18.30 °Brix.

The observations recorded by Sebastian (2021) on the effect of different levels of fertigation and foliar sprays on papaya cv. Arka Surya showed that, among the water spray treatments, plants that received 100 per cent RDF of N and K2O recorded highest values for total soluble solids (14.01 0 Brix), total sugar (8.73 %), reducing sugar (7.21 %), non-reducing sugars (1.51 %) and sugar-acid ratio (51.35) and a lowest value for titrable acidity (0.17 %).

According to the research conducted by Gawade *et al.* (2022) on the influence of fertigation levels on banana cv. Grand Naine, quality attributes like total soluble solids (23.02 °Brix), titrable acidity (0.16 %), total sugar (19.90 %), reducing sugar (12.70 %) and non-reducing sugar (7.20 %) were at their maximum in the plants supplied with 100 per cent RDF through fertigation. The lowest values for all the above attributes were noticed in the control plants supplied with 100 per cent RDF through soil application.

b. Ascorbic acid

Singh *et al.* (1999) and Kumar *et al.* (2000) reported that spacing level did not show any significant effect on the fruit quality parameters like pulp percentage, peel percentage, total soluble solids, total sugars and ascorbic acid content of papaya fruits.

In papaya cv. CO 7, plants getting 100 % RD of N and K2O through drip recorded the highest ascorbic acid content (69.54 mg g^{-1}), and plants receiving 50 % RD of N and K2O through drip recorded the lowest value (62.10 mg g^{-1}) (Jeyakumar *et al.*, 2010).

Sebastian *et al.* (2021) observed that 125 per cent RDF of N and K2O supplied through fertigation recorded highest ascorbic acid content (63.59 mg 100 g^{-1}) in papaya fruits, followed by 100 per cent RDF ofN and K2O (62. 91 mg 100 g^{-1}). The lowest content of ascorbic acid was found in the fruits that received fertigation@ of 50 per cent RDF ofN and K2O (43.42 mg g^{-1}).

c. Total carotenoids

Jeyakumar *et al.* (2010) investigated the effect of different fertigation levels on the total carotenoid content of papaya cv. CO 7 and observed that there was no significant difference between the fertigation treatments. The plants supplied with 60 per cent RDF recorded the highest content of total carotenoids (3.51 mg 100 g-1) followed by the control treatment (3.48 mg 100 g^{-1}) supplied with RDF through soil application. The plants receiving 100 per cent and 80 per cent RDF produced fruits with lowest carotenoid content of 3.46 mg 100 g^{-1} and 3.45 mg 100 g^{-1} respectively.

According to Tank *et al.* (2011), the total carotenoid content of fruits of the papaya variety Madhu Bindu did not show any significant difference with respect to different levels of fertigation. A higher total carotenoid content of 2.33 mg 100 $g^{-1}$of pulp was recorded by plants receiving drip irrigation at 0.4 PEF along with N and K2O at 60 % RDF, while a lower carotenoid content (2.17 mg 100 g^{-1} of pulp) was noted in treatments getting drip irrigation at 0.8 PEF combined with N and K2O at 100 % RDF.

d. Shelf life

The results from the study conducted by Sebastian (2021) showed that the shelf life of the papaya fruits increased with the increase in the level of RDF of N and K2O supplied through fertigation. Maximum shelf life was observed in 125 % and 100 % RDF ofN and K2O (4.56 days) followed by the control treatment (4.44 days). Minimum days of shelf life were observed in 75 % RDF of N and K2O through drip (3.78 days).

e. Sensory evaluation

The analysis of organoleptic characteristics indicated the superiority of fruits grown with wider spacing. The organoleptic characteristics of papaya fruits decreased as plant spacing decreased (Mathew, 2005).

According to Haneef *et al.* (2014), fertigation with 125% RDN in pomegranate cv. Bhagwa produced the highest overall organoleptic score of 7.52, followed by fertigation with 100% RDN (7.46). The lowest score was obtained with 50% RDN (6.94) through drip.

2.2.4. Pest and disease incidence

When plants are fertigated with an excessive amount of nitrogen, they become more susceptible to pests and diseases and lose marketable quality (Batal *et al.*, 1994). Similarly, Patnaik *et al.* (1998) noted that the use of a balanced fertiliser dose resulted in good quality fruits with less damage.

2.2.5. Soil analysis

Tank and Patel (2013) investigated the impact of various fertigation levels on the soil nutrient status of papaya var. Madhu Bindu. The findings showed that the plots that were treated with higher levels of fertiliser recorded higher levels of available N and K and that the phosphorus status of the soil after various treatments was not significantly different. Similarly, Sebastian (2021) registered a similar trend in the nutrient status of soil subjected to fertigation and foliar sprays, wherein she observed that phosphorous content did not show any significant variation with respect to different levels of fertigation supplied to the papaya plants.

2.2.6. Content of primary secondary and micro nutrients

Jeyakumar *et al.* (2010) investigated variations in the leaf nutrient content of papaya cv. CO 7 following application of various doses of fertigation. The maximum leaf N and leaf K were obtained with 100 % **RD** of N and K20 by drip

(1.72 % and 2.91 %, respectively). The leafN and K content of control plants (full dose of fertilizers through soil application) were 1.37 % and 2.46 %, respectively. Plants receiving 50 % RD ofN and K2O through drip had the lowest leafN and K levels (1.28 % and 2.23 %, respectively).

Valji (2011) came to the conclusion that various fertigation treatments considerably affected the leaf nitrogen content of papaya (*Carica papaya* L.) var. Madhu Bindu. Highest contents of leaf nitrogen (1.82%), potassium (2.91%), and phosphorus (0.43%) were found in the papaya leaves of plants receiving drip irrigation at 0.8 PEF coupled with N and K2O at 100% RD. The papaya plant grown under drip irrigation at 0.4 PEF and N and K2O at 60% RD was found to have a lowest nitrogen (1.15%), potassium (2.25%), and phosphorus content (0.38%) in the leaves. Similar results were noted by Sebastian (2021), suggesting no significant difference in the phosphorous content of papaya leaves subjected to different fertigation and foliar sprays,

The analysis of the nutritional status of papaya leaves revealed that fertigation had significant effect on the nitrogen and potassium levels of papaya leaves but not on the phosphorus content (Tank and Patel, 2013).

2.2.7. Economic analysis

According to Reddy (1995), a reduced plant density increased the cost-benefit ratio in papaya cv. Coorg Honey Dew. The net profit and B:C were higher at a closer spacing of 1.50 m x 1.50 m.

Singh *et al.* (2006) observed that fertigation led to greater fruit development and maturation in pomegranate cv. Ganesh, which resulted in well-developed fruits that can fetch a decent price in the market.

The study conducted by Pandey *et al.* (2013) gave an insight into the influence of drip irrigation, fertigation and dripper spacing on the cost of papaya cultivation. They found that closer dripper spacing increased the yield and income of the papaya orchard, while a wider dripper spacing improved the water saving percentage and reduced the disease and weed incidence in the orchard.

The cost of cultivation analysis by Godi *et al.* (2020) found that 120 per cent RDF maximized the net returns (Rs. 1014878 ha-^{1}) and B:C ratio (2.11) in the Red Lady papaya orchard. It was followed by 100 per cent RDF for net returns (Rs. 946699 ha-^{1}) and a B:C ratio of 2.04.

Materials and Methods

3. MATERIALS AND METHODS

The research programme on "Genotype evaluation and production technology development for high density planting system in papaya (*Carica papaya* L.)" was carried out during 2021-2022 in the college orchard attached to the Department of Fruit Science, College of Agriculture, Vellanikkara. The study was conducted simultaneously as two separate experiments.

1. Screening of genotypes suitable for table purpose under Kerala condition
2. Effect of fertigation and spacing levels in papaya under high density planting system

3.1 EXPERIMENT I

SCREENING OF GENOTYPES SUITABLE FOR TABLE PURPOSE UNDER KERALA CONDITION

3.1.1 Experimental site

a. Location

The experimental plot was located in the college orchard attached to the Department of Fruit Science, College of Agriculture, Vellanikkara. It is situated at 10°32' North latitude and 76°16' East longitude at an altitude of22.25 metres above MSL.

b. Soil and climate

The soil in experimental plot was sandy loam and it was chemically analyzed for nitrogen (N), phosphorous (P), potassium (K), secondary nutrients (Ca, Mg, S), micronutrients (Zn and B), organic carbon, pH and electrical conductivity, before taking up the field planting according to the methods suggested in Table 1. The details of soil analysis are given in the Appendix I. The experiment I was conducted during January 2021 to April 2022. The weather data (monthly rainfall, maximum temperature, minimum temperature, relative humidity, evaporation and sunshine hours) during the cropping season are furnished in Fig 1 and Appendix II.

Methods followed in soil analysis are given below

Particulars	Method followed	Reference
Organic carbon (%)	Walkley and Black method	Jackson, 1958
Available N (kg/ha)	Alkaline KMn04 method	Subbiah and Asija, 1956
Available **P** (kg/ha)	Ascorbic acid reduced molybdophosphoric blue colour method	Watanabe and Olsen, 1965
Available K (kg/ha)	Ammonium acetate method	Jackson, 1958
Soil pH	pH meter	Jackson, 1958
Electrical conductivity (dS/m)	Digital conductivity meter	Jackson, 1958

3.1.2. Selection of genotypes

Twenty-five different genotypes/varieties were collected from different research stations in India, along with the local types obtained from the homesteads situated at different locations in Kerala viz., Kottayam, Emakulam, Thrissur, Malappuram, and Palakkad districts. Thus, 25 genotypes of papaya, including 16 local types and 9 released varieties, were used for the study. The selection of local papaya genotypes was carried out based on the plant and fruit characters, namely tolerance of the plant to pests and diseases, yield, appearance, quality, and size of the fruit. The seeds were raised based on the Package of Practices Recommendations (PoP) ofKAU for papaya.

3.1.3. Layout of experiment

The experiment was laid out in randomized block design with 25 genotypes replicated twice (Plate 1). The treatment details are furnished in Table 2.

Design of experiment	: RBD
No. of genotypes	: 25
No. of replications	: 2
Plot size	: 40 m^2
Plant spacing	: 2 m x 2 m
No. of plants/treatment	: 10

3.1.4 Cultivation practices

a. Crop establishment

The seeds were pre-soaked in water overnight along with the bio-control agent *Pseudomonas fluorescence* @ 10 g/kg of seed (KAU PoP, 2016). On the next day, the water was decanted and the pre-soaked seeds were sown in the protrays filled with media. The protray medium composed of an equal proportion of vermiculite, perlite, and vermicompost and pre-soaked seeds were sown in the protrays at the rate of one seed per cell.

The papaya seedlings were transplanted into the polybags fifteen days after germination. The polybags were filled with a mixture of soil, sand, and vermicompost at a proportion of 2:2:1. The seedlings were supplied with weekly sprays of 19:19:19 and *Pseudomonas fluorescence* at the rate of 2 g/1 and 20 g/1 respectively. These seedlings were transplanted to the main field within forty to forty-five days of polybag transplanting. A foliar spray of neem oil and imidacloprid mixture was given to all the seedlings @ 5 ml and 2 ml respectively in 10 L of water, one day prior to the field planting. The two month old seedlings were planted in the main field.

b. Plant protection

In a research conducted at KAU by Harish and Cherian (2019) to study the effect of eco-friendly management measures against papaya ringspot mosaic virus (PRSV), it was observed that foliar sprays of bougainvillea extract (10 %) reduce

Table 1. Details of genotypes used in the experiment

SI. No.	Code for genotypes	Type of genotype	Source of seed
1	CPV 1	Local type	NBPGR, Vellanikkara
2	CPV2	Local type	Emakulam
3	CPV3	Local type	Emakulam
4	CPV4	Local type	Malappuram
5	CPV5	Local type	Malappuram
6	CPV6	Local type	Kottayam
7	CPV7	Local type	Kottayam
8	CPV8	Local type	Kottayam
9	CPV9	Local type	Kottayam
10	CPV 10	Local type	Palakkad
11	CPV 11	Local type	Kottayam
12	CPV 12	Local type	Thrissur
13	CPV 13	Local type	Thrissur
14	CPV 14	Local type	Thrissur
15	CPV 15	Local type	Emakulam
16	CPV 16	Local type	Thrissur
17	Arka Prabhath	Released variety	IIHR, Bangalore
18	Arka Surya	Released variety	IIHR, Bangalore
19	CO 1	Released variety	TNAU, Coimbatore
20	CO2	Released variety	TNAU, Coimbatore
21	CO3	Released variety	TNAU, Coimbatore
22	CO4	Released variety	TNAU, Coimbatore
23	CO6	Released variety	TNAU, Coimbatore
24	CO7	Released variety	TNAU, Coimbatore
25	Red Lady	Released variety	Taiwan

Plate 1. Layout of experiment I

the severity of PRSV in papaya. Hence, 10 percent bougainvillea extract was prepared as suggested by Harish and Cherian (2019) and applied to one-month-old transplanted seedlings in polybags. This foliar spraying was done five times to all the plants at fortnightly intervals.

c. Trichoderma enriched cow dung

Trichoderma enriched cow dung is a mixture of cow dung, neem cake, and trichoderma. It was prepared by mixing cow dung and neem cake in a ratio of 9:1 ie., 90 kg of dried cow dung mixed thoroughly with 10 kg of dry and powdered neem cake. This mixture was moistened by sprinkling water, to which commercial preparation of trichoderma was added @ 2 kg/100 kg of cow dung-neem cake mixture. After thoroughly mixing all the three ingredients, it was covered with a wet jute sack and kept in the shade for 4-5 days for the multiplication of trichoderma. It was mixed well and kept for another three days for further multiplication. This mixture was kept moist until it was ready for use in the field. Trichoderma enriched cow dung mix was ready for soil incorporation in 15 days.

d. Main field planting

The two-month-old papaya seedlings were transplanted to the main field after land preparation. The experiment was laid out in Randomized Block Design with twenty-five genotypes replicated twice and planted at a spacing of 2 x 2 m. The experimental plot was ploughed twice and levelled. Pits of 50 x 50 x 50 cm were taken. Lime was applied in the pits (500 g/pit) fifteen days before planting in order to neutralize the acidic soil. Due to the deficiency of boron in the soil, ayar (secondary and micro nutrient mixture) was applied to the plants at 3 MAP and 5 MAP, at the rate of 100 g/plant/application. On the day of planting, the pits were filled with 3 kg of Trichoderma enriched farm yard manure along with the top soil. The remaining quantity of Trichoderma enriched farm yard manure (12 kg) was applied as equal splits at bimonthly intervals. Fertilizers were applied as per the KAU PoP for papaya. Single seedling was planted per pit and irrigation water was supplied@ 8 litres/day/plant. All other intercultural operations were carried out as per the package of practices recommendation of KAU for papaya. The layout of the experimental plot and the general view of the experimental site are furnished in Plate 1 and 2 respectively.

3.1.5 Observations

A. Biometric characters

Biometric characters of the plant such as height of plant, girth of plant, number of leaves, length of petiole, colour of mature leaf petiole, height at first flowering, days to flowering, sex expression of plant, number of flowers per cluster, fruit set percentage, days for first harvest, etc. were recorded.

i. Height of plant

Height of plant was recorded by measuring the distance from ground level to the top of the plant using a measuring tape at bimonthly intervals up to peak harvesting stage. The average was worked out and expressed in centimetre (cm).

ii. Girth of plant

Girth of plant was recorded by measuring the plant girth above 10 cm from the ground level using a measuring tape at bimonthly intervals up to peak harvesting stage. The average was calculated and expressed in centimetre (cm).

iii. Number of leaves

The number of newly emerged, fully developed leaves excluding the dead and dry leaves were taken at bimonthly intervals up to peak harvesting stage and the average was worked out.

iv. Length of petiole

Petiole length was recorded by measuring the length of five middle leaves and average was calculated and expressed in centimetre (cm).

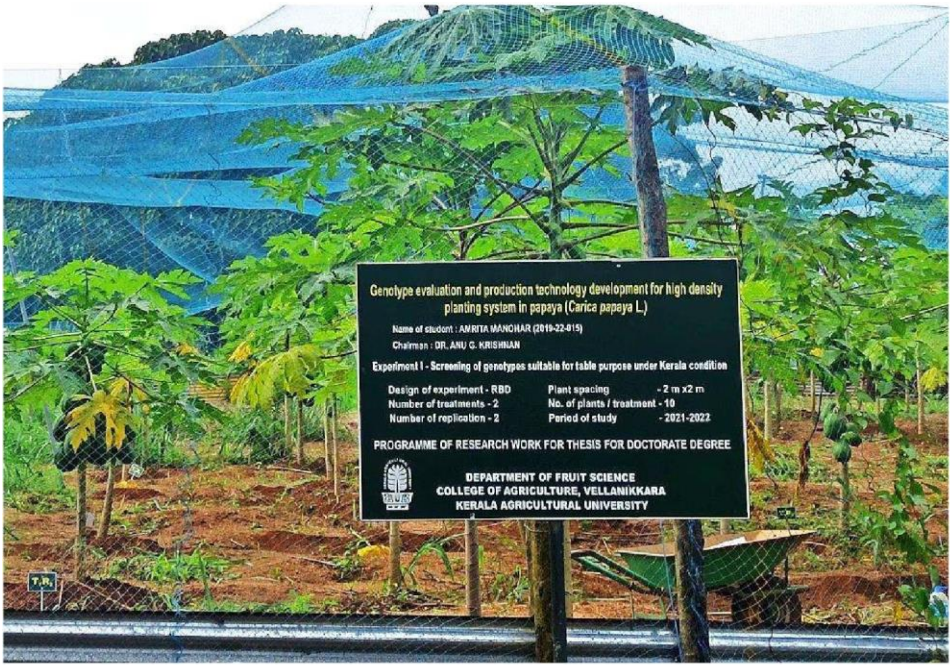

Plate 2. Field board of experiment I

Plate 3. General view of experiment I

v. Colour of mature leaf petiole

Colour of petiole was recorded as per the score given m the IBPGR descriptor (Table 4).

vi. Height at first flowering

Height at which first flower appeared was recorded using a measuring tape. The average was worked out and expressed in centimetre (cm).

vii. Days to flowering

Number of days from planting to flower bud initiation was recorded for each treatment and expressed as number of days.

viii. Sex expression of plant

Sex expression of individual plant was recorded as male, female and hermaphrodite.

ix. Number of flowers/cluster

Number of flowers present in a cluster was counted and recorded from all observation plants and average was worked out.

x. Fruit set

Total number of female and hermaphrodite flowers and fruits produced per plant was recorded from all the observational plants. The average was worked out and expressed in percentage(%).

$$\text{Fruit set percentage} = \frac{\text{Number of fruit set/plant}}{\text{Number of flowers/plant}} \times 100$$

xi. Days for first harvest

The number of days from transplanting to the first fruit harvest were recorded in all observational plants and average was worked out.

B. Yield characters

Yield characters like fruit weight, fruit length, fruit girth, fruit volume, flesh thickness, flesh colour, shape of fruit, cavity diameter, pulp-peel ratio, fruits per plant, seeds per fruit, weight of 100 seeds, yield per plant (kg), yield (kg/ha), days from fruit set to maturity, days from maturity to ripening, were recorded for various treatments.

i. Fruit weight

Fruit weight of five randomly selected fruits from each observational plant was recorded. Average was worked out and expressed in grams (g)

ii. Fruit length

The length of fruits from the stalk end to the tip was measured and average was worked out and expressed in centimetre (cm). Five fruits selected randomly from each observational plant were used to measure fruit length.

iii. Fruit girth

Fruit girth was measured at the widest part of the fruit using a thread and measuring scale and the average of five fruits per experimental plant were worked out and expressed in centimetre (cm).

iv. Fruit volume

Fruit volume was calculated by the water displacement method using five fruits selected randomly from each experimental plant and the average was worked out and expressed in cubic centimetre (cc).

v. Flesh thickness

Flesh thickness was measured from five fruits selected randomly from each

Seeds soaked in pseudomonas

Protray media- Perlite, vermiculite and vermi compost

Fi.Hing the protra.y with media

Sowing of pre soaked seeds

Protect,ing seeds using net

Spraying of water

Soil:sand:vermi compost mixture preparation and filling of polybags

Bagging of 15 days old seedling

Plate 4. Raising of seedlings for main field planting

observational plant and average was calculated and expressed in centimetre (cm).

vi. Flesh colour

Flesh colour of the fruit was recorded as per the score given in the IBPGR descriptor.

vii. Shape of fruit

Shape of the fruit was noted as per the score given in the IBPGR descriptor.

viii. Fruits per plant

Total number of fruits produced from each observational plant was noted and average was calculated.

ix. Seeds per fruit

Total number of seeds extracted from five fruits selected randomly from each observational plant were counted and average was worked out.

x. Weight of 100 seeds

Average dry weight of 100 seeds from five fruits selected randomly per plant was calculated and expressed in grams (g).

xi. Yield per plant (kg)

Yield per plant was calculated by multiplying total number of fruits per plant with average fruit weight and expressed in kilogram/plant (kg/plant).

xii. Yield (kg/ha)

It was calculated by multiplying yield per plant with number of plants per hectare and expressed as kilogram/hectare (kg/ha).

xiii. Days from fruit set to maturity

On the day of anthesis, the flowers of each observation plant were tagged, and the number of days from fruit set to harvest maturity (fully green mature stage) was noted.

xiv. Days from maturity to ripening

Number of days taken by the fruit to reach fully ripe stage while on tree from harvest maturity was recorded as days taken from maturity to ripening.

C. Fruit quality characters

Quality attributes like total soluble solids, acidity, reducing sugars, non-reducing and total sugars were estimated.

i. Total Soluble Solids

Total Soluble Solids (TSS) of fruit were measured with the help of a hand refractometer using the juice extracted from the pulp and expressed as degree brix (°Brix).

ii. Titrable acidity

Titrable acidity was estimated by the method suggested by A. 0. A. C. (1984). Ten gram of fruit sample was grinded in a mortar and pestle with distilled water and made up to 100 ml and filtered. Ten ml of aliquot of this filtered solution and 10 ml distilled water were titrated against 0.1 N NaOH using phenolphthalein indicator. The titrable acidity was expressed as percentage of citric acid and was calculated using the formula

$$\text{Titrable acidity(\%)} = \frac{\text{Titre value x Volume made up x 0.064}}{\text{Weight of sample taken x Volume of the aliquot}} \text{ x 100}$$

Plate 5. Two-month-old seedlings ready to transplant to the main field

iii. Total carotenoids

Total carotenoids were estimated by extracting the fruit pulp with acetone and petroleum ether. The absorbance at 452 nm was measured m a spectrophotometer using petroleum ether as blank. Total carotenoids were expressed as µg/100 g of material (Ranganna, 1997).

$$\text{Total carotenoids } (\mu g/100 \text{ g}) = \frac{3.857 \text{ x Optical density x Volume made up}}{\text{Weight of sample}} \text{ x } 100$$

iv. Ascorbic acid

To estimate ascorbic acid, five gram of the fruit pulp was extracted with 4 per cent oxalic acid and titrated against the standard indicator dye 2,6-dichlorophenol indophenol. It is expressed as mg/100 g of fruit (Sadasivam and Manickam, 1996).

v. Total sugar

Total sugars were estimated by boiling 50 ml of the clarified solution (filtrate of reducing sugars) along with 5 g citric acid and 50 ml distilled water. It was neutralized with IN NaOH after the solution became cool and the volume was made up to 250 ml in a volumetric flask. This solution was titrated against a mixture of Fehling A and Fehling B. The titre value was recorded and total sugar was calculated as

$$\text{Total sugar } (\%) = \frac{0.05 \text{ x Volume of dilution x Volume made up}}{\text{Titre value x Weight of sample x Volume of clarified juice}} \text{ x } 100$$

vi. Reducing sugar

Reducing sugar content was estimated using the method given by Ranganna (1986). Twenty-five millilitre of concentrated fruit juice was taken in a 250 ml volumetric flask along with 50 ml of distilled water. It was neutralized with 1 N Sodium Hydroxide (NaOH) and clarified using 2 ml neutral lead acetate. Excess lead acetate was removed by adding 2 ml potassium oxalate and the volume was made up to 250 ml. This solution was filtered and the filtrate was titrated against a mixture of Fehling A and B using methylene blue as indicator. Reducing sugars was calculated as

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

vii. Non reducing sugar

Non-reducing sugars of fruit were calculated by subtracting reducing sugars from total sugars and expressed in percentage(%).

viii. Sugar/acid ratio

The sugar acid ratio was calculated by the formula

$$\text{Sugar/acid ratio} = \frac{\text{Total sugar(\%)}}{\text{Titrable acidity (\%)}} \times 100$$

ix. Shelf life (days)

The number of days taken by the fruit to reach full ripe stage possessing optimum marketing and consumption potential.

x. Organoleptic evaluation (Nine-point hedonic scale)

The organoleptic evaluation of fruit was done using a nine-point hedonic scale where a score card was prepared according to the parameters like appearance, texture, colour, flavour, aroma, taste, after taste and overall acceptability. The evaluation was done by a panel of 10 judges following the ranking procedure given by Kruskal and Wallis (Seigel, 1959).

D. Pest and disease incidence

The pest and disease attacks observed throughout the papaya cultivation were recorded. The symptoms, causal organism and the management practices followed were also noted.

Plate 6. Land preparation and planting

F. Soil analysis before and after the experiment

From the experimental plot, soil samples were collected before and after the completion of the experiment. It was air dried, powdered, and sieved through a 2 mm sieve and the composite samples taken from each individual plot were then analyzed for N, P and K using the procedures listed in Table 1.

G. Plant analysis

The index leaf of papaya (sixth leaf and petiole from the apex) was taken at bimonthly intervals (2,4,6,8,10,12 MAP) for leaf analysis. The leaf samples were oven dried at 70°C until they reached a constant weight. These samples were powdered and the required quantity was used for the leaf nutrient analysis for primary, secondary and micronutrients (Band Zn). The analytical methods adopted for each element are furnished in Appendix III.

H. Economics of cultivation

i. Cost of cultivation

Cost of cultivation was calculated by taking into account of the input costs that were prevalent at the time of their procurement (Appendix IV).

Cost of conventional method of cultivation of papaya is presented **m** Appendix V.

The market price of papaya fruit during the investigation period was taken into account for calculating gross income per hectare and expressed as ha^{-1}. Market price of the produce is shown in Appendix VI.

Net income was calculated by deducting cost of cultivation from gross income and expressed in ha·'.

The ratio of gross income to cost of cultivation was calculated to give the B:C ratio.

$$B:C\ ratio = \frac{Gross\ income\ (ha^{-1})}{Cost\ of\ cultivation\ (ha^{-1})}$$

3.1.5.8 Statistical analysis

The method formulated by Panse and Sukhatme (1985) was used to conduct analysis of variance of the data. The softwares Wasp 2. 0 and MS-Excel were utilized for computation and analysis.

3.2 EXPERIMENT II

EFFECT OF FERTIGATION AND SPACING LEVELS IN PAPAYA UNDER HIGH DENSITY PLANTING SYSTEM

3.2.1 Experimental site

a. Location

The experimental site was located in the college orchard attached to the Department of Fruit Science, College of Agriculture, Vellanikkara. It was located at an altitude of 22.25 metres above MSL at 10°32' North latitude and 76°16' East longitude.

b. Soil and climate

The soil of the experimental plot was sandy loam. The analysis of soil was conducted prior to the field operations. The details of soil analysis are given in Appendix VIL The experiment was conducted during January 2021 to April 2022. The weather data (monthly rainfall, maximum temperature, minimum temperature, relative humidity, evaporation, and sunshine hours) during the cropping season are furnished in Fig 1 and Appendix II.

3.2.3 Experimental unit

The experiment was carried out using the papaya variety Arka Prabhath released from the Indian Institute of Horticultural Research (IIHR), Bangaluru. It

Plate 7. Layout of experiment II

was gynodioecious in nature and was obtained from a three-way cross of (Surya x Tainung-1) x Local Dwarf. Pure and healthy seeds of the papaya variety Arka Prabhath were collected from IIHR.

3.2.4 Layout and design of experiment

The experiment was conducted to evaluate the effect of different levels of fertigation and spacing on high density planting (HDP) system in papaya and to formulate a package of practice (PoP) recommendation for the HDP system of papaya cultivation. The experiment was laid out in a randomized block design with seven treatments replicated thrice. The layout of the experiment is depicted in Plate 7.

Design of experiment	: RBD
No. of treatments	: 7 (2 x 3 + 1)
No. ofreplications	:3
Plot size	: $24m^2$
No. of plants/treatment	:6

a. Treatment details

The experiment was conducted in combination of two levels of spacing and three levels of fertigation.

Factor A: Spacing (S)

1. S_1 - 1.25 m x 1.25 m
2. S2 - 1.50 m x 1.50 m

Factor B: Fertilizer (F)

The quantity of fertilizers for different fertigation levels was determined based on the N and K recommendations as per KAU PoP for papaya (240: 480 g N K2O/plant/year) based on soil test results.

1. F1 - 60 per cent ofrecommended dose (RDF) ofN and K_2O

2. F2 - 80 per cent of recommended dose (RDF) of N and K_2O

3. F3-lO0 per cent ofrecommended dose (RDF) ofN and K_2O

Control

C - Soil application of nutrients as per KAU PoP under conventional method of irrigation without mulching. The seedlings were planted at a spacing of 2 m x 2 m. The modified KAU PoP based on soil result is 130:60:340 g NPK $planr^{1}year^{-1}$

b. Treatment combinations

No. of treatments= 7 (2 x 3 + 1)

Tl - SlFl	T2 - S1F2	T3 - S1F3
T4 - S2Fl	*TS* - S2F2	T6 - S2F3
T7 - Control		

c. Details of fertigation unit

Irrigation water was collected in an already built tank in the college orchard. A 2 hp pump was used to supply water to the papaya plot. A disc filter was also fitted in the unit to remove impurities in water. The main line was connected to three submains to distribute water and fertilizers to the plot. These submains were again linked to laterals to supply fertilizers and water to the respective plots as per the treatment combination. The water circulated each plant through the hooped lateral, which in tum was connected to the main lateral. There were four emitters (2 litres/hour/emitter) placed at regular intervals in this hooped lateral through which water got discharged to the plant. This helped to supply water uniformly to the plant from all four sides. A venturi was attached for supplying fertilizers through irrigation water. The unit was also provided with a flush valve at the end of submains to flush out water and fertilizers after each application.

Plate 8. Field board of experiment II

Plate 9. General view of experiment II

3.2.4 Cultivation practices

The seed treatment and sowing were carried out as explained in 3.1.4.1. The seedlings of papaya variety Arka Prabhath at four leaf stage were transplanted to the polybags as given in 3.1.4.2. The experimental field was ploughed up to a depth of 50 cm. Raised beds of 30 cm height and 1 m width were prepared, with channels between the beds spaced at 1.25 m and 1.50 m as per the treatment combination. These channels helped to provide proper drainage and also to reduce the capillary movement of water to the adjacent beds. Since the soil was acidic, 500 g of lime was applied per plant during the preparation of beds. These beds were irrigated for 10 days in order to wash out the acids from the soil. The requirement of phosphorous was fulfilled by the basal application of rock phosphate in the pits (15-20 cm depth). Since there were two spacing levels (1.25 m x 1.25 m and 1.50 m x 1.50 m), adjacent beds had different spacing and alternate beds had the same spacing (Fig 3). The quantity of lime and phosphorus were decided based on the initial soil status and were applied uniformly to all the treatments. Organic manure (trichoderma enriched cow dung) was applied uniformly to all the treatments@ 15 kg/plant as basal dose. Plastic mulching was provided for all the treatments except control. Ayar was applied to the plants at 3 MAP and 5 MAP @ 100 g/plant/application.

For the control treatment (T7), seedlings were planted in pits measuring 50 cm x 50 cm x 50 cm taken at a spacing of2 m x 2 m. Lime was applied in these pits (500 g/pit) fifteen days before planting and irrigated for 10 days. Organic manure (trichoderma enriched cow dung) and fertilizers (urea, rock phosphate, and muriate of potash) were provided uniformly to the plants as per the KAU PoP recommendations for papaya.

3.2.5. Fertigation schedule

Fertigation was started one month after the main field planting at a weekly interval. A total of 48 equal split doses were scheduled for 12 months. Nitrogen and potassium requirements of plants were met by the application of urea and Muriate of Potash (MOP) through irrigation water. A nutrient solution was made by dissolving the required quantity of fertilizers in a plastic container. This nutrient solution was fed into the fertigation unit with the help of a venturi, which was immersed in the plastic container containing the fertilizer solution. The nutrients moved along with the irrigation water through the pipeline system and got discharged through the four emitters encircling the plant.

In order to clean the fertigation system, before every fertigation, the mains and submains were flushed with water alone. Once fertigation was complete, drip irrigation was continued for another 10-15 minutes. The screen filter was cleaned with water every two days in order to reduce the clogging of pores. During the rainy season, fertigation was given when there was no surface or subsurface runoff, so as to provide sufficient time for the plants to absorb the nutrients. Other cultural operations were carried out as per KAU PoP recommendation for papaya. The total quantity of urea and MOP provided to the plants per year and weekly split doses of individual treatments are furnished in Table 2 and 3, respectively. The control plants were supplied with urea and MOP at bimonthly intervals starting from 1 MAP (47 g and 95 g/plant/bimonthly).

Table 2. Total quantity of fertilizers applied to the plants

Fertigation	Urea (g/plant/year)	MOP (g/plant/year)
60%RDF	169	341
80%RDF	225	455
100%RDF	282	568

Plate 10. Land preparation and planting of experiment II

Plate 11. Papaya plants receiving different fertigation treatments

Table 3. Weekly split dose of Urea and MOP

Treatment No.	Urea (g/plant/week)	MOP (g/plant/week)
T1	3.5	7.1
T2	4.7	9.5
T3	5.9	11.8
T4	3.5	7.1
T5	4.7	9.5
T6	5.9	11.8

3.2.6 Observations

All the observations on biometric, yield and quality parameters as well as pest and disease incidence, soil analysis, leaf analysis and economics of cultivation were recorded as in Experiment I.

Results

4. RESULTS

The results of the research entitled "Genotype evaluation and production technology development for high density planting system in papaya (*Carica papaya* L.)" are presented in this chapter based on the study conducted at the Department of Fruit Science, College of Agriculture, Vellanikkara, from January 2021 to April 2022. Results are furnished below as two separate experiments.

4.1 SCREENING OF GENOTYPES SUITABLE FOR TABLE PURPOSE UNDER KERALA CONDITION

4.1.1 Biometric characters

a. Height of plant (cm)

The height of the plants was recorded at bimonthly intervals starting from 2 months after planting (MAP) to 12 MAP. The observations on plant height showed significant variation among different genotypes. The data recorded for different months are presented in Table 4.

At all growth stages, CPV 15 and CPV 8 recorded higher values of plant height, whereas dwarfer plants were observed for CO 7.

At 2 MAP, CPV 15 (201.79 cm), CO 4 (192.53 cm) and CO 3 (190.64 cm). were superior with respect to plant height compared to others and were statistically on par. CO 7 (129.19 cm) and Red Lady (138.01 cm), CPV 16 (138.85 cm) and CPV 11 (143.65 cm) recorded lower values and were at par. The average plant height at 2 MAP ranged from 129.19 cm- 201.79 cm.

At 4 MAP, the tallest plants were recorded in CPV 15 (244.82 cm), followed by CPV 8 (228.74 cm). Meanwhile, the shortest plants were observed for CO 7 (155.79 cm), which was found to be on par with CPV 16 (162.56 cm) and Red Lady (169.19 cm).

The observation recorded at 6 MAP showed that the highest plant height was recorded in CPV 15 (266.70 cm), followed by CPV 8 (251.04 cm). The lowest plant height was registered by CO 7 (180.34 cm), followed by Red Lady (191.31 cm).

At 8 MAP, the highest plant height was observed in CPV 15 (293.31 cm), followed by CPV 8 (275.70 cm). The variety CO 7 recorded the lowest plant height of 203.73 cm, followed by Red Lady (214.64 cm).

At 10 MAP, highest plant height was noted in CPV 15 (317.36 cm), followed by CPV 8 (299.70 cm). Among all the genotypes evaluated, CO 7 was found to be the shortest at 10 MAP (228.01 cm), followed by Red Lady (239.58 cm).

The data pertaining to the height of papaya plants at 12 MAP showed that the tallest plants were observed in CPV 15 (342.47 cm), followed by CPV 8 and CPV 12 (324.42 and 316.37 cm). The variety CO 7 recorded the lowest plant height at the end of the final observation (249.39 cm) and was found to be on par with Red Lady (259.47 cm).

b. Girth of plant (cm)

The girth of papaya plants was recorded at bimonthly intervals from 2 months after planting (MAP) up to the peak harvesting stage (12 MAP). The girth of the plant differed significantly among the genotypes, and the result is presented in Table 5.

At 2 MAP, the data on the collar girth showed that CO 6 exhibited highest collar girth (24.62 cm), which was on par with CO 4 and CO 1 (23.86 cm and 23.21 cm, respectively). Similarly, CPV 16 and CPV 6 at 2 MAP showed the lowest value for collar girth (9.65 cm and 9.81 cm, respectively), which was on par with CO 3, CPV 3, Arka Prabhath, and CPV 4.

The results of girth of plant revealed that at 4 MAP, highest collar girth was observed in the genotypes CO 4 (32.21 cm), CPV 13 (31.65 cm), CO 7 (30.92 cm)

Table 4. Height of the papaya genotypes (cm) at various growth stages

Genotype	Plant height (cm)					
	2MAP	**4MAP**	**6MAP**	**8MAP**	**lOMAP**	**12MAP**
CPV 1	153.10	176.53	206.10	230.32	250.27	272.66
CPV2	174.04	196.99	225.91	251.47	277.53	301.36
CPV3	179.26	199.81	231.70	257.15	281.31	312.15
CPV4	164.96	174.27	203.76	228.37	252.60	283.32
CPV 5	157.90	175.60	210.11	235.83	261.95	284.33
CPV6	162.42	188.52	221.26	245.76	270.32	296.04
CPV7	182.67	183.02	223.52	248.63	274.52	297.85
CPV8	173.78	228.74	251.04	275.70	299.70	324.42
CPV9	159.45	183.16	221.82	247.99	273.21	300.53
CPV 10	171.87	193.04	219.85	245.12	270.24	293.35
CPV 11	143.65	182.73	224.08	250.19	275.08	298.25
CPV 12	176.40	194.89	230.43	256.93	282.71	316.37
CPV 13	175.06	206.02	226.77	244.09	267.37	287.63
CPV 14	170.60	191.20	230.72	255.55	280.71	304.77
CPV 15	201.79	244.82	266.70	293.31	317.36	342.48
CPV 16	138.85	162.56	199.25	224.08	248.58	268.92
Arka Prabhath	170.74	196.28	213.78	239.06	264.56	288.45
Arka Surya	172.95	198.40	0.00	0.00	0.00	0.00
CO 1	169.47	203.99	231.28	256.00	280.11	299.94
CO2	175.64	198.36	232.55	258.21	281.99	306.27
CO3	190.64	197.15	231.42	257.53	282.75	290.86
CO4	192.53	212.94	234.95	260.81	285.92	307.66
CO6	168.91	200.52	227.89	252.12	276.90	303.30
CO7	129.19	155.79	180.34	203.73	228.01	249.39
Red Lady	138.01	169.19	191.31	214.64	239.58	259.47
CV(%)	4.26	3.78	1.97	1.68	1.58	**1.14**
CD (5%)	14.75	15.06	8.72	8.23	8.53	6.96

Table 5. Girth of the papaya genotypes (cm) at various growth stages

Genotype	Girth of plant (cm)					
	2MAP	**4MAP**	**6MAP**	**8MAP**	**lOMAP**	**12MAP**
CPV 1	17.77	27.14	36.31	43.64	52.14	57.98
CPV2	21.54	29.89	42.56	51.56	61.56	65.06
CPV3	12.01	22.40	30.32	35.36	43.02	46.36
CPV4	12.27	20.62	28.12	35.12	46.12	51.12
CPV 5	12.11	23.13	26.30	35.46	41.96	45.13
CPV6	9.81	20.99	26.49	35.83	45.83	50.99
CPV7	18.62	27.49	34.99	41.32	50.33	54.99
CPV8	13.15	22.83	29.66	36.83	47.17	52.00
CPV9	17.86	30.88	31.04	39.54	46.87	51.88
CPV 10	18.55	29.40	35.57	42.40	51.40	59.23
CPV 11	16.30	27.31	34.48	41.98	50.31	53.98
CPV 12	17.14	27.82	32.49	41.82	48.49	53.82
CPV 13	18.97	31.65	33.99	43.49	51.15	56.65
CPV 14	18.40	27.75	31.75	40.59	49.92	54.92
CPV 15	20.08	29.76	34.43	42.93	59.11	64.10
CPV 16	9.65	21.50	27.67	34.34	41.50	46.84
Arka Prabhath	12.06	22.58	31.91	37.91	49.41	54.58
Arka Surya	12.69	24.54	0.00	0.00	0.00	0.00
CO 1	23.21	29.69	36.36	42.86	52.35	57.69
CO2	19.92	29.43	37.44	48.10	52.60	57.94
CO3	11.05	19.91	25.07	32.24	37.73	43.24
CO4	23.86	32.21	40.05	45.88	54.04	60.38
CO6	24.62	29.80	38.48	45.64	53.97	66.64
CO7	18.89	30.92	36.24	41.24	53.91	59.08
Red Lady	20.22	26.57	31.57	38.57	46.07	50.74
CV(%)	8.24	10.26	4.08	3.65	5.71	4.50
CD (5%)	2.86	5.64	2.67	2.93	5.59	4.89

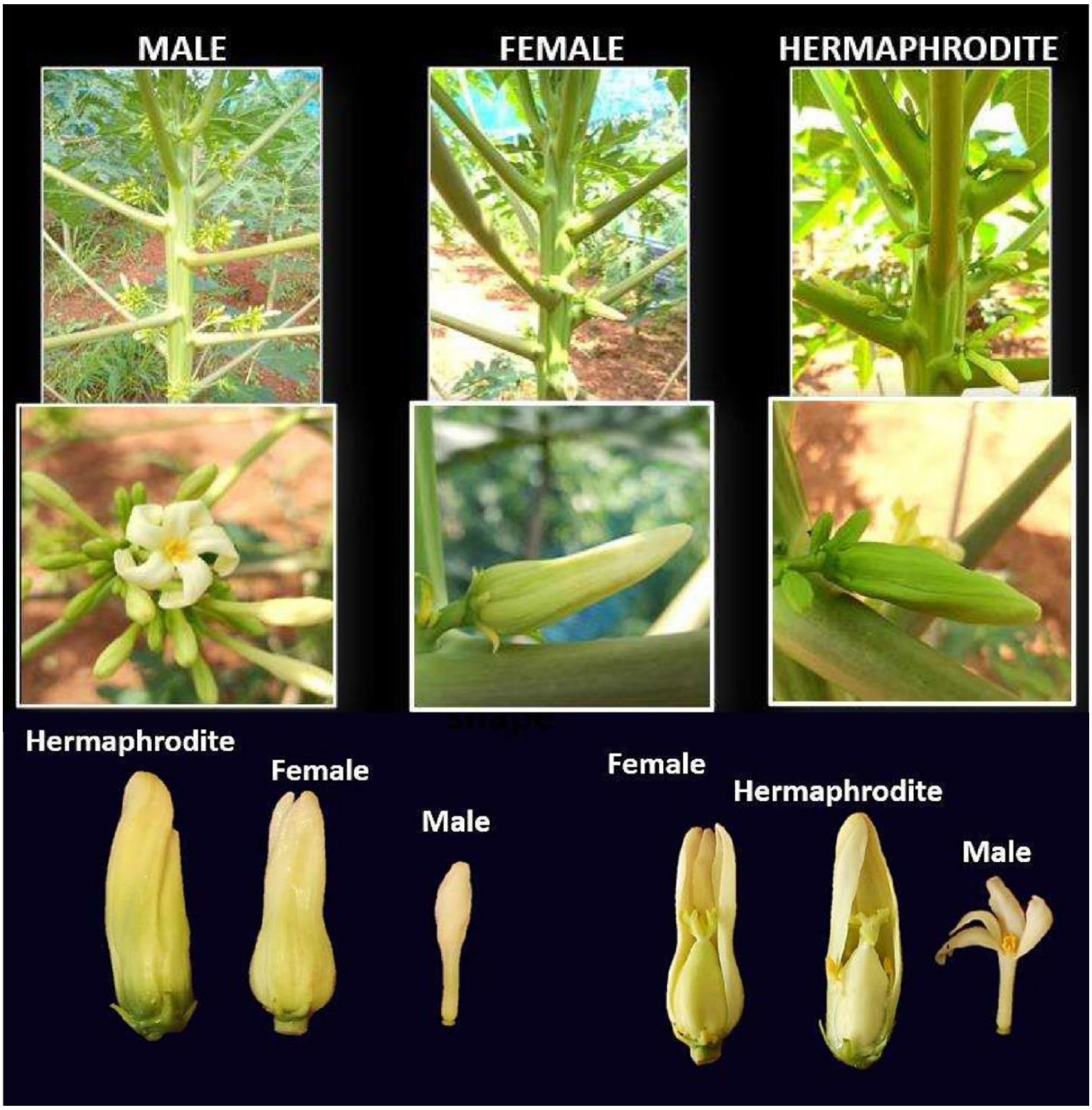

Plate 12. Flower types of papaya

and CPV 9 (30.88 cm). Among the genotypes, CO 3 and CPV 4 showed the lowest collar girth of 19.91 cm and 20.62 cm, respectively at 4 MAP.

While analysing the data pertaining to the girth of the plant at 6 MAP, the highest collar girth was exhibited by CPV 2 (42.56 cm), which was on par with CO 4 (40.05 cm). The lowest collar girth was recorded by CO 3 (25.07 cm), which was on par with CPV 5 (26.3 cm), CPV 6 (26.49 cm), and CPV 16 (27.67 cm).

Statistical analysis of the plants at 8 MAP showed that the highest collar girth was found in CPV 2 (51.56 cm), followed by CO2 (48.10 cm), which was on par with CO 4 (45.88 cm) and CO 6 (45.64 cm), while the lowest collar girth was recorded in CO 3 (32.24 cm), which was on par with CPV 16 (34.34 cm) and CPV 4 (35.12 cm).

While analysing the data pertaining to 10 MAP, it was clear that the highest collar girth was noted in CPV 2 (61.56 cm), which was on par with CPV 15 (59.11 cm). As observed in the previous months, CO 3 recorded the lowest collar girth of 37.73 cm, which was on par with CPV 16 (41.50 cm) and CPV 5 (41.96 cm).

The results of collar girth at 12 MAP exhibited highest collar girth for CO 6 (66.64 cm) and were found to be on par with CPV 2 (65.06 cm), which was in tum on par with CPV 15 (64.10 cm). The lowest value for collar girth at 12 MAP was recorded for CO 3 (43.24 cm) and CPV 5 (45.13 cm), which was on par with CPV 3 (46.36 cm) and CPV 16 (46.84 cm).

c. Number of leaves

The number of leaves was recorded at bimonthly intervals starting from 2 MAP till **1** year. The results of statistical analysis are furnished in Table 6.

Higher number of leaves at 2 MAP was exhibited by CPV 4 (21.90), followed by CPV 7 (19.70) and CPV 13 (18.60). However, the lower number of leaves was found in CO 7 (9.25), followed by CPV 15 (11.75) and Red Lady (11.93).

The data on number of leaves at 4 MAP showed that the highest number ofleaves were observed for CPV 7 (23.80) and CPV 4 (23.50), whereas the lowest number ofleaves were reported in Arka Surya (9.75) and CO 7 (11.75).

At 6 MAP, the highest number ofleaves were observed for CPV 7 (28.20) and CPV 4 (27.20), while the least number of leaves were observed for CO 7 (14.83).

The number of leaves recorded at 8 MAP showed the highest number of leaves in CPV 7 (28.20) and CPV 4 (27.23), followed by CPV 13 (23.20) and CO 2 (23.20), which were on par with CPV 8 and CPV 2 (22.70 and 22.00, respectively). However, the lowest number ofleaves was observed in CO 7 (14.83).

At 10 MAP, CPV 7 recorded the highest value for number of leaves (32.70) and was found to be on par with CPV 4 (32.20). However, variety CO 7 (17.50) recorded the lowest number of leaves among the genotypes, followed by Red Lady (23.13) and Arka Prabhath (23.17).

The number of leaves at the end of the observation period (12 MAP) showed the highest value of 33.30 for CPV 4, which was found to be on par with CO2, CPV 7, and CPV 13 (31.20, 31.20, and 30.80, respectively), while the lowest number of leaves were observed for CO 7 (18.08).

d. Length of petiole (cm)

The genotypes exhibited significant differences with respect to the length of the leaf petiole and the data is presented in Table 7. The longest petiole was recorded for CPV 2 (89.15 cm), and it was found to be on par with CPV 9 and CPV 3 (87.56 cm and 86.73 cm, respectively). The genotype Arka Prabhath showed the lowest value for length of leaf petiole (59.83 cm), followed by CO 3 (65.64 cm), CPV 14 (65.67 cm), and CO 7 (65.82 cm).

Table 6. Number of leaves of the papaya genotypes at various growth stages

Genotype	Number of leaves					
	2MAP	**4MAP**	**6MAP**	**8MAP**	**lOMAP**	**12MAP**
CPV 1	15.20	16.80	20.70	20.70	26.40	26.10
CPV2	13.10	14.70	18.90	18.90	26.60	25.41
CPV3	13.60	18.40	22.00	22.00	27.10	28.43
CPV4	21.90	23.50	27.20	27.23	32.20	33.30
CPV 5	15.20	17.00	19.70	21.35	25.50	24.57
CPV6	14.50	17.60	20.80	20.80	25.20	26.43
CPV7	19.70	23.80	28.20	28.20	32.70	31.20
CPV8	14.50	17.20	22.70	22.70	26.80	28.81
CPV9	12.50	15.70	18.90	18.90	24.50	25.10
CPV 10	14.03	16.08	18.66	18.66	24.25	25.66
CPV 11	14.66	17.66	21.00	21.00	27.83	26.50
CPV 12	13.91	18.25	20.83	20.83	25.00	25.75
CPV 13	18.60	19.40	23.20	23.20	30.40	30.80
CPV 14	13.10	16.60	19.80	19.80	23.80	25.00
CPV 15	11.75	15.83	20.50	20.50	25.75	26.91
CPV 16	14.07	17.57	20.07	20.07	25.28	25.21
Arka Prabhath	13.66	16.16	19.91	19.91	23.17	24.66
Arka Surya	13.37	9.75	0.00	0.00	0.00	0.00
CO 1	12.16	16.08	18.91	18.91	24.41	24.75
CO2	15.10	20.10	23.20	23.20	29.00	31.20
CO3	12.66	16.66	20.16	20.16	26.83	27.83
CO4	12.83	15.91	19.33	19.33	25.25	27.08
CO6	13.37	17.12	21.37	21.37	27.75	29.37
CO7	9.25	11.75	14.83	14.83	17.50	18.08
Red Lady	11.93	17.375	19.565	19.565	23.13	24.75
CV(%)	6.63	6.22	3.63	3.71	4.18	5.91
CD (5%)	1.94	2.19	1.50	1.54	2.16	3.14

Table 7. Length and colour of leaf petiole of the papaya genotypes

Genotype	Length of mature leaf petiole	Colour of petiole
CPV 1	80.81	Normal green
CPV2	89.14	Green and shades of red-purple
CPV3	86.73	Green and shades ofred-purple
CPV4	69.76	Green and shades ofred-purple
CPV5	82.00	Green and shades of red-purple
CPV6	85.15	Red purple
CPV7	78.10	Green and shades of red-purple
CPV8	84.55	Pale green
CPV9	87.56	Pale green
CPV 10	78.45	Green and shades of red-purple
CPV 11	77.61	Green and shades of red-purple
CPV 12	78.67	Green and shades of red-purple
CPV 13	75.90	Green and shades of red-purple
CPV 14	65.67	Pale green
CPV 15	83.52	Green and shades of red-purple
CPV 16	71.06	Pale green
Arka Prabhath	59.83	Green and shades of red-purple
Arka Surya	61.45	Green and shades of red-purple
CO 1	83.33	Green and shades of red-purple
CO2	78.57	Green and shades of red-purple
CO3	65.64	Green and shades of red-purple
CO4	85.30	Green and shades of red-purple
CO6	85.63	Green and shades of red-purple
CO7	65.82	Green and shades of red-purple
Red Lady	72.83	Pale green
CV(%)	1.77	NA
CD (5%)	2.73	NA

e. Colour of mature leaf petiole

The colour of the petiole is furnished in Table 7. The genotypes showed variation in the colour of the leaf petiole. There were four different colours observed in the genotypes: pale green, normal green, red purple, and green and shades of red purple.

f. Height at first flowering (cm)

The height at first flowering showed a significant difference among the genotypes (Table 8). The statistical data revealed that CO 7 and CPV 16 exhibited the lowest height at first flowering (82.32 cm and 82.69 cm, respectively). Meanwhile, the highest value for height at first flowering was noted in CO 6 (131.95 cm), which was on par with CPV 3 (123.65 cm), CPV 5 (121.25 cm), and CPV 12 (121.09 cm).

g. Days to flowering

All the genotypes showed significant variation for days to first flowering and the data is presented in Table 8. Among the genotypes, early flowering occurred in CPV 2 (52.89 days), followed by CPV 14 (53.56 days). However, the time taken for flowering was the longest for Arka Prabhath (97.94 days), followed by CPV 5 (85.61 days) and CPV 11 (66.55 days).

h. Sex expression of plant

The observations on sex expression are presented in Table. 8. The genotypes can be grouped as dioecious or gynodioecious in nature. The genotypes, CPV 1, CPV 3, CPV 5, CPV 6, CPV 7, CPV 8, CPV 10, CPV 11, CPV 15, CPV 16, Arka Prabhath, Arka Surya, CO 3, CO 7 and Red Lady were observed to be gynodioecious. Whereas, CPV 2, CPV 4, CPV 9, CPV 12, CPV 13, CPV 14, CO 1, CO2, CO 4 and CO 6 were dioecious.

i. Number of flowers/cluster

The genotypes varied significantly with respect to the number of flowers per cluster, and the highest value was recorded for CO 7 (4.92), which was found to be on par with Red Lady (4.20). Among the genotypes, the lowest number of flowers per cluster was observed in CPV 10 and CPV 11 (1.40), which was on par with Arka Prabhath (1.60) (Table 9).

j. Fruit set(%)

A significant variation was exhibited by the genotypes with respect to the fruit set percentage (Table 9). The highest fruit set percentage was recorded in CPV 9 (79.74 %), which was on par with CO 4 (78.81 %), CPV 12 (77.11 %), CPV 7 (74.26 %), CPV 15 (73.82 %), and CPV 14 (73.62 %). Meanwhile, the lowest fruit set percentage was observed in CPV 16 (46.06 %), followed by CO 7 (52.60 %) and CPV 13 (53.33 %).

k. Days for first harvest

The comparison of genotypes with respect to the number of days to harvest showed a significant difference (Table 9). The genotype, CPV 2 (196.60 days) took the lowest number of days to harvest and was on par with CO 7 (201.50 days). Whereas, the highest number of days to harvest were taken by CPV 7, CO 2, CO 6, Arka Prabhath, and CPV 5 (222.67, 221.50, 220.50, 218.67, and 217.83 days, respectively).

4.1.2 Yield characters

a. Fruit weight (g)

The genotypes showed significant variation in fruit weight (Table 12). The highest fruit weight was recorded for CO 6 (1908.20 g), which was on par with CO 4 (1779.72 g) and CO 1 (1626.27 g). While the lowest fruit weight was observed for Arka Prabhath (736.60 g), which was on par with CPV 16 (818.94 g), followed by CPV 5, CO 3, CPV 6, CO 7, CPV 8, CPV 4, and CPV 3.

Table 8. Height at first flowering, days to flowering and sex expression of the papaya genotypes

Genotype	Height at first flowering	Days to flowering	Sex expression
CPV 1	95.94	54.44	Gynodioecious
CPV2	102.12	52.89	Dioecious
CPV3	123.65	55.61	Gynodioecious
CPV4	97.41	54.66	Dioecious
CPV 5	121.25	85.61	Gynodioecious
CPV6	97.43	55.33	Gynodioecious
CPV7	111.00	55.72	Gynodioecious
CPV8	118.42	55.00	Gynodioecious
CPV9	105.34	57.16	Dioecious
CPV 10	119.00	54.11	Gynodioecious
CPV 11	97.34	66.55	Gynodioecious
CPV 12	121.09	57.61	Dioecious
CPV 13	111.31	55.67	Dioecious
CPV 14	109.49	53.56	Dioecious
CPV 15	110.72	54.89	Gynodioecious
CPV 16	82.69	55.11	Gynodioecious
Arka Prabhath	104.77	97.94	Gynodioecious
Arka Surya	109.52	55.05	Gynodioecious
CO 1	101.06	54.78	Dioecious
CO2	116.77	53.83	Dioecious
CO3	106.74	55.78	Gynodioecious
CO4	118.56	54.94	Dioecious
CO6	131.95	54.27	Dioecious
CO7	82.32	54.22	Gynodioecious
Red Lady	87.48	54.67	Gynodioecious
CV(%)	5.22	1.75	NA
CD (5%)	11.57	2.11	NA

Table 9. Number of flowers per cluster, fruit set percentage and days for first harvest of the papaya genotypes

Genotype	Number of flowers/cluster	Fruit set (%)	Days to first harvest
CPV 1	3.16	62.47	202.60
CPV2	3.10	62.75	196.60
CPV3	3.30	68.34	203.60
CPV4	2.50	60.51	201.80
CPV 5	2.40	68.84	217.83
CPV6	3.75	57.38	201.75
CPV7	2.16	74.26	222.67
CPV8	2.58	73.53	208.37
CPV9	2.16	79.74	208.12
CPV 10	1.40	62.86	208.50
CPV 11	1.40	58.02	207.00
CPV 12	2.42	77.11	203.00
CPV 13	2.20	53.33	205.67
CPV 14	3.25	73.62	202.50
CPV 15	2.16	73.82	202.66
CPV 16	2.60	46.06	203.83
Arka Prabhath	1.60	60.64	218.67
Arka Surya	2.06	0.00	0.00
CO 1	1.70	73.02	206.62
CO2	2.08	71.35	221.50
CO3	2.30	63.39	203.00
CO4	2.33	78.81	210.08
CO6	1.70	67.25	220.50
CO7	4.92	52.60	201.50
Red Lady	4.20	60.88	203.64
CV(%)	17.78	4.69	1.59
CD (5%)	0.93	6.12	6.54

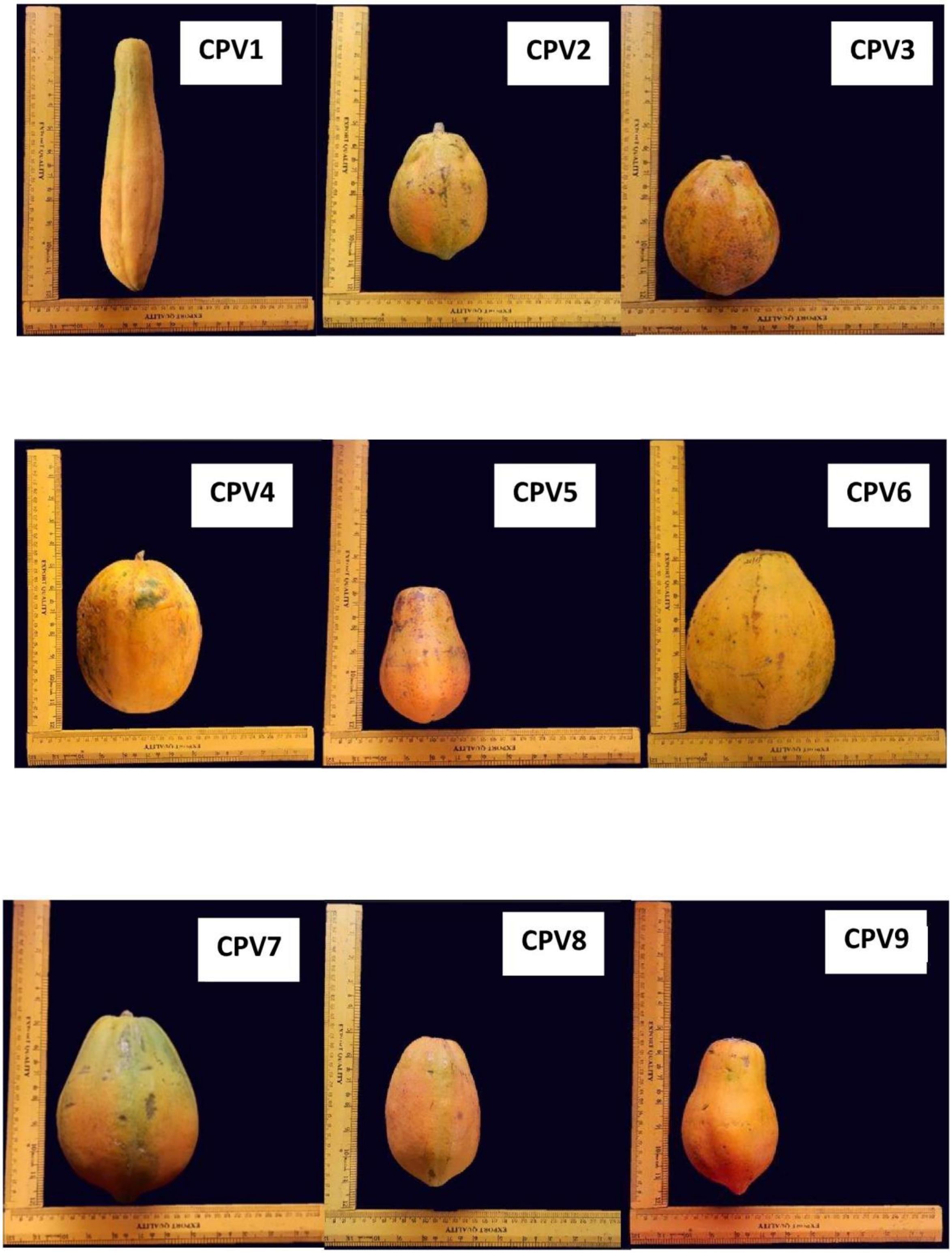

Plate 13. Individual fruits of papaya genotypes

b. Fruit length (cm)

All the genotypes varied significantly in fruit length and the data on fruit length is furnished in Table 11. The longest fruits were found in CPV 1 (35.01 cm), followed by CPV 6 (22.59 cm), which was on par with CPV 15 (22.38 cm) and CPV 4 (22.17 cm). However, the shortest ones were found in CPV 5 (14.36 cm).

c. Fruit girth (cm)

The genotypes showed significant differences in fruit girth (Table 11). Among the genotypes, CO 6 (35.02 cm) was reported to have the highest fruit girth, followed by CO 4 (22.60 cm), which was on par with CPV 10 (22.41 cm) and CPV 14 (22.21 cm). However, lowest fruit girth was observed in CPV 1 (13.37 cm).

d. Fruit volume (cm^3)

The genotypes varied significantly for fruit volume (Table 11). On comparing the values of fruit volume, highest value was recorded in CPV 10 (1178.62 cm^3), which was on par with CO 4 (1105.23 cm^3). Meanwhile, the lowest fruit volume was recorded for CPV 5 (389.13 cm^3) followed by CPV 6 and CPV 11 (465.13 and 468.12 cm^3, respectively).

e. Flesh thickness (cm)

The data on flesh thickness is presented in Table 11. It revealed that the genotypes showed a significant difference in flesh thickness. The highest flesh thickness of 3.26 cm and 3.18 cm was recorded for CO 6 and CO 4, respectively, while the lowest thickness for the pulp was noted in CPV 1 (1.19 cm).

f. Flesh colour

The flesh colour of the genotypes showed variation. The observations were made using the IBPGR descriptor. There were four different colours observed in the fruits viz. light yellow, bright yellow, deep yellow to orange, and reddish orange. The details of the flesh colour are presented in Table 10.

g. Shape of fruit

The genotypes exhibited differences with regard to the shape of the fruits (Table 10). The observations were recorded as per the IBPGR descriptor for papaya. A total of nine different shapes were observed among the genotypes, like club shape, elongate, oblong-ellipsoid, pear shape, acron, globular, oval, elliptic and lengthened cylindrical.

h. Fruits per plant

The genotypes differed significantly with regard to the number of fruits per plant (Table 12). The genotype CPV 2 (29.25) was observed to have the highest number of fruits, followed by CPV 3 (23.75) and Red Lady (23.63), whereas CPV 16 and CPV 7 were observed to have the lowest number of fruits (11.13 and 11.37) among the genotypes.

i. Seeds per fruit

A significant variation was observed among the genotypes for the number of seeds per fruit (Table 13). The highest number of seeds was found in CPV 10 (1270.12), followed by CPV 14 (964.12), CO 6 (959.00), and CPV 15 (941.13), while the lowest number of seeds was observed for CPV 16 and Arka Prabhath (349.75 and 377.12, respectively).

j. Weight of 100 seeds

On comparing the weight of 100 seeds, it was found that the genotypes varied significantly for this parameter and the data is furnished in Table 13. The highest weight was found in CPV 16 (4.01 g), which was on par with CPV 10 (3.95 g) and CPV 15 (3.91 g). Whereas the lowest weight of 100 seeds was recorded for Red Lady (2.39 g), which was on par with CPV 1 (2.58 g).

k. Yield per plant (kg)

The genotypes differed significantly for yield per plant, and the highest yield per plant was observed for genotype CO 4 (33.59 kg), followed by CO 6 (29.88 kg).

Table 10. Colour of flesh and shape of fruits of papaya genotypes

Genotype	Colour of flesh	Shape of fruit
CPV 1	Reddish orange	Club shaped
CPV2	Deep yellow to orange	Acron
CPV3	Bright yellow	Oval
CPV4	Deep yellow to orange	Oblong
CPV5	Deep yellow to orange	Pear shaped
CPV6	Bright yellow	Globular
CPV7	Light yellow	Oblong-ellipsoid
CPV8	Deep yellow to orange	Elliptic
CPV9	Bright yellow	Acron
CPV 10	Bright yellow	Oval
CPV 11	Reddish orange	Acron
CPV 12	Deep yellow to orange	Elongate
CPV 13	Bright yellow	Globular
CPV 14	Deep yellow to orange	Oval
CPV 15	Bright yellow	Elongate
CPV 16	Reddish orange	Oblong-ellipsoid
Arka Prabhath	Reddish orange	Elliptic
Arka Surya		
CO 1	Bright yellow	Acron
CO2	Deep yellow to orange	Oval
CO3	Reddish orange	Pear shaped
CO4	Bright yellow	Oval
CO6	Deep yellow to orange	Acron
CO7	Reddish orange	Pear shaped
Red Lady	Reddish orange	Lengthened-cylindrical
CV(%)	NA	NA
CD (5%)	NA	NA

Table 11. Fruit length, fruit girth, fruit volume and flesh thickness of papaya genotypes

Genotype	Fruit length (cm)	Fruit girth (cm)	Fruit volume (cm^3)	Flesh thickness (cm)
CPV 1	35.01	13.37	525.12	1.19
CPV2	15.65	15.65	521.12	2.39
CPV3	15.75	15.80	509.50	1.88
CPV4	22.17	19.23	608.09	2.18
CPV 5	14.36	17.46	389.12	2.29
CPV6	22.59	21.67	465.12	2.40
CPV7	21.36	21.37	859.00	2.86
CPV8	19.95	19.45	850.45	2.38
CPV9	17.46	19.95	554.37	2.30
CPV 10	19.22	22.41	1178.62	2.63
CPV 11	16.72	15.35	468.12	1.98
CPV 12	17.71	17.41	593.75	2.29
CPV 13	17.39	17.72	759.12	1.76
CPV 14	21.39	22.21	987.62	2.57
CPV 15	22.38	16.90	649.00	2.42
CPV 16	16.56	16.67	524.75	0.35
Arka Prabhath	15.35	16.72	632.75	2.42
Arka Surya	0.00	0.00	0.00	0.00
CO 1	22.01	22.15	1035.25	2.69
CO2	22.14	22.06	713.875	2.48
CO3	17.09	22.01	543.00	2.43
CO4	19.45	22.60	1105.25	3.18
CO6	21.66	35.02	980.37	3.26
CO7	22.01	17.09	648.12	2.31
Red Lady	16.91	21.39	921.00	2.45
CV(¾)	1.97	1.89	5.26	5.67
CD (5%)	0.77	0.79	73.97	0.26

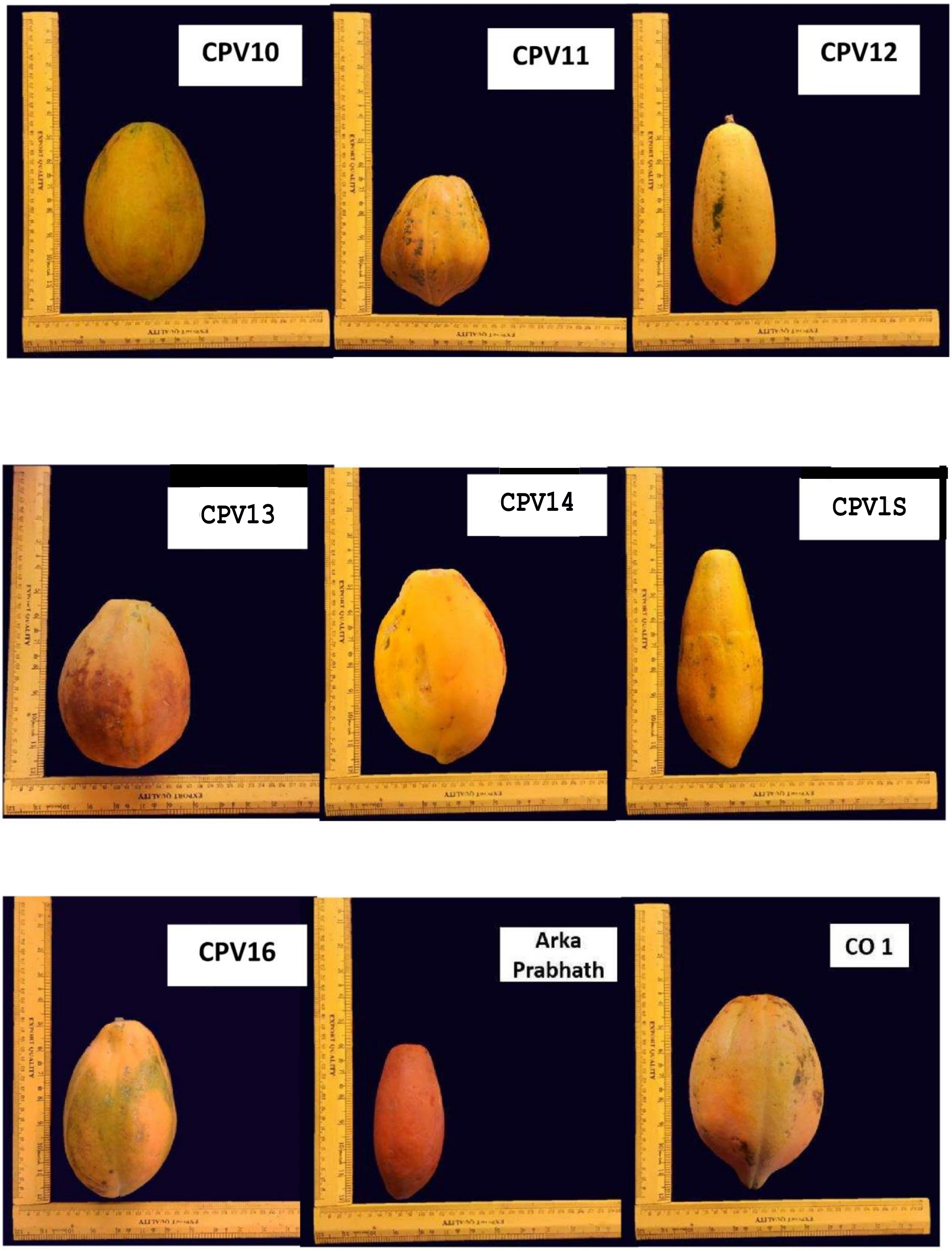

Plate 14. Individual fruits of papaya genotypes

However, the lowest yield per plant was recorded for CPV 16 (9.59 kg), which was on par with CPV 7 (10.32 kg) (4.1.9).

I. Yield (kg/ha)

One of the main parameters that reflects the income from an orchard is the yield per hectare. In this study a significant variation was observed among the genotypes for yield per hectare (Table 12). The highest per hectare yield was recorded by CO 4 (83.97 kg ha^{-1}), followed by CO 6 (74.70 kg ha^{-1}) which was on par with CPV 1 and CPV 2. Meanwhile, the lowest per hectare yield was observed for CPV 16 (23.97 kg ha^{-1}).

m. Days from fruit set to maturity

There was a significant difference among the genotypes in the number of days from fruit set to maturity (Table 13). The maximum number of days taken by the fruits to mature was exhibited by CO2 (158.86 days), CO 6 (155.60 days), CPV 7 (155.17 days), and Arka Prabhath (153.17 days), while the minimum number of days were observed for CPV 5 (120.33 days), which was on par with CPV 11 (127.90 days).

n. Days from maturity to ripening

The genotypes exhibited significant variation with respect to the number of days from maturity to ripening (Table 13). The maximum number of days to ripening were found in Red Lady (6.36 days) and CO 7 (6.30 days), whereas the minimum number of days from maturity to ripening was recorded for CPV 5 (4.00 days) and CPV 11 (4.10 days), which was on par with CPV 3 and CPV 4 (4.30 days).

4.1.3. Fruit quality characters

a. Total soluble solids

All the genotypes exhibited significant variation with respect to the total soluble solids (Table 14). The highest TSS was recorded by the genotype CO 7

(13.11 °Brix), which was on par with CPV 9 (13.09 °Brix), CPV 2 (13.06 °Brix), CPV 12 (13.06 °Brix) and CPV 15 (13.05 °Brix). The TSS was lowest for CPV 13 (9.46 °Brix), followed by CPV 1 (9.79 °Brix).

b. Titrable acidity

Titrable acidity showed a significant difference among the genotypes and the data is presented in Table 14. The lowest acidity was noted for CO 7 (0.14 %), which was on par with CO2, CPV 2 andArka Prabhath (0.15 % each). Meanwhile, the highest titrable acidity was recorded for CPV 1 (0.26 %), which was on par with Red Lady (0.25 %).

c. Total carotenoids

A significant difference was exhibited by the genotypes for the total carotenoid content (Table 14). The highest content of total carotenoids was reported in CO 7 and Arka Prabhath (2.65 and 2.63 mg 100 g^{-1}, respectively), followed by CO 3 (2.25 mg 100 g^{-1}), which was on par with Red Lady (2.20 mg 100 g^{-1}). The lowest amount of total carotenoids was found in treatments CPV 15 (1.04 mg 100 g^{-1}) and CPV 6 (1.08 mg 100 g^{-1}).

d. Ascorbic acid

Among the genotypes, there existed a significant difference in the ascorbic acid content (Table 14). The highest amount of ascorbic acid was observed for CPV 9 (85.77 mg 100 g^{-1}), followed by CPV 10 (82.88 mg 100 g^{-1}). The lowest amount of ascorbic acid was recorded for CPV 8 (42.50 mg 100 g^{-1}) followed by CPV 14 (51.73 mg 100 g^{-1}).

e. Total sugars

The genotypes differed significantly for total sugars, and the highest amount of total sugars was observed for the genotypes CO 7 (11.13 %), CPV 15 (10.98 %), CPV 9 (10.94%), CPV 2 (10.94%) and CPV 12 (10.85 %). The lowest amount of total sugar was observed for CPV 13 (8.04 %). The data is presented in Table 15.

Table 14. Total soluble solids, titrable acidity, ascorbic acid, total carotenoids of papaya genotypes

Genotype	Total soluble solids (^{0}Brix)	Titrable acidity(%)	Ascorbic acid (mg 100 g-^{1})	Total carotenoids (mg 100 g-^{1})
CPV 1	9.79	0.26	64.29	1.76
CPV2	13.06	0.15	70.38	1.57
CPV3	11.34	0.22	53.07	1.99
CPV4	10.53	0.22	59.16	1.39
CPV 5	10.08	0.23	58.84	1.74
CPV6	10.91	0.21	66.54	1.08
CPV7	10.41	0.22	54.04	1.18
CPV8	11.38	0.19	42.50	1.47
CPV9	13.09	0.18	85.77	1.47
CPV 10	11.89	0.20	82.88	1.58
CPV 11	10.86	0.20	52.75	1.73
CPV 12	13.05	0.16	60.96	1.49
CPV13	9.46	0.23	54.04	1.65
CPV 14	10.79	0.23	51.73	1.30
CPV 15	13.05	0.17	77.11	1.04
CPV 16	10.46	0.23	66.54	2.13
Arka Prabhath	10.38	0.15	80.09	2.63
Arka Surya	0.00	0.00	0.00	0.00
CO 1	11.55	0.19	73.19	1.57
CO2	11.82	0.15	59.81	1.72
CO3	11.15	0.23	63.45	2.25
CO4	10.38	0.23	56.34	1.90
CO6	10.33	0.21	69.42	1.69
CO7	13.11	0.14	65.57	2.65
Red Lady	10.40	0.25	57.12	2.20
CV(%)	1.145	5.53	0.69	3.07
CD (5%)	0.255	0.02	0.87	0.11

Table 15. Total sugars, reducing sugars, non-reducing sugars, sugars/acid ratio and shelf life of papaya genotypes

Genotype	Total sugars(%)	Reducing sugars(%)	Non reducing sugars(%)	Sugars/acid ratio	Shelf life (days)
CPV 1	8.27	6.42	1.86	31.23	6.32
CPV2	10.94	9.57	1.37	73.29	7.16
CPV3	9.41	7.23	2.19	41.70	5.86
CPV4	8.53	7.01	1.53	39.07	6.06
CPV 5	7.57	6.47	1.09	32.01	5.67
CPV6	9.17	7.16	2.01	43.68	6.61
CPV7	8.80	7.27	1.54	39.49	7.61
CPV8	8.53	7.37	1.17	43.13	6.91
CPV9	10.94	9.59	1.35	60.61	7.54
CPV 10	10.05	8.16	1.89	50.33	6.56
CPV 11	8.20	6.22	1.98	39.79	6.10
CPV 12	10.85	9.51	1.21	64.25	6.86
CPV13	8.04	6.85	1.19	34.11	6.80
CPV 14	9.13	7.51	1.62	39.57	7.45
CPV 15	10.98	9.57	1.41	63.43	7.53
CPV 16	8.11	6.74	1.36	34.15	7.17
Arka Prabhath	8.57	5.80	2.77	58.43	8.10
Arka Surya	0.00	0.00	0.00	0.00	0.00
CO 1	9.65	8.61	1.04	50.67	6.90
CO2	9.05	8.23	0.81	63.87	5.77
CO3	8.81	7.27	1.54	38.35	5.24
CO4	8.73	7.37	1.36	37.99	6.78
CO6	8.18	6.55	1.63	38.68	6.71
CO7	11.13	9.79	1.33	83.29	7.84
Red Lady	8.79	8.27	0.52	34.49	8.62
CV(%)	4.27	5.65	11.08	9.50	4.30
CD (5%)	0.77	0.86	0.33	8.91	0.58

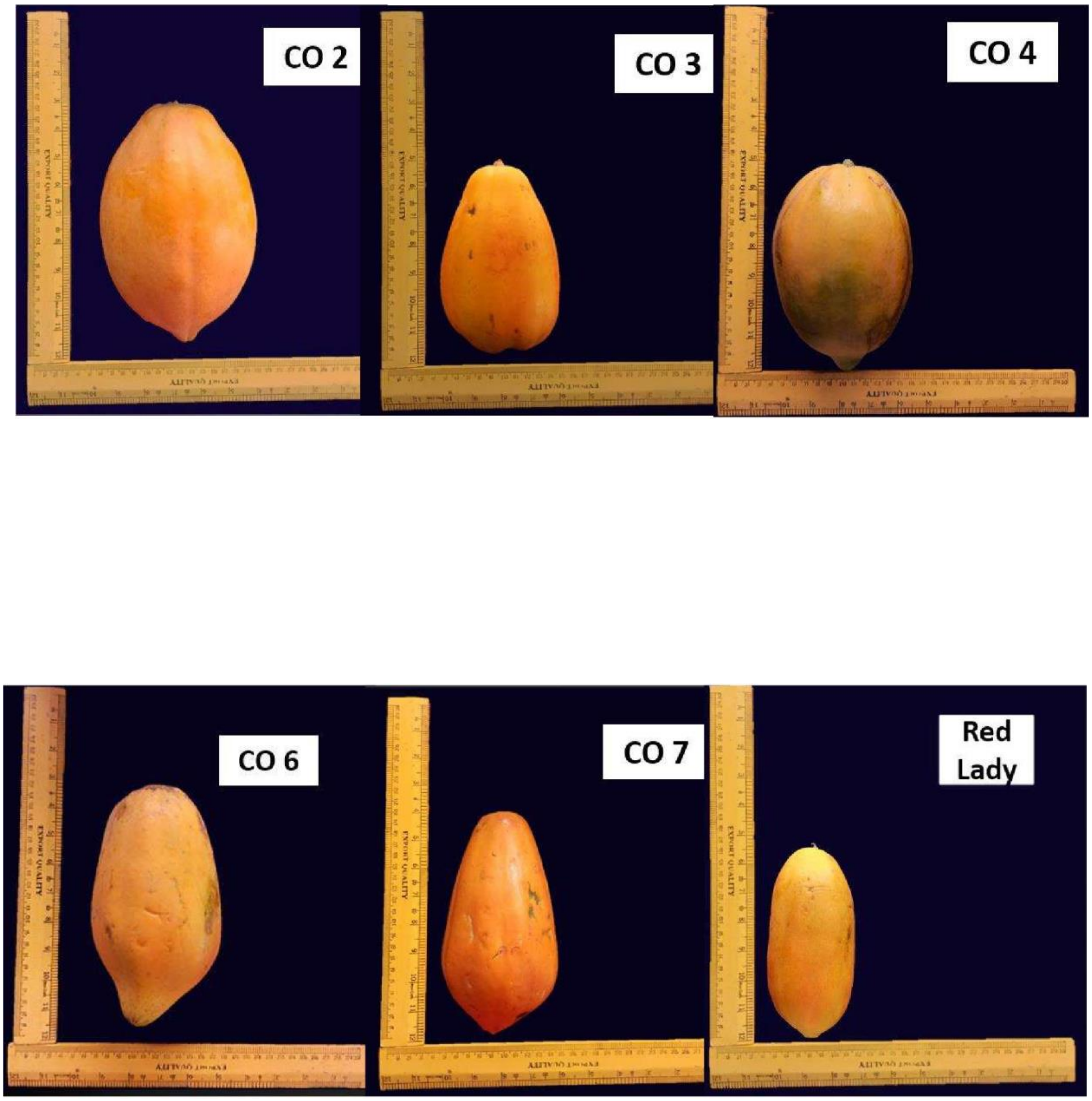

Plate 15. Individual fruits of papaya genotypes

f. Reducing sugars

The genotypes exhibited a significant difference for this parameter, and the highest percentage of reducing sugar was recorded for the genotypes CO 7 (9.79 %), CPV 9 (9.59 %), CPV 2 (9.57 %), CPV 15 (9.57 %), and CPV 12 (9.51 %). The amount of reducing sugars was the lowest for Arka Prabhath (5.80 %) (Table 15).

g. Non reducing sugars

The non reducing sugars varied significantly among the genotypes and the data is presented in Table 15. The highest percentage of non-reducing sugars was observed for Arka Prabhath (2.77 %), followed by CPV 3 (2.19 %), whereas, the lowest concentration of non-reducing sugar was found in Red Lady (0.52 %).

h. Sugar/acid ratio

On comparing the sugar-acid ratio of genotypes, it was revealed that the genotypes showed significant variation (Table 15). The highest sugar-acid ratio was reported in CO 7 (83.29), followed by CPV 2 (73.29). Meanwhile, the lowest sugar-acid ratio was found in CPV 1 (31.23) and was found to be on par with Red Lady (35.82).

i. Shelf life

The shelflife varied significantly among the genotypes and the data on shelf life is furnished in Table 15. The maximum shelf life was recorded in Red Lady (8.62 days), which was on par with Arka Prabhath (8.10 days). The least number of shelf life was found in CO 3 (5.24 days), which was on par with CPV 5 (5.67 days).

j. Organoleptic evaluation

The fruits of the genotypes were evaluated for organoleptic parameters on a nine-point hedonic scale by a panel of 10 judges. The mean rank scores of appearance, colour, flavour, odour, taste, aftertaste, and overall acceptability are furnished in Table 16.

Among the genotypes, the highest mean score for appearance was observed for CPV 12 (8.50), followed by CO 6 (8.45) and CO 3 (8.30). For colour, the highest rank was given for CO 7 (8.30) and CPV. 2 (8.25). The papaya cv. CO 7 recorded the highest mean rank for taste (8.45), followed by CPV. 15 (8.30), CPV. 9 (8.25), CPV. 2 (8.20) and CPV 12 (8.05). The variety CO 7 also recorded the highest rank for overall acceptability (8.30), followed by CPV. 2 (8.15), CPV. 15 (8.10), CPV. 9 (8.10), and CPV 12 (7.95).

4.1.4. Pest and disease incidence

The disease observed during the period of study were incidence of collar rot *(Pythium aphanidermatum)*, anthracnose *(Colletotrichum gleosporioides)*, and papaya ring spot virus (PRSV). The crop was managed with the timely application of plant protection chemicals. As a precautionary measure against PRSV, 10 % bougainvillaea extract was sprayed at fortnightly intervals. A total of five sprays were given to all the plants under study. Arka Surya was found very susceptible at 5 MAP, the plants of Arka Surya were found to be highly susceptible to the PRSV infection, and neither precautionary nor protective measures could save those plants. It was noted that Arka Surya was highly susceptible to PRSV under Kerala conditions and hence was not included in further evaluation.

4.1.5. Soil analysis after the experiment

The soil of experiment was acidic in reaction with pH of 5.01, EC of 0.05 dS m-1, and organic carbon of 1.65 %. The nitrogen, phosphorous and potassium content of the soil after experiment are 214.42, 29.27 and 352.70 kg ha-^{1}, respectively.

4.1.6. Plant analysis

The genotypes showed significant differences in the nutrient content of the index leaves. The statistical data of different genotypes on the leaf analysis before flowering and after harvest, varied significantly for plant nutrients like nitrogen, phosphorous, potassium, calcium, magnesium, sulphur, zinc, and boron (Tables 17 to 19). The report ofleaf analysis before flowering showed that the highest nitrogen content (1.66 %) was observed for CPV 15, which was on par with CO 4 and CO 3

Table 12. Fruit weight, number of fruits, yield per plant, yield per ha of papaya genotypes

Genotype	Fruit weight (g)	Number of fruits	Yield/plant (kg)	Yield/ha (kg ha^{-1})
CPV 1	1331.44	22.00	29.28	73.20
CPV2	1160.32	29.25	29.17	72.92
CPV3	972.55	23.75	23.29	58.24
CPV4	970.38	22.00	21.20	53.01
CPV 5	882.00	14.75	12.90	32.25
CPV6	941.60	20.12	21.06	52.66
CPV7	1045.02	11.37	10.32	25.81
CPV8	959.05	22.87	24.14	60.36
CPV9	1032.78	14.25	14.34	35.86
CPV 10	1020.26	15.00	16.41	41.04
CPV 11	1043.21	22.00	19.83	49.60
CPV 12	1011.72	18.75	20.73	51.82
CPV13	1013.71	14.00	13.27	33.17
CPV 14	1209.46	13.75	20.90	52.26
CPV 15	1162.11	17.87	13.96	34.92
CPV 16	818.94	11.12	9.59	23.97
Arka Prabhath	736.60	20.37	12.05	30.01
Arka Surya	0.00	0.00	0.00	0.00
CO 1	1626.27	15.25	24.80	62.00
CO2	1439.50	18.62	26.81	67.02
CO3	939.85	22.75	21.28	53.20
CO4	1779.72	18.87	33.59	83.97
CO6	1908.22	15.62	29.88	74.70
CO7	944.22	22.25	21.00	52.49
Red Lady	1184.66	23.62	27.96	69.90
CV(%)	15.87	2.82	7.40	7.40
CD (5%)	355.72	1.05	3.04	76.05

Table 13. Seeds per fruit, days from fruit set to maturity and days from maturity to ripening of papaya genotypes

Genotype	Seeds/fruit	100 seed weight	Days from fruit set to maturity	Days from maturity to ripening
CPV 1	551.31	2.58	136.90	4.70
CPV2	497.12	2.97	131.90	5.50
CPV3	653.37	2.86	136.00	4.30
CPV4	635.62	3.18	135.60	4.30
CPV5	526.50	3.14	120.33	4.00
CPV6	600.37	3.41	133.87	4.75
CPV7	670.50	2.78	155.16	6.00
CPV8	520.50	3.28	141.62	5.70
CPV9	821.75	3.71	143.12	4.60
CPV 10	1270.12	3.95	143.62	4.75
CPV 11	623.12	3.02	127.90	4.10
CPV 12	598.19	3.13	135.00	5.10
CPV 13	747.00	3.76	138.20	5.20
CPV 14	964.12	3.25	138.70	6.10
CPV 15	941.12	3.91	138.33	5.20
CPV 16	349.75	4.01	138.50	4.90
Arka Prabhath	377.11	2.80	153.17	5.70
Arka Surya	0.00	0.00	0.00	0.00
CO 1	782.11	3.75	141.62	5.40
CO2	918.00	3.57	158.60	5.20
CO3	720.00	3.75	137.66	4.75
CO4	672.00	3.26	143.60	4.70
CO6	959.00	3.14	155.60	4.90
CO7	599.25	2.77	136.40	6.30
Red Lady	884.25	2.39	134.50	6.36
CV(%)	3.56	3.50	2.73	4.84
CD (5%)	49.67	0.23	7.56	0.45

Table 16. Organoleptic evaluation of papaya genotypes

Genotype	Appearance	Colour	Texture	Flavour	Odour	Taste	After taste	Overall acceptability	Total score
CPV 1	7.05 (7.65)	8 (13.95)	6.25 (3.00)	6.95 (5.75)	6.8 (6.25)	7.6 (9.10)	7.45 (12.15)	7.5 (10.85)	57.6
CPV2	8.1 (14.00)	8.25 (16.35)	8.05 (16.85)	8.15 (19.30)	8 (17.25)	8.2 (16.35)	7.85 (16.15)	8.15 (17.85)	64.75
CPV3	7.4 (11.00)	7.85 (11.35)	7.25 (10.00)	7.65 (13.45)	7.6 (14.00)	7.95 (13.10)	7.35 (10.10)	7.55 (11.35)	60.60
CPV4	7.29 (7.70)	8.05 (12.80)	7.1 (8.25)	7.25 (8.90)	7.85 (15.35)	7.65 (10.00)	7.6 (13.50)	7.45 (10.20)	60.24
CPV5	7.5 (8.55)	7.6 (8.30)	7.05 (7.95)	7.35 (9.45)	7.3 (9.45)	7.3 (6.75	7.4 (11.20)	6.55 (4.60)	58.05
CPV6	7.61 (9.80)	7.8 (10.85)	7.5 (11.00)	7.3 (9.20)	7.4 (11.30)	7.92 (13.55)	7.2 (9.60)	7.1 (10.35)	59.83
CPV7	7.45 (8.60)	8 (13.30)	7.95 (17.40)	7.2 (8.95)	7.15 (8.65)	7.8 (11.65)	7.75 (15.30)	7.25 (8.95)	60.55
CPV8	7.88 (13.35)	7.55 (7.50)	7.9 (17.75)	7.25 (10.20)	7.25 (9.15)	7.6 (9.15)	7.8 (14.85)	7 (6.45)	60.23
CPV9	8.05 (13.65)	8.05 (14.75)	8.15 (18.05)	8.25 (19.85)	7.95 (16.600	8.25 (17.10)	7.95 (17.25)	8.1 (17.40)	64.75
CPV 10	8.25 (16.55)	8 (13.30)	7.67 (13.95)	7.2 (8.95)	7.94 (16.85)	8.05 (15.65)	7.81 (15.20)	7.91 (14.75)	62.83
CPV 11	8 (14.10)	8.1 (15.05)	7.2 (9.65)	7.55 (14.00)	7.15 (8.65)	7.55 (9.30)	7.15 (8.50)	7.45 (11.75)	60.15
CPV 12	8.5 (19.70)	8.15 (15.50)	**7.74** (15.75)	**7.92** (13.15)	7.91 (16.95)	8.05 (15.65)	7.5 (12.15)	7.95 (15.55)	63.72
CPV 13	7.15 (5.50)	7.9 (12.35)	7.25 (9.65)	7.2 (8.95)	7.8 (15.45)	7.4 (9.05)	7.4 (10.95)	7.4 (11.15)	59.50
CPV 14	7.88 (12.15)	7.55 (7.50)	7.01 (6.95)	7.25 (10.20)	7.4 (10.30)	7.89 (12.55)	7.5 (12.25)	7.29 (8.95)	59.77
CPV 15	8.15 (14.55)	8.1 (15.75)	8.1 (17.55)	8.3 (20.40)	7.9 (15.80)	8.3 (17.90)	7.85 (16.15)	8.1 (17.40)	64.8
CPV 16	8.15 (16.00)	7.8 (11.50)	7.2 (9.65)	7.4 (10.60)	7.4 (11.20)	7.4 (9.20)	7.4 (11.20)	7.9 (14.55)	60.65
Arka Prabhath	8.1 (15.60)	7.55 (7.50)	7.4 (12.65)	7.7 (15.15)	7.1 (10.45)	7.65 (13.65)	7.1 (10.80)	7.75 (14.05)	60.35
CO 1	7.97 (13.05)	7.7 (9.90)	7.29 (10.80)	7.54 (12.45)	7.25 (9.30)	7.95 (13.65)	7.25 (9.25)	7.5 (11.50)	60.45
CO2	8.16 (14.95)	8.09 (14.65)	7.7 (13.65)	7.5 (11.10)	7.65 (13.65)	7.85 (13.85)	7.15 (9.60)	7.75 (13.95)	61.85
CO3	8.3 (16.50)	7.55 (7.50)	7.75 (15.05)	7.2 (8.25)	7.29 (9.75)	7.8 (12.40)	7.2 (9.60)	7.59 (11.35)	60.68
CO4	8.25 (17.05)	7.8 (11.80)	7.4 (11.15)	7.25 (10.20)	7.1 (10.45)	7.75 (12.05)	7.55 (12.00)	7.4 (10.15)	60.50
CO6	8.45 (19.25)	**8.1** (15.05)	7.2 (9.35)	7.35 (10.75)	7.25 (9.30)	7.53 (8.90)	7.38 (10.45)	7.2 (8.95)	60.46
CO7	8.25 (15.80)	8.3 (17.15)	8 (16.40)	8.4 (21.00)	7.95 (16.65)	8.45 (19.05)	7.9 (16.25)	8.3 (19.05)	65.55
Red Lady	8.2 (15.15)	8.15 (16.35)	8.1 (17.55)	8.2 (19.80)	8 (17.25)	7.75 (12.50)	7.8 (15.55)	8.25 (18.90)	64.45
Kendall's W ·	0.321	0.225	0.364	0.425	0.269	0.221	0.160	0.323	

Table 17. Nutrient analysis of index leaf of genotypes

Genotype	Before flowering			After harvest		
	Nitrogen (%)	Phosphorous (%)	Potassium (%)	Nitrogen (%)	Phosphorous (%)	Potassium (%)
CPV 1	1.14	0.72	2.30	1.43	0.61	2.29
CPV2	1.49	0.76	2.29	1.43	0.64	2.28
CPV3	1.52	0.81	2.22	1.24	0.66	2.21
CPV4	1.42	0.76	2.19	1.21	0.69	2.17
CPV5	1.40	0.80	2.09	1.16	0.76	2.08
CPV6	1.39	0.73	2.21	1.22	0.67	2.20
CPV7	1.46	0.79	2.08	1.11	0.78	2.07
CPV8	1.49	0.82	2.22	1.32	0.64	2.21
CPV9	1.38	0.71	2.14	1.18	0.77	2.13
CPV 10	1.44	0.72	2.15	1.24	0.73	2.13
CPV **11**	1.31	0.64	2.21	1.26	0.68	2.19
CPV 12	1.45	0.80	2.24	1.20	0.66	2.23
CPV 13	1.41	0.79	2.14	1.13	0.77	2.12
CPV **14**	1.39	0.77	2.22	1.23	0.71	2.21
CPV 15	1.66	0.84	2.11	1.21	0.74	2.10
CPV 16	1.31	0.69	2.07	1.04	0.79	2.05
Arka Prabhath	1.34	0.74	2.15	1.11	0.70	2.14
Arka Surya	0.00	0.00	0.00	0.00	0.00	0.00
CO 1	1.28	0.72	2.19	1.30	0.63	2.17
CO2	1.43	0.76	2.25	1.38	0.64	2.24
CO3	1.59	0.83	2.18	1.29	0.67	2.16
CO4	1.61	0.86	2.33	1.49	0.59	2.30
CO6	1.39	0.79	2.29	1.46	0.63	2.26
CO7	1.24	0.76	2.13	1.24	0.69	2.12
Red Lady	1.30	0.78	2.27	1.38	0.66	2.25
CV(%)	3.01	2.48	0.17	0.42	1.91	0.09
CD (5%)	0.11	0.38	0.01	0.014	0.26	0.004

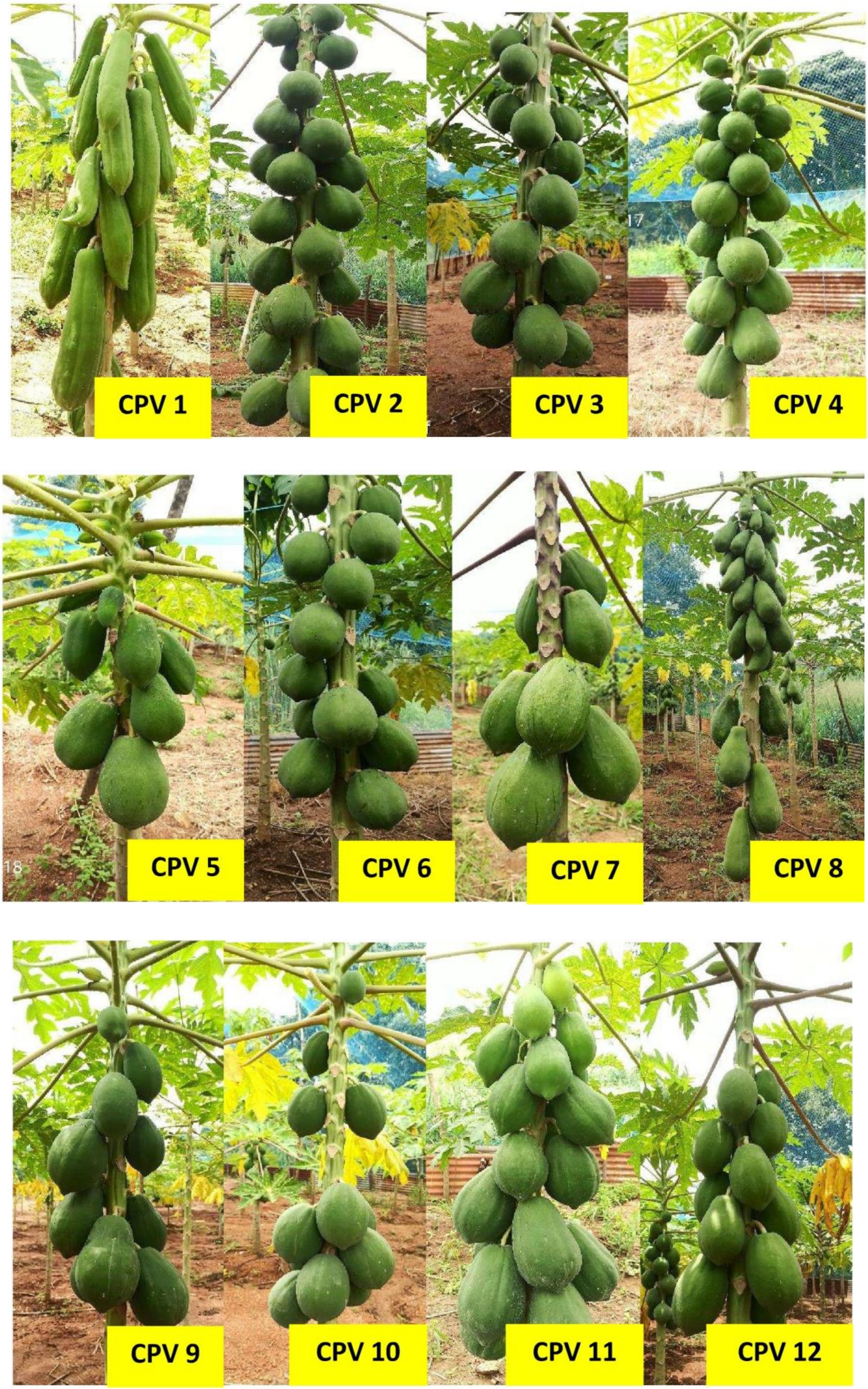

Plate 16. Performance of papaya genotypes under field condition

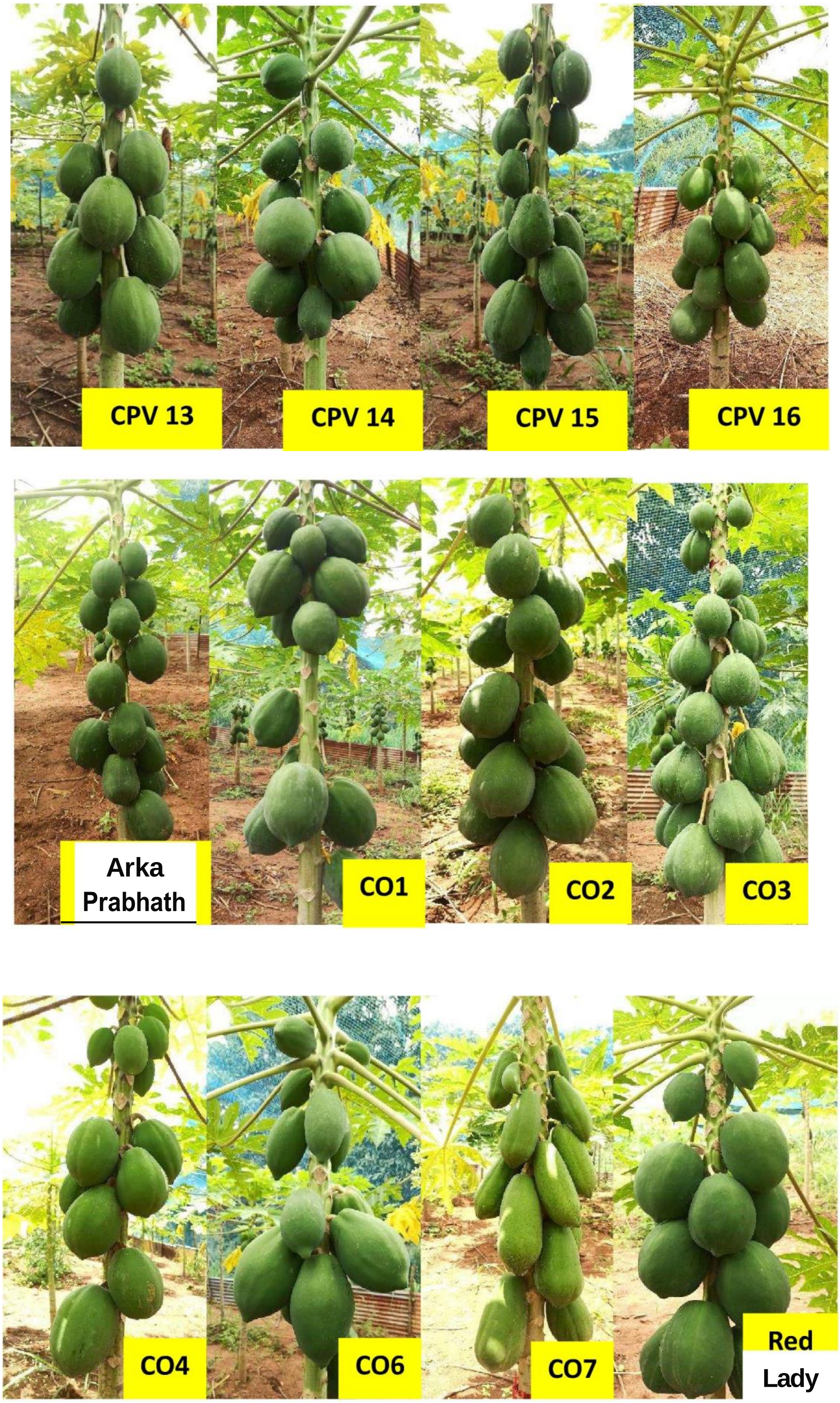

Plate 17. Performance of papaya genotypes under field condition

Table 18. Nutrient analysis of index leaf of genotypes

Genotype	Before flowering			After harvest		
	Calcium (%)	Magnesium (%)	Sulphur (%)	Calcium (%)	Magnesium (%)	Sulphur (%)
CPV 1	0.43	0.25	0.31	0.38	0.21	0.25
CPV2	0.45	0.27	0.33	0.40	0.23	0.29
CPV3	0.51	0.33	0.39	0.46	0.29	0.34
CPV4	0.53	0.35	0.41	0.48	0.31	0.37
CPV5	0.55	0.38	0.43	0.51	0.33	0.38
CPV6	0.51	0.33	0.39	0.46	0.29	0.35
CPV7	0.53	0.35	0.41	0.48	0.31	0.36
CPV8	0.50	0.32	0.38	0.45	0.28	0.33
CPV9	0.52	0.34	0.40	0.47	0.30	0.36
CPV 10	0.51	0.33	0.39	0.46	0.29	0.35
CPV 11	0.45	0.27	0.33	0.40	0.23	0.28
CPV 12	0.48	0.30	0.36	0.43	0.26	0.32
CPV 13	0.51	0.33	0.39	0.46	0.29	0.35
CPV 14	0.50	0.32	0.38	0.45	0.28	0.33
CPV 15	0.47	0.29	0.35	0.42	0.25	0.31
CPV 16	0.54	0.36	0.42	0.49	0.32	0.38
Arka Prabhath	0.48	0.30	0.36	0.43	0.26	0.31
Arka Surya	0.00	0.00	0.00	0.00	0.00	0.00
CO 1	0.46	0.28	0.34	0.41	0.24	0.30
CO2	0.49	0.31	0.37	0.44	0.27	0.33
CO3	0.55	0.37	0.42	0.50	0.33	0.39
CO4	0.44	0.26	0.32	0.39	0.22	0.27
CO6	0.42	0.25	0.30	0.37	0.20	0.26
CO7	0.53	0.35	0.41	0.48	0.31	0.37
Red Lady	0.45	0.27	0.33	0.40	0.23	0.28
CV(%)	1.19	1.39	0.91	0.73	0.58	1.33
CD (5%)	0.012	0.02	0.06	0.01	0.01	0.01

Table 19. Nutrient analysis of index leaf of genotypes

Genotype	Before flowering		After harvest	
	Zinc (ppm)	Boron (ppm)	Zinc (ppm)	Boron (ppm)
CPV 1	14.24	16.54	14.44	19.65
CPV2	14.13	16.43	14.33	19.54
CPV3	13.33	15.63	13.53	18.74
CPV4	13.83	16.13	14.03	19.24
CPV 5	9.33	11.63	9.53	14.74
CPV6	13.42	15.72	13.62	18.83
CPV7	8.35	10.65	8.55	13.76
CPV8	12.43	14.73	12.63	17.84
CPV9	10.24	12.54	10.44	15.65
CPV 10	12.31	14.61	12.51	17.72
CPV 11	13.36	15.66	13.56	18.77
CPV 12	14.08	16.38	14.28	19.49
CPV 13	11.22	13.52	11.42	16.63
CPV 14	13.82	16.12	14.02	19.23
CPV 15	11.34	13.64	11.54	16.75
CPV 16	8.21	10.51	8.41	13.62
Arka Prabhath	9.64	11.94	9.84	15.05
Arka Surya	0.00	0.00	0.00	0.00
CO 1	14.20	16.50	14.40	19.61
CO2	15.22	17.52	15.42	20.63
CO3	13.81	16.11	14.01	19.22
CO4	16.22	18.52	16.42	21.64
CO6	15.18	17.48	15.38	20.59
CO7	13.94	16.24	14.14	19.35
Red Lady	14.20	16.50	14.40	19.61
CV(%)	0.07	0.03	0.28	0.04
CD (5%)	0.02	0.01	0.07	0.02

(1.61 % and 1.59 %, respectively). Meanwhile, the lowest nitrogen content was observed in the leaves ofCPV 1 (1.14 %). The highest content of phosphorous was also recorded for CO 4 (0.86 %), whereas the lowest value was recorded for CPV 11 (0.64 %). The potassium content was found to be highest in CO 4 (2.33 %) followed by treatment CPV 1 (2.30 %). The leaves of genotypes showed the highest calcium content before flowering in CPV 5 and CO 3 (0.55 %). The highest magnesium content was observed for CPV 5 (0.38 %) and CO 3 (0.37 %), while the lowest content was recorded for CO 6 (0.25 %). The highest sulphur content was recorded for CPV 5 (0.43%), and CO 3 (0.42 %). With regard to zinc content in leaves, CO 4 (16.22 ppm) recorded the highest value, followed by CO2 (15.22 ppm), while the lowest zinc content was observed for CPV 16 (8.21 ppm). Likewise, the highest boron content was recorded for CO 4 (18.53 ppm), followed by CO2 (17.52 ppm).

After the harvest, significant variation was observed among the genotypes for nitrogen, phosphorous, and potassium content. The highest nitrogen was recorded for CO 4 (1.49 %) followed by CO 6 (1.46 %), while the lowest nitrogen was found in CPV 16 (1.04 %). On comparing the phosphorous content, treatments CPV 16 recorded the highest value of 0.79 %, which was on par with CPV 7, CPV 13 and CPV 9 (0.79 %, 0.78 % and 0.78 %). The data on the potassium content in the index leaf of the treatments showed that the highest potassium content was recorded for CO 4 (2.30 %) followed by CPV 1 (2.29 %). The lowest potassium content was noted in CPV 16 (2.05 %). The genotypes varied significantly for calcium content, and the highest percentage of calcium was observed in the index leaf of CPV 5 (0.51 %), and CO 3 (0.50 %), while the lowest value was noticed in CO 6 (0.37 %). The highest content of magnesium was recorded in CPV 5 (0.33 %) and CO 3 (0.33 %), while the lowest magnesium content was noticed in CO 6 (0.20 %). The statistical data on sulphur content revealed that there was significant variation among the treatments and the highest value was noted for CO 3, CPV 5 and CPV 16 (0.39 %, 0.38 %. 0.38 %, respectively). Meanwhile, the lowest sulphur content was noted in CPV 1 (0.25 % each).

While comparing the zinc and boron content in the index leaf of the genotypes., the highest percentage of zinc was exhibited by CO 4 (16.42 ppm), which was followed by CO 2 and CO 6 (15.42 and 15.38 ppm, respectively). However, the lowest zinc content was observed for CPV 16 (8.41 ppm), which was on par with T7 (8.55 ppm). The data on boron content showed the highest value for CO 4 (21.64 ppm), followed by CO2 (20.63 ppm). While the lowest boron content was observed for CPV 16 (13.63 ppm).

4.2 EFFECT OF FERTIGATION AND SPACING LEVELS IN PAPAYA UNDER HIGH DENSITY PLANTING SYSTEM

4.2.1 Biometric characters

a. Height of plant (cm)

The plant height of papaya was recorded at bimonthly intervals from 2 months after planting (MAP) up to the peak harvesting stage (12 MAP). The height of the plant differed significantly among the genotypes and the result is presented in Table 20.

The observation recorded at 2 MAP indicated highest plant height in treatment T6 (119.66 cm), which was on par with treatment T5 (111.62 cm). The control treatment, T7, was found to be on par with T3 (99.90 cm and 106.39 cm, respectively). The lowest plant height was registered by the plants spaced at 1.25 m x 1.25 m, receiving 60 per cent RD ofN and K2O (Tl-92.00 cm).

At 4 MAP, the highest plant height was observed in treatment T6 (147.32 cm), which was on par with treatment T5 (139.84 cm). It was followed by treatment T4 (131.37 cm) and control treatment T7 (130.38 cm). The treatment T2 recorded the lowest plant height of 120.22 cm at 4 MAP.

Results of data on plant height at 6 MAP revealed that treatment T3 recorded the highest value for plant height (183.41 cm), followed by treatment T2 (173.33 cm) and T6 (173.02 cm). At 6 MAP, the shortest plants were recorded in the treatment T4 (152.33), which was on par with the treatment T7 (158.61 cm).

Plate 18. Discarded genotype Arka Surya (PRSV attacked)

Plate 19. Collar rot of papaya

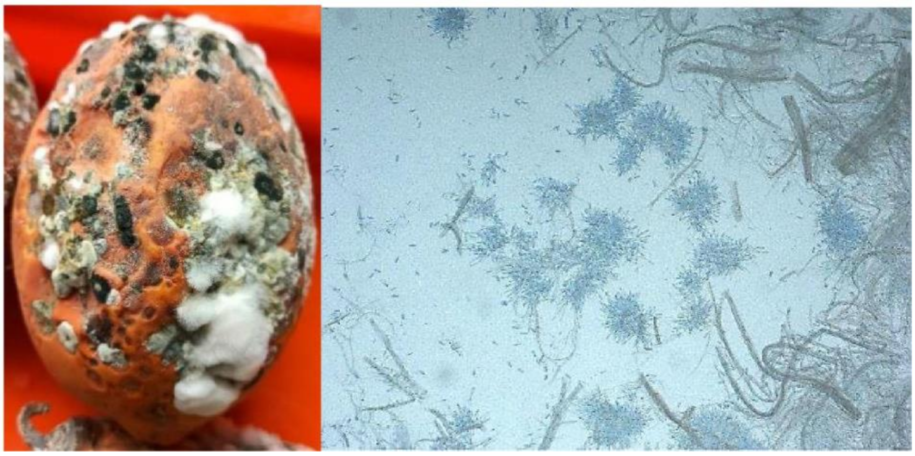

Plate 20. Anthracnose affected papaya fruit and microscopic view of its conidia

At 8 MAP, highest plant height was noted in treatment T3 (223.55 cm), followed by treatment T2 and T6 (216.31 cm and 215.84 cm, respectively). Among the seven treatments, treatment T4 was found to be the shortest at 8 MAP (183.55 cm).

The data pertaining to the height of papaya plants at 10 MAP showed that the tallest plants were observed in treatment T3 (277.52 cm), followed by treatment T5 and T6 (239.49 and 239.18 cm). The treatment T4 recorded the lowest plant height at 10 MAP (214.55 cm) and was found to be on par with treatments T 1 (221.66 cm) and T 7 (223.20 cm).

At 12 MAP, treatment T3 registered the highest value for plant height (297.29 cm), followed by treatment T6 (272.18 cm) and T5 (259.59 cm). However, the shortest plants observed at the end of the study were in treatments T 1 (242.91 cm) and T 4 (243.66 cm).

b. Girth of plant (cm)

The girth of the plants was recorded at bimonthly intervals starting from 2 MAP to 12 MAP (peak harvesting stage). The observations on plant girth for different months are presented in Table 21.

The results of the plant girth revealed that at 2 MAP, highest collar girth was observed in treatment T6 (8.51 cm), followed by treatment T3 and T5 (8.33 cm and 8.13 cm, respectively). Among the treatments, treatment Tl showed a min lowest imum collar girth of 7.19 cm at 2 MAP.

At 4 MAP, the data on the collar girth clearly showed that the trend was similar to that at 2 MAP: the treatment T6 exhibited highest collar girth of 16.67 cm, followed by the treatments T3 and T5 (15.59 cm and 15.17 cm, respectively). Similarly, treatment Tl showed the lowest value for collar girth at 4 MAP (13.69 cm).

Statistical analysis of the plants at 6 MAP showed a similar trend to that of 2 MAP and 4 MAP. The highest collar girth was found in T6 (25.65 cm), followed by T3 (25.40 cm) and T5 (24.19 cm), while the lowest collar girth was recorded in Tl (21.46 cm).

At 8 MAP, highest collar girth was exhibited by treatment T 6 (34.55 cm), and it was on par with treatment T3 (33.97 cm). The lowest collar girth was recorded by the treatment Tl (27.97 cm).

While analysing the data pertaining to 10 MAP, it was clear that the highest collar girth was noted in the treatment T 6 (40.58 cm), followed by T3 (39.33 cm). Similar to the trend showed in the previous months, treatment Tl recorded the lowest collar girth (32.29 cm) among the treatments.

The results of collar girth at 12 MAP exhibited a similar trend as that of 10 MAP, with the highest collar girth for treatment T6 (45.49 cm) and the lowest for treatment Tl (36.49 cm).

c. Number of leaves

During the period of study, the number of leaves was recorded at 2 MAP, 4 MAP, 6 MAP, 8 MAP, 10 MAP, and 12 MAP. The results of the statistical analysis are furnished in Table 22.

At 2 MAP, the highest number of leaves were exhibited by treatments T6 (11.77) and T7 (11.390). This was followed by the treatments T5 (10.61), T2 (10.45), and T3 (10.45). However, the lowest number of leaves was found in treatment T4 (9.610).

The data for number of leaves at 4 MAP showed that the maximum number of leaves were observed in treatments T6 (13.92) and T 7 (13.61), whereas the lowest number ofleaves were reported in treatments T 4 and T 1 (11.77 and 11.85, respectively).

At 6 MAP, the highest number of leaves was recorded in treatments T6 and T7 (15.46 and 15.15, respectively), followed by T5, T3, and T2 (14.38, 14.16, and 14.11, respectively). Meanwhile, the least number of leaves were observed in treatments T4 (13.29) and Tl (13.39).

Table 20. Effect of fertigation and spacing on height of plant (cm)

Treatments	Height of plant (cm)					
	2MAP	**4MAP**	**6MAP**	**8MAP**	**lOMAP**	**12MAP**
Tl (SlFl)	92.00	123.19	164.07	195.32	221.66	242.91
T2 (SlF2)	93.98	120.22	173.33	216.31	229.28	251.29
T3 (SlF3)	106.39	126.15	183.41	223.55	277.52	297.29
T4 (S2Fl)	99.45	131.37	152.33	183.55	214.55	243.66
T5 (S2F2)	111.62	139.84	165.22	215.67	239.49	259.59
T6 (S2F3)	119.66	147.32	173.02	215.84	239.18	272.18
T7 (Control)	99.90	130.38	158.61	201.36	223.20	253.31
CV(%)	6.86	6.34	2.17	1.73	2.32	0.89
CD (5%)	12.62	14.81	6.48	6.38	9.70	4.14

S1- 1.25 m x 1.25 m S2- 1.50 m x 1.50 m

Fl- 60 % RDF ofN and K2O F2- 80 % RDF ofN and K2O F3-100 % RDF ofN and K2O

Control- 2 m x 2 m + Soil application of N:P2Os:K2O as per KAU PoP under conventional method of irrigation without mulching

*RDF- recommended dose of fertilizer

Table 21. Effect of fertigation and spacing on girth of plant

Treatments	Girth of plant (cm)					
	2MAP	**4MAP**	**6MAP**	**8MAP**	**lOMAP**	**12MAP**
Tl (SlFl)	7.19	13.69	21.46	27.97	32.29	36.49
T2 (S1F2)	8.02	14.46	23.68	32.31	36.427	41.63
T3 (S1F3)	8.33	15.59	25.40	33.97	39.33	44.57
T4 (S2Fl)	7.97	14.03	22.31	29.66	34.48	38.41
T5 (S2F2)	8.13	15.17	24.19	31.427	37.53	41.79
T6 (S2F3)	8.51	16.67	25.65	34.55	40.58	45.49
T7 (Control)	7.83	15.03	23.72	31.13	37.18	40.43
CV(%)	1.20	1.57	0.93	1.05	0.76	0.86
CD (5%)	0.17	0.41	0.39	0.59	0.50	0.63

S1- 1.25 m x 1.25 m S2- 1.50 m x 1.50 m

Fl- 60 % RDF ofN and K2O F2- 80 % RDF ofN and K2O F3-100 % RDF ofN and K2O

Control- 2 m x 2 m + Soil application of N:P2Os:K2O as per KAU PoP under conventional method of irrigation without mulching

*RDF- recommended dose of fertilizer

Table 22. Effect of fertigation and spacing on number of leaves

Treatments	Number of leaves					
	2MAP	**4MAP**	**6MAP**	**8MAP**	**lOMAP**	**12MAP**
Tl (SlFl)	9.72	11.85	13.39	17.49	21.35	16.97
T2 (S1F2)	10.45	12.57	14.11	18.01	23.27	21.11
T3 (S1F3)	10.45	12.61	14.16	16.85	23.45	21.42
T4 (S2Fl)	9.61	11.77	13.29	17.69	21.56	18.92
T5 (S2F2)	10.61	12.85	14.38	18.21	23.95	22.37
T6 (S2F3)	11.77	13.92	15.46	17.91	24.19	22.62
T7 (Control)	11.39	13.61	15.15	18.99	23.97	22.39
CV(%)	2.81	2.34	2.10	1.48	3.43	3.80
CD (5%)	0.53	0.53	0.53	0.47	1.41	1.41

Sl- 1.25 m x 1.25 m S2- 1.50 m x 1.50 m

Fl- 60 % RDF ofN and K2O F2- 80 % RDF ofN and K2O F3-100 % RDF ofN and K2O

Control- 2 m x 2 m + Soil application of N:P2Os:K2O as per KAU PoP under conventional method of irrigation without mulching

*RDF- recommended dose of fertilizer

Table 23. Effect of fertigation and spacing on height at first flowering, days to flowering and sex expression of the plant

Treatments	Height at first flowering	Days to flowering	Sex expression
Tl (SlFl)	100.16	74.83	Gynodioecious
T2 (S1F2)	91.31	74.05	Gynodioecious
T3 (S1F3)	84.72	71.39	Gynodioecious
T4 (S2Fl)	96.15	75.443	Gynodioecious
T5 (S2F2)	89.78	72.55	Gynodioecious
T6 (S2F3)	78.62	67.77	Gynodioecious
T7 (Control)	94.05	79.77	Gynodioecious
CV(%)	2.23	2.68	NA
CD (5%)	3.60	3.52	NA

S1- 1.25 m x 1.25 m S2- 1.50 m x 1.50 m

Fl- 60 % RDF ofN and K2O F2- 80 % RDF ofN and K2O F3-100 % RDF ofN and K2O

Control- 2 m x 2 m + Soil application of N:P2Os:K2O as per KAU PoP under conventional method of irrigation without mulching

*RDF- recommended dose of fertilizer

The number of leaves recorded at 8 MAP showed the highest number of leaves in treatment T7 (18.99), followed by *TS* (18.21), which was on par with T2 and T6 (18.01 and 17.91, respectively). However, the lowest number of leaves was observed in treatment T3 (16.85).

At 10 MAP, treatment T6 recorded the highest value for number of leaves (24.19) and was found to be on par with T7 (23.97), *TS* (23.95), T3 (23.45), and T2 (23.27). However, treatments T 1 (21.35) and T4 (21.56) recorded the lowest number of leaves among the treatments.

The number of leaves at the end of observation (12 MAP) showed the highest value of 22.62 for the treatment T6, and it was found to be on par with T7, T5, and T3 (22.39, 22.37, and 21.42, respectively). Meanwhile, the lowest number ofleaves was observed in treatment Tl (16.97).

d. Height at first flowering (cm)

The statistical analysis of height at first flowering showed a significant difference among the treatments (Table 23).

The data clearly showed the positive effect of treatment T 6 (1.50 m x 1.50 m spacing coupled with 100 per cent RD of N and K20) on the height at first flowering. The lowest height at first flowering was observed in treatment T6 (78.62 cm), followed by T3 (84.72 cm). Meanwhile, the highest value of height at first flowering was noted in treatment Tl (100.16 cm), followed by treatment T4 (96.15 cm), which was on par with the control T7 (94.05 cm).

e. Days to flowering

The treatments differed significantly with respect to the number of days to first flowering (Table 23). The results indicated that early flowering occurred in treatment T6 (67.77 days), followed by T3 (71.39 days). The treatments *TS*, T2, and **Tl** (72.55 days, 74.05 days, and 74.83 days, respectively) were on par with treatment T3. However, the longest duration for flowering was taken by control treatment T7 (79.77 days)

f. Sex expression of plant

The details of sex expression of the treatments is furnished in Table 23. All the treatment plants under study were gynodioecious in nature, consisting of both female and hermaphrodite plants.

g. Number of flowers/cluster

The data on the number of flowers per cluster showed a significant variation among the treatments (Table 24). The treatments T6 (100 per cent RD ofN and K2O planted at 1.50 m x 1.50 m) and T3 (100 per cent RD ofN and K2O planted at 1.25 m x 1.25 m) exhibited the highest number of flowers per cluster (2.34 and 2.32, respectively). Meanwhile, the least number of flowers per cluster was recorded in the control treatment T7 (1.39).

h. Fruit set(%)

A significant variation was exhibited by the treatments with respect to the fruit set percentage (Table 24). The highest percentage of fruit set was recorded in treatment T6 (72.11%), followed by T3 (65.21 %). Treatment T1 showed the lowest fruit set percentage of 43. 24 %.

i. **Days for first harvest**

The statistical data on the number of days to harvest showed a significant difference among the treatments (Table 24). The treatment T6 (207.33 days) took the lowest number of days to harvest, while the maximum days were taken by treatments Tl (226.00 days) and T7 (225.83 days). It was followed by T2 (222.40 days), T3 (220.13 days), and T4 (219.92 days) for the first harvest.

4.2.2. Yield characters

a. Fruit weight (g)

On comparing the values of fruit weights for different treatments, it was observed that the treatments showed a significant difference for fruit weight (Table 26).

Table 24. Effect of fertigation and spacing on number of flowers/cluster, fruit set percentage and days for first harvest of the plant

Treatments	Number of flowers/cluster	Fruit set (%)	Days for first harvest
Tl (SlFl)	1.56	43.24	226.00
T2 (S1F2)	1.82	53.97	222.40
T3 (S1F3)	2.32	65.21	220.13
T4 (S2Fl)	1.79	54.51	219.92
TS (S2F2)	1.91	57.32	213.91
T6 (S2F3)	2.34	72.11	207.33
T7 (Control)	1.39	50.59	225.83
CV(%)	15.05	4.22	0.87
CD (5%)	0.502	4.26	3.39

Sl- 1.25 m x 1.25 m   S2- 1.50 m x 1.50 m

Fl- 60 % RDF ofN and K2O   F2- 80 % RDF ofN and K2O   F3-100 % RDF ofN and K2O

Control- 2 m x 2 m + Soil application of N:P2Os:K2O as per KAU PoP under conventional method of irrigation without mulching

*RDF- recommended dose of fertilizer

Table 25. Effect of fertigation and spacing on fruit length, fruit girth, fruit volume and flesh thickness of papaya

Treatments	Fruit length (cm)	Fruit girth (cm)	Fruit volume (cm^3)	Flesh thickness (cm)
Tl (SIFI)	15.65	15.713	450.05	1.66
T2 (S1F2)	15.73	16.120	453.53	1.82
T3 (S1F3)	16.20	19.583	624.32	2.19
T4 (S2Fl)	15.68	18.673	678.42	2.24
T5 (S2F2)	15.38	21.057	699.11	2.30
T6 (S2F3)	16.45	22.737	715.02	2.43
T7 (Control)	15.18	11.280	582.55	2.28
CV(%)	1.22	20.60	1.05	10.70
CD (5%)	0.47	6.55	11.24	0.40

Sl- 1.25 m x 1.25 m S2- 1.50 m x 1.50 m

Fl- 60 % RDF ofN and K2O F2- 80 % RDF ofN and K2O F3-100 % RDF ofN and K2O

Control- 2 m x 2 m + Soil application of N:P2Os:K2O as per KAU PoP under conventional method of irrigation without mulching

*RDF- recommended dose of fertilizer

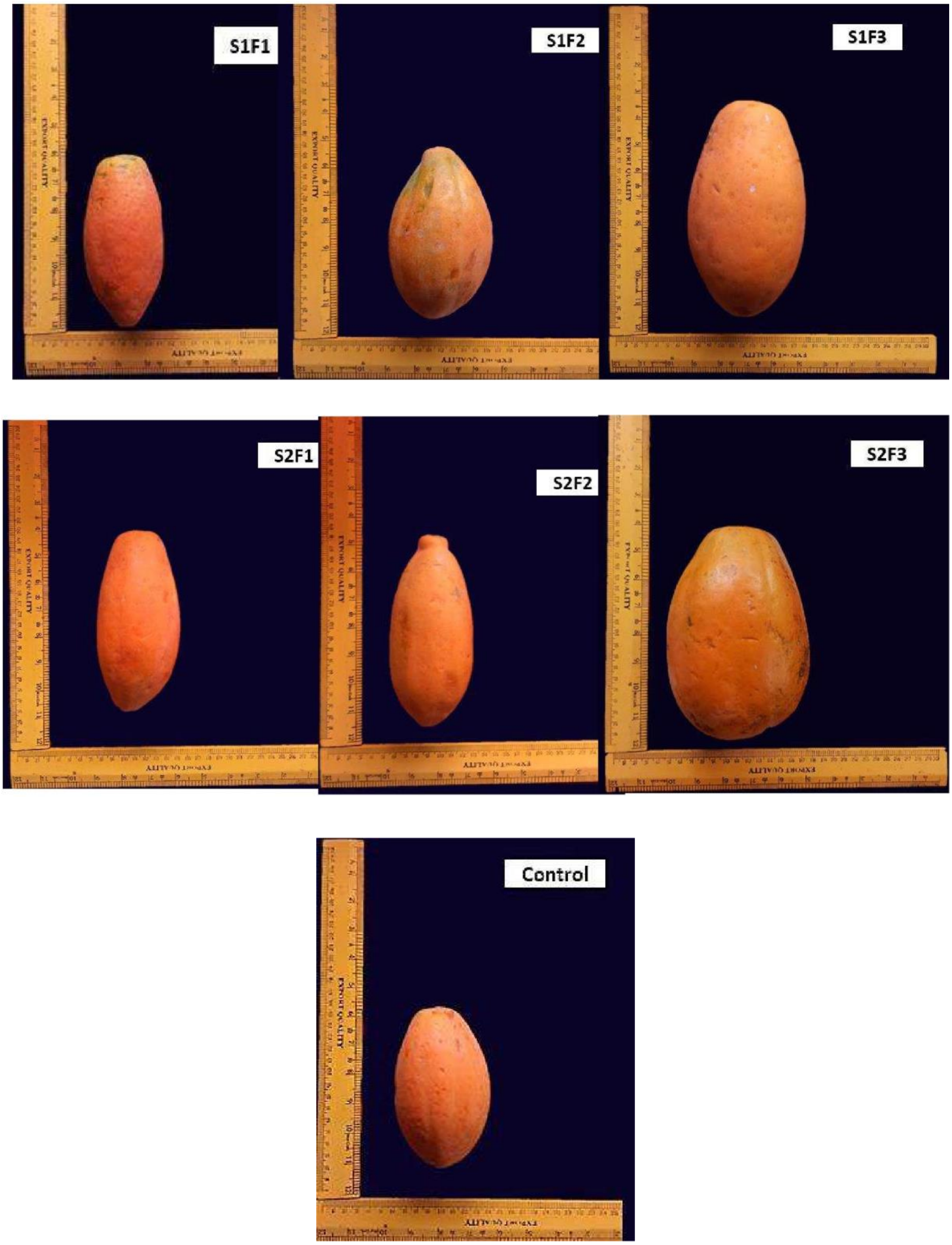

Plate 21. Effect of fertigation and spacing on fruit size of papaya

The highest fruit weight was recorded for treatment T6 (657.08 g), followed by treatments T3 and T5 (577.64 g and 567.40 g, respectively), and then by other treatments T7, T2, Tl, and T4 (524.69 g, 513.66 g, 497.46 g, and 498.52 g, respectively). The fruit weights were found to range between 657.08-498.52 g for the treatments under study.

b. Fruit length (cm)

All the treatments varied significantly in fruit length (Table 25). The longest fruits were found in treatments T 6 (16.45 cm) and T3 (16.20 cm), while the shortest ones were found in treatment T7 (15.18 cm). Treatment T5 was on par with T7 for fruit length (15.38 cm).

c. Fruit girth

Treatments showed significant difference in fruit girth. Among the treatments, treatment T6 (22.73 cm) was reported to have the highest fruit girth, which was on par with treatments T5 (21.06 cm), T3 (19.58 cm), and T4 (18.67 cm). However, the lowest fruit girth was observed in control treatment T7 (11.28 cm) (Table 25).

d. Fruit volume (cm^3)

The treatments varied significantly in fruit volume (Table 25). On comparing the values of fruit volume, the highest value was recorded for treatment T6 (715.02 cm^3), followed by treatment T5 (699.11 cm^3). Meanwhile, the lowest fruit volume was exhibited by Tl (450.05 cm^3) and T2 (453.53 cm^3).

e. Flesh thickness (cm)

The flesh thickness of the fruits showed a significant difference among the treatments. The highest flesh thickness of 2.43 cm was recorded for treatment T6, followed by T5 (2.30 cm), T7 (2.28 cm), and T4 (2.24 cm). The lowest thickness for the pulp was noted in treatment Tl (1.66 cm).

f. Fruits per plant

The treatments differed significantly with respect to the number of fruits per plant. The treatment T6 (23.71) was observed to have the highest number of fruits, followed by T5 (20.57), whereas treatment Tl (17.62) was found to have the lowest number of fruits among the treatments (Table 26).

g. Seeds per fruit

A significant variation was observed among the treatments for the number of seeds per fruit (Table 27). The highest number of seeds was found in fruits of treatment Tl (490.22), while the lowest number of seeds was observed for treatment T4 (387.11).

h. Yield per plant (kg)

The details of the yield per plant is furnished in Table 26. The treatments differed significantly for yield per plant, and the highest yield per plant was observed for treatment T6 (14.82) followed by T5 (11.76 kg), which was on par with treatments T3 (10.44 kg) and T7 (10.19 kg).

i. Yield (kg/ha)

Significant variation was exhibited by the treatments with regard to the yield per hectare (Table 26). The highest per hectare yield was recorded for treatments T6 (65.87 kg ha^{-1}), T3 (65.34 kg ha^{-1}) and T2 (64.22 kg ha^{-1}). Meanwhile, the lowest per hectare yield was observed for control treatment T7 (25.46 kg ha^{-1}).

j. Days from fruit set to maturity

There was a significant difference among the treatments for the number of days from fruit set to maturity. The highest number of days taken for the fruits to mature was exhibited by treatment Tl (146.50 days), while the lowest number of days was observed for treatments T6 (122.77 days) and T3 (124.92 days) (Table 27).

Table 26. Effect of fertigation and spacing on number of fruits, fruit weight, number of fruits, yield per plant, yield per ha of papaya

Treatments	Fruit weight (g)	Number of fruits	Yield/plant (kg)	Yield/ha (kg ha-1)
Tl (SIFI)	498.52	17.62	8.573	53.46
T2 (S1F2)	513.66	19.43	10.03	64.22
T3 (S1F3)	577.64	20.00	10.44	65.34
T4 (S2Fl)	497.46	19.14	9.99	44.40
T5 (S2F2)	567.40	20.57	11.76	54.72
T6 (S2F3)	657.08	23.71	14.82	65.87
T7 (Control)	524.69	19.81	10.19	25.46
CV(%)	3.52	3.43	8.66	6.84
CD (5%)	3.43	1.71	2.34	6.50

S1- 1.25 m x 1.25 m S2- 1.50 m x 1.50 m

Fl- 60 % RDF ofN and K2O F2- 80 % RDF ofN and K2O F3-100 % RDF ofN and K2O

Control- 2 m x 2 m + Soil application of N:P2Os:K2O as per KAU PoP under conventional method of irrigation without mulching

*RDF- recommended dose of fertilizer

Table 27. Effect of fertigation and spacing on seeds per fruit, days from fruit set to maturity and days from maturity to ripening of papaya

Treatments	Seeds/fruit	Days from fruit set to maturity	Days from maturity to ripening
Tl (SlFl)	490.22	146.50	5.73
T2 (S1F2)	479.30	130.25	5.60
T3 (S1F3)	482.19	124.92	5.13
T4(S2Fl)	387.11	137.33	5.73
TS (S2F2)	417.17	130.16	5.27
T6 (S2F3)	404.29	122.77	5.00
T7 (Control)	483.60	139.75	6.20
CV(%)	0.34	3.55	3.35
CD (5%)	2.71	8.40	0.33

S1- 1.25 m x 1.25 m S2- 1.50 m x 1.50 m

Fl- 60 % RDF ofN and K2O F2- 80 % RDF ofN and K2O F3-100 % RDF ofN and K2O

Control- 2 m x 2 m + Soil application of N:P2Os:K2O as per KAU PoP under conventional method of irrigation without mulching

*RDF- recommended dose of fertilizer

Table 28. Effect of fertigation and spacing on total soluble solids, titrable acidity, ascorbic acid, total carotenoids of papaya

Treatments	Total soluble solids (⁰Brix)	Titrable acidity(%)	Ascorbic acid (mg 100 g^{-1})	Total carotenoids (mg 100 g^{-1})
Tl (SIFI)	9.13	0.20	72.34	3.16
T2 (S1F2)	10.09	0.19	74.98	3.09
T3 (S1F3)	10.63	0.18	76.51	2.91
T4 (S2Fl)	9.23	0.19	74.21	3.21
TS (S2F2)	10.83	0.18	80.36	3.13
T6 (S2F3)	11.21	0.16	82.34	2.92
T7 (Control)	9.84	0.18	77.38	3.16
CV(%)	1.51	1.58	0.43	1.91
CD (5%)	0.27	0.01	0.59	0.11

Sl- 1.25 m x 1.25 m S2- 1.50 m x 1.50 m

Fl- 60 % RDF ofN and K2O F2- 80 % RDF ofN and K2O F3-100 % RDF ofN and K2O

Control- 2 m x 2 m + Soil application ofN:P2Os:K2O as per KAU PoP under conventional method of irrigation without mulching

*RDF- recommended dose of fertilizer

Table 29. Effect of fertigation and spacing on total sugars, reducing sugars, non-reducing sugars, sugars/acid ratio and shelf life of papaya

Treatments	Total sugars(%)	Reducing sugars(%)	Non reducing sugars(%)	Sugars/acid ratio	Shelf life (days)
Tl (SlFl)	8.08	6.67	1.41	39.71	7.46
T2 (S1F2)	8.27	6.94	1.33	42.62	7.93
T3 (S1F3)	9.14	7.93	1.56	51.79	8.13
T4(S2Fl)	8.15	6.76	1.38	40.11	7.80
TS (S2F2)	8.41	7.16	1.38	45.36	7.86
T6 (S2F3)	9.81	8.18	1.95	59.97	8.20
T7 (Control)	8.38	7.01	1.37	45.69	7.93
CV(%)	0.78	0.80	9.93	3.30	2.15
CD (5%)	0.11	0.10	0.26	2.73	0.30

S1- 1.25 m x 1.25 m S2- 1.50 m x 1.50 m

Fl- 60 % RDF ofN and K2O F2- 80 % RDF ofN and K2O F3-100 % RDF ofN and K2O

Control- 2 m x 2 m + Soil application of N:P2Os:K2O as per KAU PoP under conventional method of irrigation without mulching

*RDF- recommended dose of fertilizer

k. Days from maturity to ripening

A significant variation was exhibited by the treatments with respect to the number of days from maturity to ripening (Table 27). The highest number of days was observed for control treatment T7 (6.20 days), whereas the lowest number of days from maturity to ripening was observed for treatments T6 (5.00 days), T3 (5.13 days), and T5 (5.27 days).

4.2.3. Fruit quality characters

a. Total soluble solids

The treatments exhibited significant variation with respect to the total soluble solids (Table 28). The highest TSS was observed for the treatment T6 (11.21 °Brix), followed by T5 (10.83 °Brix). The TSS was lowest for the treatments Tl (9.13 °Brix) and T4 (9.23 °Brix).

b. Titrable acidity

Titrable acidity showed a significant difference among the treatments (Table 28). The lowest acidity was observed for the treatment T6 (0.16 %) and the highest was recorded for **Tl** (0.20 %).

c. Total carotenoids

The treatments showed significant differences in the total carotenoid content. The highest content of total carotenoids was exhibited by treatment T4 (3.21 mg 100 g^{-1}), which was on par with treatments T7, Tl, and T5. The lowest amount of total carotenoids was found in treatments T3 (2.91 mg 100 g^{-1}) and T6 (2.92 mg 100 g^{-1}).

d. Ascorbic acid

Among the treatments, there was a significant difference in the ascorbic acid content and the data is presented in Table 28. The highest amount of ascorbic acid was observed for treatment T6 (82.34 mg 100 g^{-1}), followed by treatment T5 (80.36

mg 100 g^{-1}). Treatment Tl was found to have the lowest amount of ascorbic acid (72.34 mg 100 g^{-1}).

e. Total sugars

The treatments differed significantly for total sugars, and the highest amount of total sugars was recorded for the treatment T6 (9.81%), followed by T3 (9.14%). The lowest amount of total sugars was observed for **Tl** (8.08 %). The values of total sugars are presented in Table 29.

f. Reducing sugars

The treatments exhibited a significant difference for this parameter, and the highest percentage of reducing sugar was observed for the treatment T6 (8.18 %) followed by T3 (7.93%). The amount recorded was the lowest for **Tl** and T4 (6.67 % and 6.78%, respectively) (Table 29).

g. Non-reducing sugars

The non-reducing sugars varied significantly among the treatments (Table 29). The highest percentage of non-reducing sugars was observed for T6 (1.95 %), followed by T3 (1.56 %), whereas Tl, T5, T4, T7, and T2 were on par with T3.

h. Sugar/acid ratio

The treatments differed significantly for sugar/acid ratio and the data is furnished in Table 29. The sugar/acid ratio was highest for treatment T6 (59.97) followed by treatment T3 (51.79), while the lowest sugar/acid ratio was observed for treatment **Tl** (39.71), followed by T4 (40.11).

i. Shelf life

The shelf life varied significantly among the treatments (Table 29). The maximum number of shelf life were recorded in treatment T6 (8.20 days), which was on par with T3 (8.13 days). The least number of shelf life was found in treatment **Tl** (7.46 days).

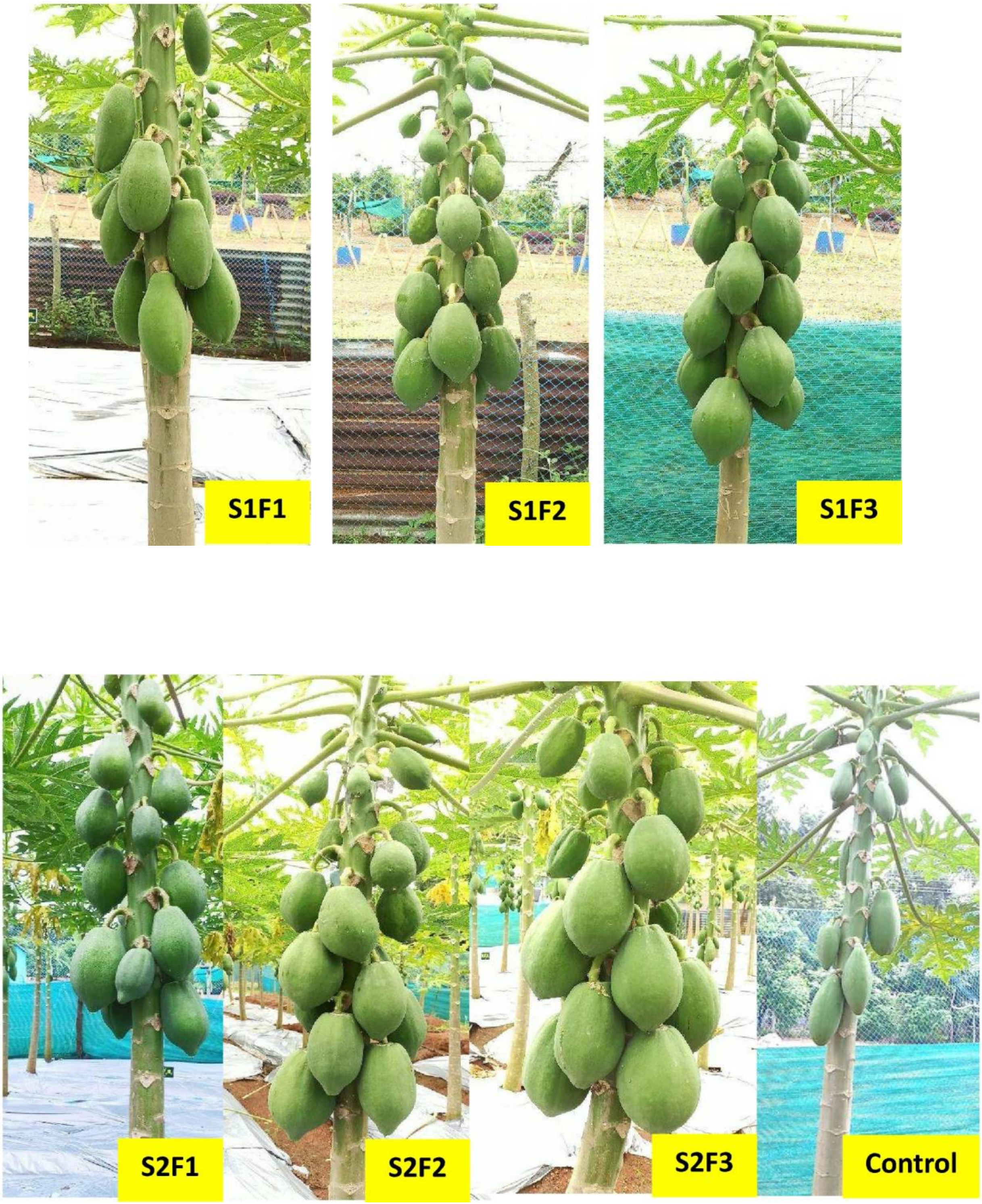

Plate 22. Performance of papaya plants under different treatments

Table 30. Effect of fertigation and spacing on organoleptic scoring of papaya

Treatments	Appearance	Colour	Texture	Flavour	Odour	Taste	After taste	Overall acceptability	Total score
Tl (SlFl)	7.15 (3.00)	7.50 (2.50)	7.55 (3.95)	7.15 (2.80)	6.80 (2.65)	7.30 (3.35)	7.40 (3.85)	7.20 (3.70)	58.05
T2 (S1F2)	7.40 (3.70)	8.00 (4.20)	7.60 (4.00)	7.25 (4.70)	7.45 (3.85)	7.70 (4.20)	7.45 (3.45)	7.30 (3.75)	60.15
T3 (S1F3)	7.70 (5.10)	8.15 (4.75)	7.75 (4.65)	7.05 (2.50)	6.80 (4.50)	7.85 (3.25)	7.40 (3.65)	7.55 (3.70)	60.25
T4 (S2Fl)	7.20 (3.15)	7.75 (3.65)	7.20 (3.00)	7.45 (3.55)	7.15 (3.40)	7.50 (4.65)	7.65 (4.10)	7.25 (3.60)	59.15
TS (S2F2)	7.55 (4.10)	8.05 (4.40)	7.55 (3.65)	7.55 (4.60)	7.50 (4.90)	7.95 (4.50)	7.75 (5.00)	7.50 (4.05)	61.40
T6 (S2F3)	7.85 (5.35)	8.20 (4.90)	7.90 (5.15)	7.60 (5.60)	7.80 (5.35)	8.06 (4.30)	7.90 (5.05)	8.10 (5.15)	63.41
T7 (Control)	7.35 (3.60)	7.80 (3.60)	7.40 (3.60)	7.10 (4.25)	7.35 (3.35)	7.50 (3.75)	7.30 (2.90)	7.40 (4.05)	59.20
Kendall's wa	0.26	0.18	0.14	0.31	0.24	0.08	0.15	0.07	

Table 31. Effect of fertigation and spacing on soil chemical parameters and nutrient status

Parameter	Nutrient properties of soil after experiment						
	Tl	T2	T3	T4	TS	T6	T7
pH	4.53	4.49	5.03	4.57	4.98	5.34	4.72
EC (dS m^{-1})	0.04	0.04	0.06	0.04	0.05	0.07	0.03
QC(%)	1.41	1.57	1.63	1.55	1.5	1.77	1.39
N (kg ha^{-1})	198.71	209.29	224.75	201.32	206.83	230.79	193.32
P (kg ha^{-1})	75.13	76.27	74.03	75.69	75.17	74.14	74.33
K (kg ha^{-1})	289.18	294.62	307.79	291.41	299.32	313.19	283.04

Sl- 1.25 m x 1.25 m S2- 1.50 m x 1.50 m

Fl- 60 % RDF ofN and K2O F2- 80 % RDF ofN and K2O F3-100 % RDF ofN and K2O

Control- 2 m x 2 m + Soil application ofN:P2Os:K2O as per KAU PoP under conventional method of irrigation without mulching

*RDF- recommended dose of fertilizer

Plate 23. Organoleptic evaluation of papaya fruits

j. Organoleptic evaluation

The fruits of the treatment plants were evaluated for organoleptic parameters on a nine-point hedonic scale by a panel of 10 judges. The mean rank scores of appearance, colour, flavour, odour, taste, aftertaste, and overall CPVeptability are furnished in Table 30.

On comparing, the highest mean score for appearance was observed in treatment T6 (7.85) followed by treatment T3 (7.70) and T5 (7.55). For colour, the highest rank was observed for treatment T6 (8.20), followed by treatment T3 (8.15), T5 (8.05) and T2 (8.00). The treatment T 6 recorded the highest mean rank for taste (8.06), followed by T5 (7.95) and T3 (7.85). The highest rank for overall CPVeptability was observed for treatment T6 (8.10), followed by T3 (7.55) and T 5 (7.5).

4.2.4. Pest and disease incidence

A few outbreaks of collar rot *(Pythium aphanidermatum)* and anthracnose (*Colletotrichum gleosporioides)* were seen during the research period. The papaya ringspot virus (PRSV) attack was a problem at closer spacing, especially in 1.25 m x 1.25 m spaced plants, while the plants of control treatment which were planted at 2 m x 2 m spacing were healthier than the other two spacing levels. Since the crop was maintained with adequate control techniques and the timely use of plant protection agents, it did not affect the quantity and quality of the produce to a greater extent. All the plants under investigation received a total of five sprays of 10 % bougainvillaea extract at fortnightly interval. Also, the fortnightly sprays of *Pseudomonas fluorescens* helped to keep the virus attack under control.

4.2.5. Soil analysis after the experiment

The data on soil analysis after the experiment showed considerable variation for **pH,** EC, organic carbon, nitrogen, phosphorous, and potassium among the treatments. The data is furnished in Table 31. The treatment T6 showed the highest pH (5.34), EC (0.07 dS m^{-1}), organic carbon (1.77 %), nitrogen (230.79 kg ha^{-1}), phosphorous (74.14 kg ha^{-1}), and potassium (313.19 kg ha^{-1}). It was followed by treatment T3, pH (5.03), EC (0.06 dS m^{-1}), organic carbon (1.63 %), nitrogen (224.75 kg ha^{-1}), phosphorous (74.03 kg ha^{-1}) and potassium (307.79 kg ha^{-1}). Meanwhile, the lowest value for all these soil parameters was observed for the control treatment T7, which was on with the treatment Tl.

4.2.6. Plant analysis

The data of different treatments on the leaf analysis before flowering and after harvest, varied significantly for plant nutrients like N, P, K, Ca, Mg, S, Zn and B (Table 32, 33 and 34). The report of leaf analysis before flowering showed that the highest nitrogen content (1.75 %) was observed for treatment T6, followed by treatment T3 (1.61 %). Meanwhile, the lowest nitrogen content was observed in the leaves of treatment T1 (1.42 %). The highest content of phosphorous was also recorded for treatment Tl and control T7 (0.88 %) followed by T4 (0.87 %), whereas the lowest value was recorded for treatment T3 (0.83 %). The potassium content was found to be highest in treatment T6 (2.82 %), followed by treatment T3 (2.79 %). There was no significant difference in the calcium and magnesium content between the treatments before flowering. A similar trend was observed in the zinc and boron content of the leaves of the treatment plants. The highest sulphur content was recorded for treatment T6 (0.44 %), followed by T3 (0.36 %).

Fertigation and spacing levels had a profound impact on the absorption of nutrients by the plant system. After the harvest, significant variation was observed among the treatments for nitrogen, phosphorous, and potassium content. The highest leaf nitrogen was recorded for treatment T6 (1.73 %) followed by treatment T5 (1.46 %), while the lowest nitrogen was found in treatment Tl (1.36 %) and T7 (1.36 %). On comparing the phosphorous content, treatment T2 recorded the highest value of 0.76 %, which was on par with treatment T5 (0.75 %). The data on the potassium content in the index leaf of the treatments showed that the highest potassium content was recorded for treatment T6 (2.77 %) followed by treatment T3 (2.69 %). The lowest potassium content was noted in the treatment Tl (2.14 %) followed by the control T7 (2.16 %). The treatment varied significantly for calcium content, and the highest percentage of calcium was observed in the index leaf of

Table 32. Effect of fertigation and spacing on leaf nutrients

Treatments	Before flowering			After harvest		
	Nitrogen (%)	Phosphorous (%)	Potassium (%)	Nitrogen (%)	Phosphorous (%)	Potassium (%)
Tl (SlFl)	1.42	0.88	2.23	1.36	0.72	2.14
T2 (S1F2)	1.46	0.86	2.34	1.40	0.76	2.27
T3 (S1F3)	1.61	0.83	2.79	1.46	0.73	2.69
T4 (S2Fl)	1.45	0.87	2.34	1.45	0.73	2.17
T5 (S2F2)	1.49	0.85	2.42	1.46	0.75	2.36
T6 (S2F3)	1.75	0.84	2.82	1.73	0.76	2.77
T7 (Control)	1.43	0.88	2.22	1.36	0.72	2.16
CV(%)	4.00	1.25	0.33	6.34	1.37	1.21
CD (5%)	0.11	0.02	2.23	1.63	0.02	5.08

Sl- 1.25 m x 1.25 m S2- 1.50 m x 1.50 m

Fl- 60 % RDF ofN and K2O F2- 80 % RDF ofN and K2O F3-100 % RDF ofN and K2O

Control- 2 m x 2 m + Soil application of N:P2Os:K2O as per KAU PoP under conventional method of irrigation without mulching

*RDF- recommended dose of fertilizer

Table 33. Effect of fertigation and spacing on secondary nutrient content on papaya leaves

Treatments	Before flowering			After harvest		
	Calcium (%)	Magnesium (%)	Sulphur (%)	Calcium (%)	Magnesium (%)	Sulphur (%)
Tl (SIFI)	0.46	0.24	0.26	0.41	0.25	0.21
T2 (SIF2)	0.44	0.27	0.31	0.45	0.28	0.30
T3 (SIF3)	0.44	0.28	0.36	0.46	0.31	0.33
T4 (S2Fl)	0.47	0.18	0.20	0.42	0.20	0.22
T5 (S2F2)	0.45	0.29	0.33	0.45	0.28	0.30
T6 (S2F3)	0.45	0.35	0.44	0.44	0.39	0.41
T7 (Control)	0.43	0.21	0.23	0.38	0.20	0.22
CV(%)	NS	NS	3.72	0.00	2.11	8.18
CD (5%)	NS	NS	0.20	0.001	0.01	0.04

Sl- 1.25 m x 1.25 m S2- 1.50 m x 1.50 m

Fl- 60 % RDF ofN and K2O F2- 80 % RDF ofN and K2O F3-100 % RDF ofN and K2O

Control- 2 m x 2 m + Soil application of N:P2Os:K2O as per KAU PoP under conventional method of irrigation without mulching

*RDF- recommended dose of fertilizer

Table 34. Effect of fertigation and spacing on zinc and boron content on papaya leaves

Treatments	Before flowering		After harvest	
	Zinc (ppm)	**Boron (ppm)**	**Zinc (ppm)**	**Boron (ppm)**
Tl (SlFl)	11.44	16.21	13.73	13.96
T2 (SlF2)	13.56	18.60	15.68	15.68
T3 (SlF3)	16.21	20.71	19.20	18.12
T4(S2Fl)	12.29	17.06	14.41	14.47
TS (S2F2)	12.87	17.91	15.93	15.32
T6 (S2F3)	16.39	20.99	20.94	18.07
T7 (Control)	11.22	15.82	13.51	13.23
CV(%)	NS	NS	0.00	2.14
CD (5%)	NS	NS	0.001	0.59

Sl- 1.25 m x 1.25 m S2- 1.50 m x 1.50 m

Fl- 60 % RDF ofN and K2O F2- 80 % RDF ofN and K2O F3-100 % RDF ofN and K2O

Control- 2 m x 2 m + Soil application of N:P2Os:K2O as per KAU PoP under conventional method of irrigation without mulching

*RDF- recommended dose of fertilizer

Table 35. Effect of fertigation and spacing on economics of papaya cultivation

Treatments	Cost of cultivation (Rs ha-1)	Gross income (Rs ha-1)	Net income (Rs ha-1)	B:C ratio
Tl (SlFl)	4,98,806	10,69,127	5,70,321	2.1
T2 (SlF2)	5,79,594	12,84,312	7,04,718	2.2
T3 (SlF3)	6,35,268	13,06,827	6,71,558	2.1
T4(S2Fl)	4,22,067	8,88,072	4,66,005	2.1
TS (S2F2)	4,81,334	10,94,413	6,13,079	2.3
T6 (S2F3)	5,29,262	13,17,345	7,88,084	2.5
T7 (Control)	3,54,000	5,09,333	1,55,334	1.4

S1- 1.25 m x 1.25 m S2- 1.50 m x 1.50 m

Fl- 60 % RDF ofN and K2O F2- 80 % RDF ofN and K2O F3-100 % RDF ofN and K2O

Control- 2 m x 2 m + Soil application of N:P2Os:K2O as per KAU PoP under conventional method of irrigation without mulching

*RDF- recommended dose of fertilizer

treatment T 3 (0.46 %), which was on par with the treatments T2 and T5 (0.45 %), while the lowest value was noticed in treatment T6 (0.38 %). The highest content of magnesium was recorded in treatment T6 (0.39 %), followed by treatment T3 (0.31 %) and T5 (0.31 %), while the lowest magnesium content was noticed in treatments T4 and T7 (0.20 %). The statistical data on sulphur content revealed that there was significant variation among the treatments, and the highest value was noted for treatment T6 (0.41 %), followed by T3 (0.33 %). Meanwhile, the lowest sulphur content was noted in treatment Tl (0.21 %).

While considering the zinc and boron content in the index leaf of the treatment plants., the highest percentage of zinc was exhibited by treatment T6 (20.94 ppm), which was found to be on par with treatment T3 (19.20 ppm). However, the lowest zinc content was observed for control treatment T7 (13.51 ppm), which was on par with Tl (13.73 ppm). The data on boron content showed the highest value for treatment T3 (18.12 ppm), which was observed to be on par with T6 (18.07 ppm). While the lowest boron content was observed for treatment T7 (13.23 ppm), which was found to be on par with treatment Tl (13.96 ppm).

4..2.7. Economic analysis

The data on the economic analysis furnished in Table 35, revealed that there were significant differences in gross income, net income, and B:C ratio among the treatments of papaya receiving different levels of fertigation and spacing.

The treatment T6 that received 100 % RD ofN and K2O planted at a spacing of 1.50 m x 1.50 m recorded the highest gross income (13,17,345.4 Rs ha^{-1}), immediately followed by treatment T3 (13,06,826.6 Rs ha^{-1}). However, the lowest gross income was observed for the control treatment T7 (5,09,333.2 Rs ha^{-1}).

On comparing the net income among the treatments, the highest value was recorded in the plants of treatment T6 that received 100 % RD ofN and K2O planted at a spacing of 1.50 m x 1.50 m (9,37,064.96 Rs ha^{-1}), followed by treatment T3 (8,42,550.61 Rs ha^{-1}).

Significant variation was noted in the treatment T6 for the benefit:cost ratio (B:C). The highest B:C ratio was noted for the treatment T6 (3.5), followed by T3 (2.8). *TS* (2.4), T2 (2.3). The lowest B:C ratio was observed for the control treatment T7 (1.5).

Discussion

5. DISCUSSION

Papaya *(Carica papaya* L.) is a fruit crop that is highly appreciated for its nutritive value, early bearing nature, and ease in cultivation. Earlier, papaya was considered as a backyard crop, but recently it has started to attain a commercial status among the farmers of Kerala. The major constraint of papaya cultivation in Kerala, is the lack of high yielding, location specific, good table purpose varieties/ genotypes. This problem can be solved only by finding out a suitable variety/ genotype, by evaluating the available released varieties and local genotypes found to be performing well under our Kerala conditions. In addition to the lack of suitable table purpose variety, the reduction in land area, scarcity of irrigation water and high labour charges make papaya cultivation even more difficult. Hence, to address these problems, the present study was formulated with the objective of evaluating different papaya genotypes suitable for table purpose and also to standardise the spacing and fertigation levels for growing papaya under high density planting system (HDP). The result of the study is discussed in this chapter.

5.1. SCREENING OF GENOTYPES SUITABLE FOR TABLE PURPOSE UNDER KERALA CONDITION

5.1.1 Biometric characters

All the genotypes exhibited significant difference for biometric characters like height of plant, girth of plant, number of leaves, length of leaf petiole, height to first flowering, days to flowering, sex expression, number of flowers per cluster, fruit set percentage, and days to harvest.

The results on the plant height at all stages of growth revealed that the tallest plant was observed for CPV 15 (local papaya type collected from Thrissur), while the shortest plant was recorded for the TNAU papaya variety CO 7. The final plant height of the genotypes under evaluation ranged from 249.39 cm to 342.48 cm. As shorter plants are more preferred for cultivation due to the ease in harvest and in carrying out spraying operations, CO 7 was observed to be a good variety that can be easily managed in the field due its short stature. The plant height of CO 7 in the present study was 249.39 cm, which was found to be closely in agreement with the finding ofThirugnanavel *et al.* (2015), who reported a plant height of223.50 cm in papaya cv. CO 7, in a study conducted by him. According to Kumar *et al.* (2015), the height of papaya plants were found to be influenced by changes in environmental factors, and hence papaya genotypes shows wide range of variation in plant height among themselves.

In the present investigation, the girth of the plant at the final observation ranged from 43.24 cm in TNAU papaya variety CO 3 to 66.64 cm in variety CO 6. The girth of the plant is an important character that has a strong influence on its vigour. The increment in the plant girth of genotypes was observed to be more during the initial stage of plant growth, and as time progressed, the plant girth showed less increment as compared to the initial phase (Reshma, 2015).

The number ofleaves per plant is one of the important biometric characters that determined the photosynthetic efficiency and yield of papaya, as reported by Reshma (2015). In the current study, at 12 MAP, the number of leaves per plant was found to be maximum in CPV 4 (local type from Malappuram) and CPV 7 (local type from Kottayam), while the minimum numbers in TNAU papaya cv. CO 7. According to Dwivedi *et al.* (1999), there was a strong and positive correlation between collar girth and the total number of leaves present on the plants at flowering.

With respect to the length and colour of mature leaf petioles, variations were observed among the genotypes. The longest petiole was found in CPV 2 (89.14 cm, a local type from Emakulam), while the shortest was observed for IIHR papaya cv. Arka Prabhath (59.83 cm). Ram (2005) suggested a favourable correlation between petiole length and the number of fruits in papaya. According to Akhil (2020), the accessions of papaya exhibited different trends in petiole growth throughout their growth phase. The colour of the leaf petiole in the genotypes were observed to exhibit four different colours: normal green, pale green, green, and shades of red purple and red purple.

A significant variation was observed in the genotypes for the height at first flowering and days to flowering. The TNAU papaya cv. CO 7 and CPV 16 (local type from Thrissur) exhibited the lowest height at first flowering (82.32 cm), while the maximum height at first flowering was observed for the variety CO 6. Ghanta *et al.* (1995) reported that the height at first flowering was positively correlated to the fruit yield of papaya and that it helped in easy harvesting of the fruits as well. With respect to the number of days to flower, CPV 2 (local type from Emakulam) flowered early, while IIHR papaya variety Arka Prabhath took the maximum number of days to flower. Kumar *et al.* (2015) opined that environmental changes had a great impact on the number of days to flowering in papaya.

On comparing the sex expression of the genotypes, there were mainly two types of sex expression, viz., gynodioecious and dioecious types. The genotypes, CPV 1, CPV 3, CPV 5, CPV 6, CPV 7, CPV 8, CPV 10, CPV 11, CPV 15, CPV 16, Arka Prabhath, CO 3, CO 7 and Red Lady were gynodioecious, while CPV 2, CPV 4, CPV 9, CPV 12, CPV 13, CPV 14, CO 1, CO2, CO 4 and CO 6 were dioecious in nature.

Flowering in papaya is a complex phenomenon that is greatly influenced by the prevailing environmental conditions. The hermaphrodite flowers in gynodioecious genotypes showed sex reversal during summer, thereby affecting the number of flowers per cluster in some of the gynodioecious genotypes. Storey (1958) and Ram *et al.* (1994) mentioned that the male and hermaphrodite flowers tend to change sex forms depending on the climate prevailing in that location, whereas the female sex forms remained to be stable and were not affected by the environmental conditions. According to Awada (1958), the vegetative growth rate, and minimum temperature had a correlation with the percentage of carpellodic flowers in papaya and compared to the hermaphrodite plants, female plants were found to be stable. The largest number of flowers per cluster was recorded for CO

7, which was on par with the papaya cv. Red Lady. Whereas, CPV 10 (local type from Palakkad) and CPV 11 (local type from Kottayam) recorded the minimum number of flowers per cluster.

For obtaining early profit from the papaya orchards, the number of days taken from flowering to harvest should be lower. The papaya genotype CPV 2 took only lower number of days to harvest, which was on par with the variety CO 7. The longest duration for crop harvest was observed for CPV 7 (local type from Kottayam), CO2, CO 6, Arka Prabhath, and CPV 5 (local type from Malappuram).

5.1.2. Yield characters

The most important aspect which is looked into during the evaluation of any fruit crop is to find out a genotype that could offer a higher yield of quality fruits. All the papaya genotypes under study were found to differ significantly in their yield characteristics.

The fruit weight was found to be the highest in the TNAU papaya variety CO 6, which was observed to be on par with CO 4 and CO 1, whereas fruits with lower fruit weight were recorded for the IIHR papaya variety Arka Prabhath. The variation in fruit weight among the genotypes may be attributed to differences in their genetic makeup and vegetative characters like number of leaves and collar girth.

With respect to the colour of flesh, the genotypes produced fruits of different colours, viz., light yellow, bright yellow, deep yellow to orange, and reddish orange. Similarly, shape of the fruits among the genotypes showed a wide variation, viz., club shape, elongate, elliptic, oblong-ellipsoid, pear shape, acron, globular, oval and lengthened cylindrical. In a study conducted, Storey (1953) observed yellow pulp to be dominant over red pulp. But for processing and table purpose, the demand for red pulp was found to be higher than that for yellow pulp (Balamohan *et al.,* 2010). According to Nakasone & Paull (1998), female trees were found to produce spherical fruits, whereas the shape of fruits on bisexual trees depended on

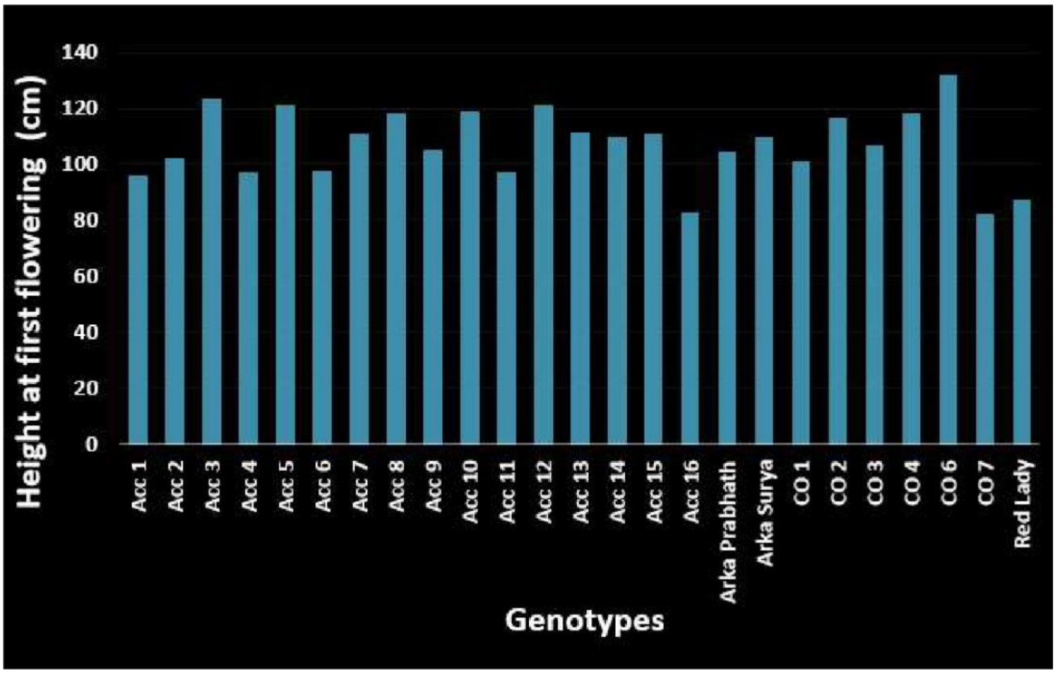

Fig 1. Height at first flowering of papaya genotypes

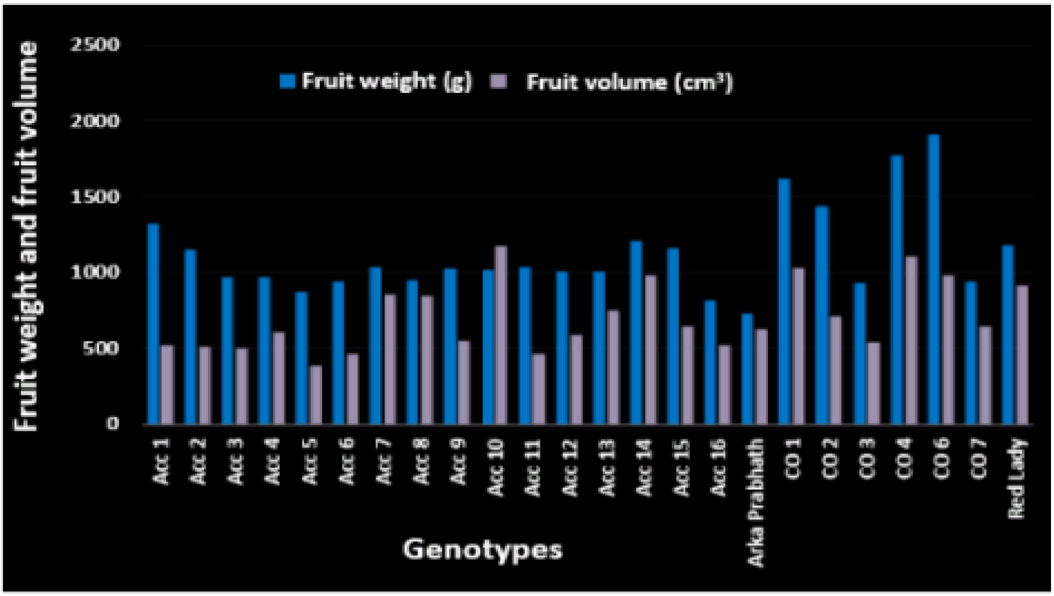

Fig 2. Fruit weight and fruit volume of papaya genotypes

environmental conditions, notably temperature, which altered the floral morphology during the early stages of inflorescence development. When produced under identical agro-ecological conditions, it was observed that the weight, volume, and shape of a particular genotype of papaya fruit remained consistent. As the fruit shape in papaya is a trait that is sex-linked, the fruit of female trees is spherical to ovoid in shape, whereas the fruit of hermaphrodite trees is long, cylindrical, or pear-shaped (Hofmeyr, 1936; Chan and Paull, 2008; Paull *et al.*, 2008).

The genotypes varied in shape and size and the longest fruits were observed in CPV 1 (local type from NBPGR, Vellanikkara), while the shortest ones were found in CPV 6 (local type from Kottayam). On comparing the fruit girth, the highest fruit girth was recorded for variety CO 6 followed by CO 4, and the minimum fruit girth was observed in CPV 1. The maximum fruit volume was found in CPV 10 (local type from Kottayam), while the minimum fruit volume was recorded for CPV 5 (local type from Malappuram). As the flesh thickness ultimately determines the edible portion of the fruit, the highest flesh thickness was recorded in CO 6 and CO 4, while the thin fleshed fruits were noted in CPV 1 (local type from NBPGR, Vellanikkara).

With regard to the yield characters, maximum number of fruits were recorded for CPV 2 (local type from Emakulam), followed by CPV 3 (local type from Emakulam), and Red Lady. On evaluating the yield per fruit, fruits of TNAU papaya varieties CO 4 and CO 6 exhibited the highest values, and hence the maximum yield per hectare was observed for CO 4. Similar results were recorded by Reni (1997), where she observed the highest yield for the papaya variety CO 6. Anh *et al.* (2011) reported a significant difference among the varieties for the number of fruits, which ranged from 12 to 24 fruits per plant. Kumar *et al.* (2015) opined that environmental factors had a significant impact on this aspect of the papaya plant. Akhil (2020) opined that fruit yield has a positive correlation with fruit weight and the number of fruits in papaya.

Since papaya is commercially grown from seeds, quality and the number of seeds per fruit are the most important aspects for successful production. The highest number of seeds per fruit was recorded in CPV 10 (local type from Palakkad), followed by CPV 14, CO 6, and CPV 15 (local type from Thrissur). The highest seed weight for 100 seeds was recorded in CPV. 16 (local type from Thrissur), which was on par with CPV 10 and CPV 15. Larger seeds recorded the highest percentage of seed germination, speed of germination, root and shoot length, vigour index, and dry matter production of seedlings (Rathinavel, 1986).

Minimum the number of days from flowering to fruit maturity, lower will be the total crop duration. The minimum number of days to fruit maturity was observed for CPV 5 (local type from Malappuram), which was on par with CPV 11 (local type from Kottayam).

5.1.3. Fruit quality characters

The genotypes exhibited significant variation for fruit quality characters like TSS, sugars, and titrable acidity. The highest TSS, total sugars and reducing sugars, were recorded for CO 7, which was found to be on par with CPV 9, CPV 2, CPV 12, and CPV 15. Ascorbic acid exhibited significant differences among the genotypes. It was highest in CPV 9 (local type from Kottayam), followed by CPV 10 (local type from Palakk:ad). The highest total carotenoid content was observed in CO 7 and Arka Prabhath, followed by CO 3.

Wall (2006) pointed out that the flesh colour of papaya fruits was governed by the carotenoids. All papaya cultivars that produced orange and yellow flesh coloured fruits contained carotenoids like p-cryptoxanthin and p-carotene. Andersson *et al.* (2008) and Yahia and Ornelas-Paz (2010) opined that the concentration of esterified carotenoids was higher during ripening, so they got integrated into the membranes more quickly, thereby enhancing the fruit colour. For photosynthetic activity, the presence of carotenoid pigments are an important factor. In the chromoplasts of flowers, fruits, and seeds of many papaya species, carotenoids builds up as a secondary metabolite to develop distinctive coloration

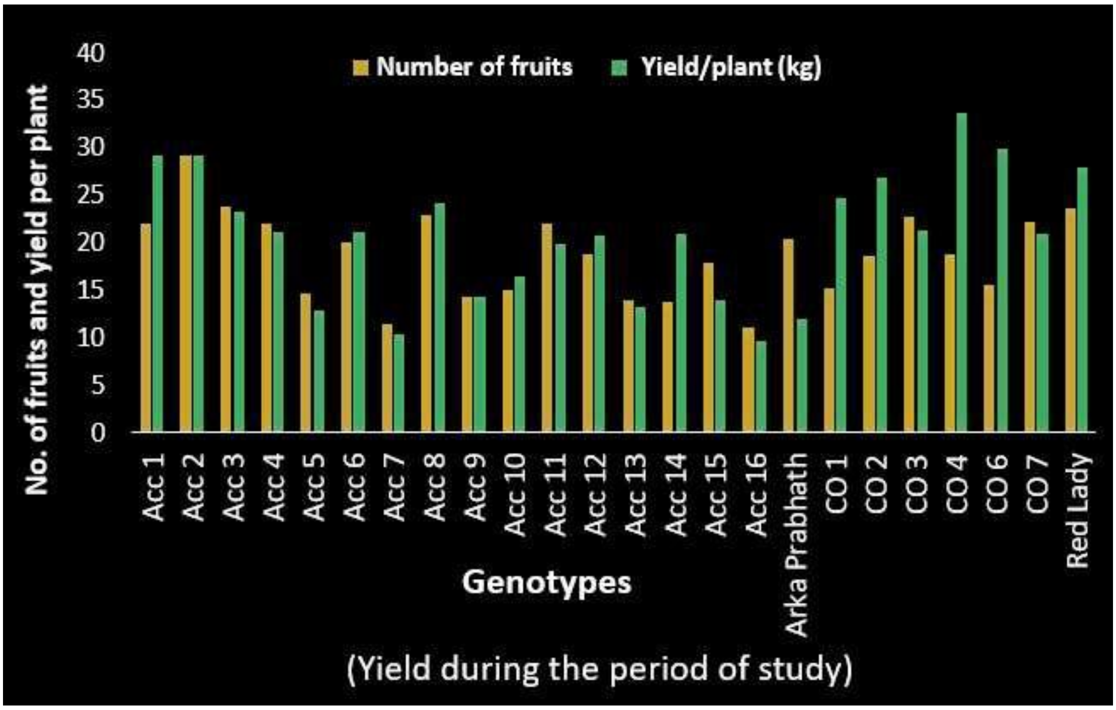

Fig 3. Number of fruits and yield per plant of papaya genotypes

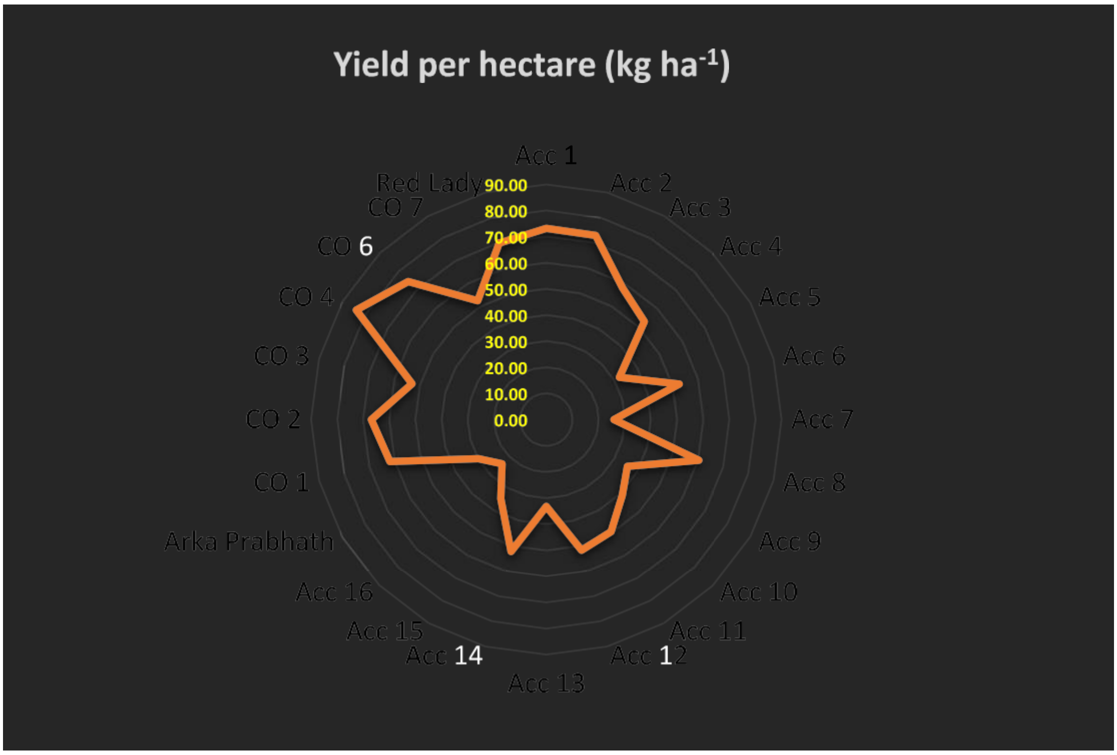

Fig 4. Yield per hectare of papaya genotypes

that ranges from yellow to orange and red. It is observed that, carotenoid is mostly present in the flesh of papaya fruits imparting the distinctive flesh colour (Devitt *et al.,* 2009). The rapid breakdown of chlorophyll and the formation of carotenoids like lutein and beta-carotene contributes to the colour change in the peel from green to yellow. Papaya varieties are of two types: red-fleshed and yellow-fleshed. Lycopene is the main carotenoid in the pulp of papayas with red flesh, whereas beta-carotene and beta-cryptoxanthin are the main carotenoids in papayas with yellow flesh (Saengmanee *et al.,* 2018).

Among the twenty-five genotypes evaluated, the highest rank for appearance was given for CPV 12 (local type from Thrissur) followed by CO 6 and CO3. For colour highest rank was given for CO 7 and CPV. 2 (local type from Ernakulam). The papaya cv. CO 7 recorded highest mean rank for taste followed by CPV. 15 (local type from Thrissur), CPV. 9 (local type from Kottayam), CPV. 2 (local type from Ernakulam) and CPV 12 (local type from Thrissur). The variety CO 7 also recorded highest rank for overall acceptability followed by CPV. 15 (local type from Thrissur), CPV. 9 (local type from Kottayam), CPV. 2 (local type from Ernakulam) and CPV 12 (local type from Thrissur. From the sensory evaluation, TNAU papaya variety CO 7 was found to be the promising type with respect to taste and overall acceptability. The genotypes CPV 15, CPV 9, CPV 2 and CPV 12 were noted to be on par with CO 7.

All the genotypes showed considerable variation for the shelf life and leaf nutrient content before flowering and after harvest.

Hence, from the present study on the screening of genotypes for table purpose under Kerala condition, it could be concluded that the TNAU papaya variety CO 7 was found to be the most suited one with respect to the short plant stature, early flowering and fruit quality parameters. The genotypes CPV 2, CPV 9, CPV 12 and CPV 15 were found to be on par with CO 7 for quality parameters of the fruits. All these selected accessions had reasonably higher sensory qualities. However further evaluation of genotypes is necessary to get confirmatory results.

5.1. EFFECT OF FERTIGATION AND SPACING LEVELS IN PAPAYA UNDER HIGH DENSITY PLANTING SYSTEM

5.1.1 Biometric characters

All the treatments exhibited significant differences for biometric characters like height of plant, girth of plant, number of leaves, height to first flowering, days to flowering, number of flowers per cluster, fruit set percentage, and days to harvest.

During the period under study, the result on the plant height at the final stages of growth revealed that the maximum plant height was observed for treatment T3 (1.25 m x 1.25 m spacing+ 100 % of recommended dose of N and K20), while the minimum plant height was recorded for treatment Tl (1.25 m x 1.25 m spacing+ 60 % of recommended dose ofN and K20). The final plant height of the treatments under evaluation were found to range from 242.91 cm to 297.29 cm. The findings of the present study were in close agreement with the findings of Sadarunnisa *et al.* (2010), who also observed that the plant height was maximum in treatment with 100 % recommended doses offertlizers (RDF) ofN and K, followed by 75 % recommended doses of fertlizers (RDF) of N and K. According to Rajasekharan (1975), wider spacing reduced plant height and height at first flowering in papaya. Similarly, Shukla *et al.* (2001) reported that maximum plant height was observed under closer spacing of 1.25 x 1.25 m in the papaya variety Pusa Delicious. Along with the higher dose, the split application of fertilisers through drip irrigation might have contributed to an increase in the uptake of nutrients during the growth phase, which might have contributed to the enhanced protein and protoplasm synthesis, ultimately leading to better growth and development of the crop (Sharma *et al.*, 2005; Sagvekar *et al.*, 2019).

In the present study, the girth of the plant at the final observation ranged from highest plant girth of 45.49 cm in treatment T6 (1.50 m x 1.50 m spacing + 100 % of recommended dose ofN and K20) to lowest plant girth of 36.49 cm in treatment (1.25 m x 1.25 m spacing+ 60 % ofrecommended dose ofN and K20). The girth of plant is a very important character, as it has a strong influence on

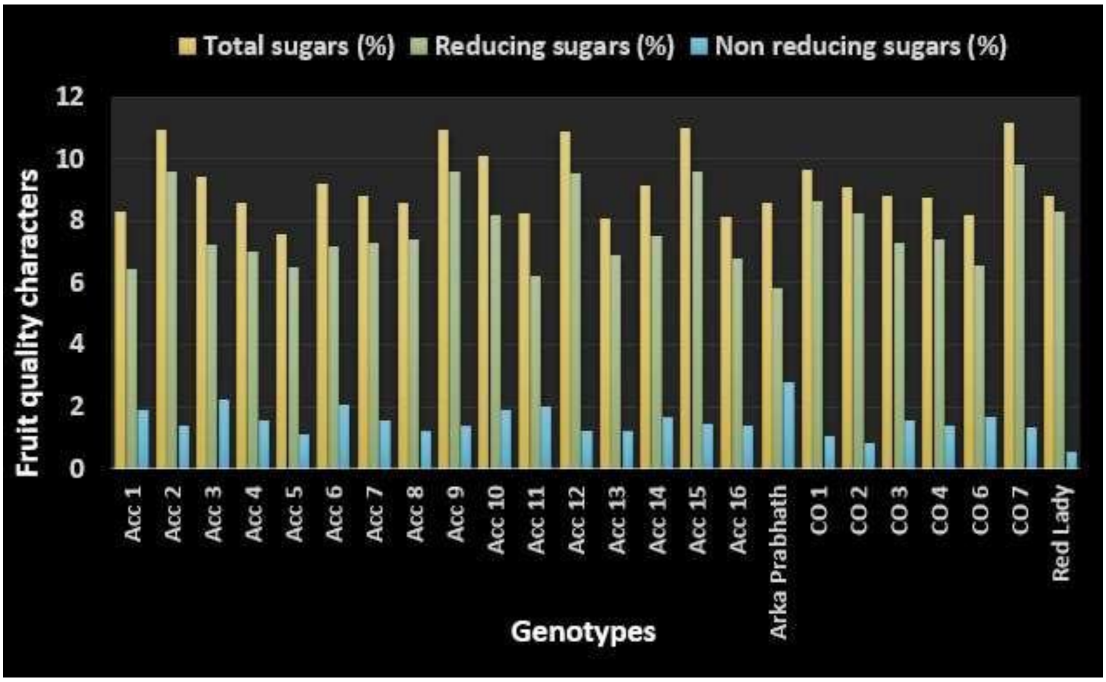

Fig 5. Sugar content of papaya genotypes

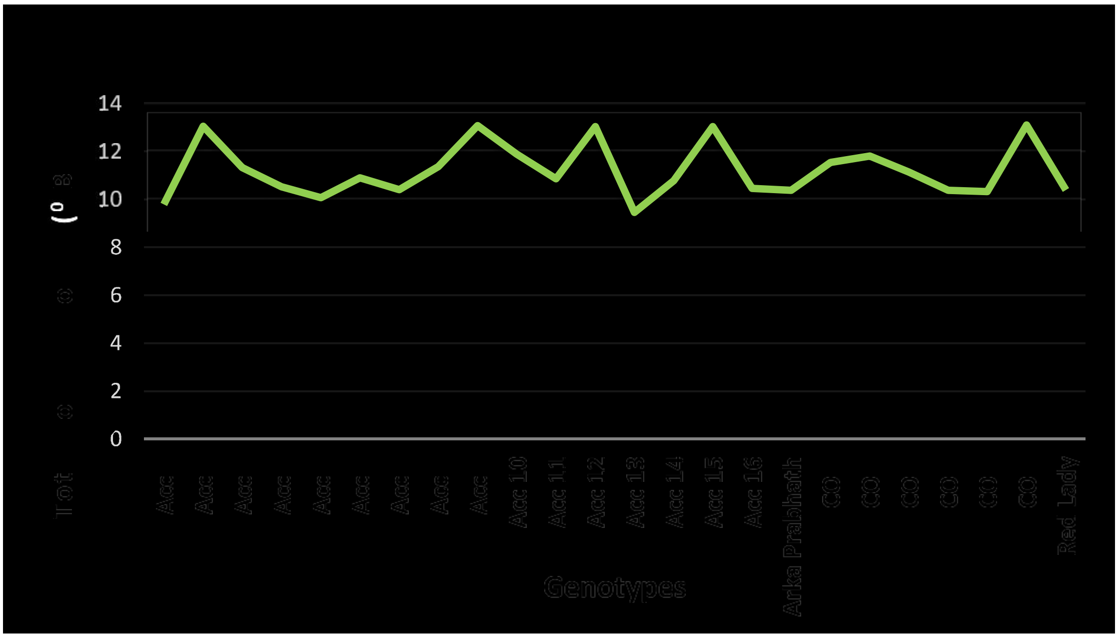

Fig 6. Total soluble solids of papaya genotypes

determining the vigour of the plant. The findings in the present investigation was in agreement with the findings of the study carried out by Babaji (2013) in the papaya variety Red Lady. Fertigation in the papaya variety Red Lady receiving 100 % RDF of N and K2O showed maximum stem girth at 180 DAP (28.33 cm), 270 DAP (42.21 cm), and 360 DAP (48.15 cm). The minimum stem girth was reported in the plants supplied with 60 % RDF of N and K2O at 180 DAP (22.39 cm), 270 DAP (36.50 cm), and 360 DAP (42.09 cm) The increase in trunk diameter could be attributed to increased nutrient intake and storage in leaf tissues, which in turn ensured photosynthetic efficiency, resulting in increased carbohydrate synthesis, translocation, and accumulation (Ghanta *et al.,* 1995). According to Prajapathi *et al.* (2017), at 270 days after transplanting in papaya, maximum plant height (171.24 cm) and stem girth (36.85 cm) were observed in plants supplied with drip irrigation with 100% RDF ofN, P, and K. This may be attributed to the presence of sufficient doses of nutrients that boosted the synthesis of IAA, which in turn stimulated cell elongation and increased plant height and stem girth (Meena *et al.,* 2020).

In the current study, at 12 MAP, the number of leaves per plant was found to be highest in treatment T6 (1.50 m x 1.50 m spacing + 100 % of recommended dose ofN and K2O), and it was found to be on par with T7 (control treatment with soil application as per KAU PoP), T5 (1.50 m x 1.50 m spacing + 80 % of recommended dose ofN and K2O), and T3 (1.25 m x 1.25 m spacing+ 100 % of recommended dose of N and K2O). Meanwhile, the lowest number of leaves was observed in treatment Tl (1.25 m x 1.25 m spacing+ 60 % ofrecommended dose of N and K2O). The number of leaves per plant is one of the important biometric characters that determine the photosynthetic efficiency and yield of papaya. As reported by Arango *et al.* (1986), they observed that with the decrease in planting distance, the height of the plant and flowering height generally increased in papaya, whereas the stem diameter and number of leaves generally decreased. Also, it was noted that planting distance had no influence on the number of nodes to the first flowering nor the number of days from transplanting to flowering. Kawarkhe (2002) observed that the maximum plant spread and number ofleaves were noticed under wider spacing. Mathew (2005) reported that a spacing ofup to 1.50 m x 1.50

m did not show any negative impact on the number of leaves in papaya. However, at a spacing of 1.25 m x 1.25 m, there was a notable reduction in the number of leaves per plant. According to Singh *et al.* (2008), it was apparent that the plant height of papaya plants was highest in closer spacing, whereas the number ofleaves was higher in wider spacing. But, when compared to the other spacings, papaya plants planted at a closer spacing were found to have the maximum number of flowers.

Significant variation was observed among the treatments for the height at first flowering and days to flowering. The data clearly showed the positive effect of treatment T 6 (1.50 m x 1.50 m spacing coupled with 100 per cent RD of N and K20) on the height at first flowering. The lowest height at first flowering was observed in treatment T6, followed by T3 (1.25 m x 1.25 m spacing + 100 % of recommended dose ofN and K20). Whereas, the maximum height at first flowering was noted in treatment Tl (1.25 m x 1.25 m spacing+ 60 % of recommended dose of N and K20), followed by treatment T4 (1.50 m x 1.50 m spacing + 60 % of recommended dose ofN and K20), which was on par with the control T7 (control treatment with soil application as per KAU PoP). This was in agreement with the finding of Jeyakumar *et al.* (2010), who also observed that in fertigated papaya plants the height at first flowering was low, and the plants of the CO 7 variety under study, that received 100 % RD ofN and K20 displayed a minimum height of 96.32 cm. The height at first flowering was highest in control plants (103.41 cm). Likewise, Valji (2011) also found significant changes in height at first flowering in papaya var. Madhu Bindu which was subjected to different fertigation treatments. The papaya plants that obtained 80 % RD ofN and K20 by fertigation flowered at the lowest height (60.45 cm), followed by fertigation at 100% RD of N and K20 (62.65 cm), whereas the plants that obtained 100% RD ofN and K20 through soil application (control) registered a flowering height of 74.71 cm. Plants fertigated with 60% RD ofN and K20 had the maximum height at first flowering (83.28 cm).

According to the findings of Mathew (2005), the height at first flowering decreased as the plant-to-plant spacing increased. So, the wider spaced plants

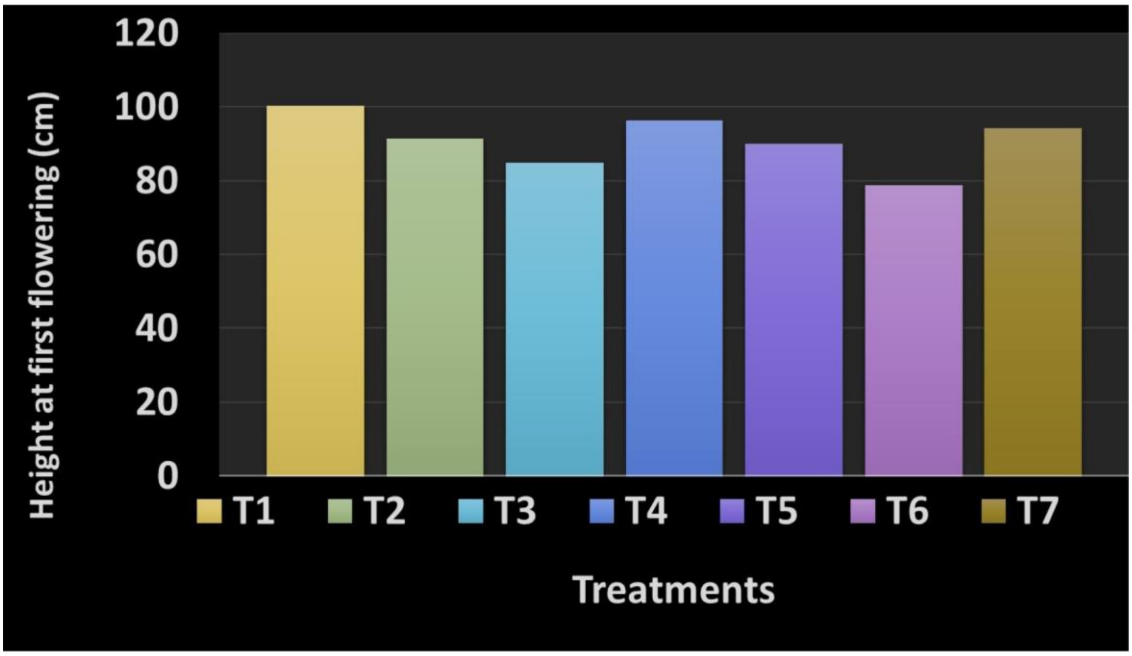

Fig 7. Effect of fertigation and spacing on height at first flowering of papaya

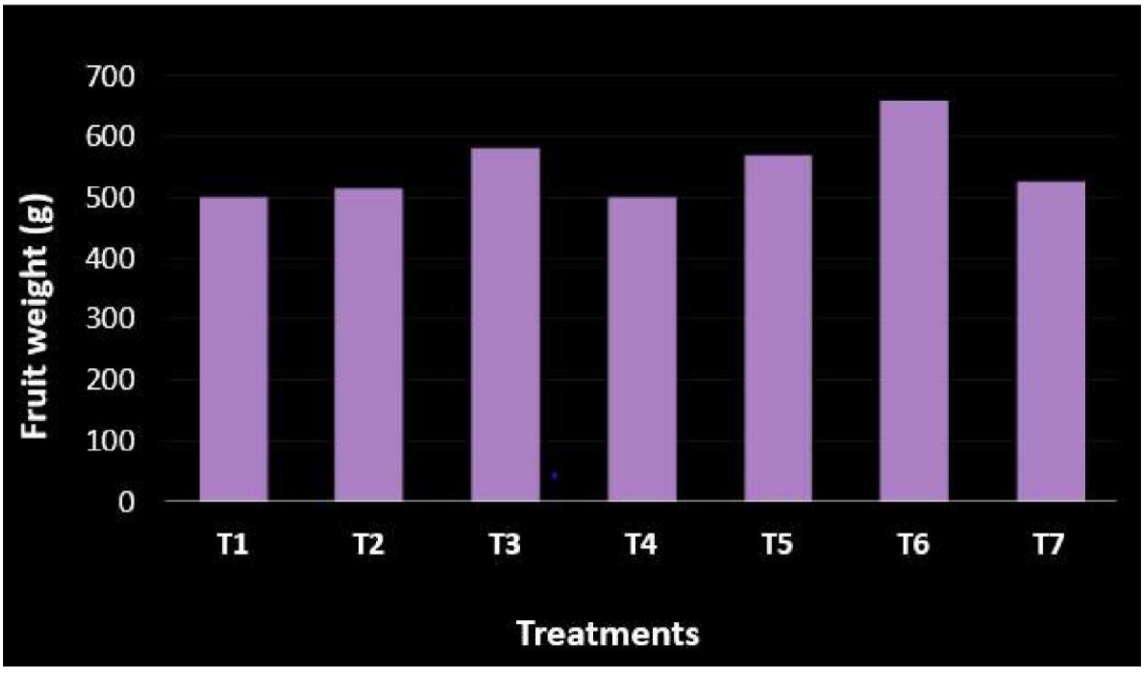

Fig 8. Effect of fertigation and spacing on fruit weight of papaya

produced flowers at a lower height compared to the closely spaced plants. Reddy *et al.* (1989) and Kumar (1995) also proposed a relationship between elevated fertiliser levels and reduced flowering height in the treatment plants of papaya.

With respect to the days to flowering, the treatments under study were found to differ significantly. Early flowering was observed in treatment T6 (1.50 m x 1.50 m spacing+ 100 % ofrecommended dose ofN and K2O), followed by T3 (1.50 m x 1.50 m spacing+ 100 % of recommended dose ofN and K2O). The treatments T5 (1.50 m x 1.50 m spacing+ 80 % of recommended dose ofN and K2O), T2 (1.25 m x 1.25 m spacing+ 80 % ofrecommended dose ofN and K2O), and Tl (1.25 m x 1.25 m spacing+ 60 % of recommended dose ofN and K2O) were found to be on par with treatment T3 (1.25 m x 1.25 m spacing+ 100 % ofrecommended dose of N and K2O). The duration for flowering was found to be the longest in the control treatment T7 (control treatment with soil application as per KAU PoP). Valji (2011) discovered that plants of papaya var. Madhu Bindu that received drip irrigation with 100 % RDF ofN and K2O flowered considerably earlier (69.10). While, the plants that received drip irrigation with 60 % RDF of N and K2O recorded more days (91.27) for the initial appearance of the flowers after transplanting. Kumar *et al.* (1989) discovered that as plant density increased, flowering was delayed, and fruit weight, flowers, and fruits per plant got reduced. They were of the opinion that, it might be due to increased competition among the closely spaced plants for nutrients and water and also due to the lesser availability of sunlight and water for photosynthesis. On studying the effect of different planting density on papaya, Mathew (2005) observed that the days taken for first flowering decreased as the plant spacing increased.

On comparing the sex expression of the genotypes, all the treatment plants were found to be gynodioecious in nature.

The maximum number of flowers per cluster was recorded for treatments T6 (1.50 m x 1.50 m spacing+ 100 % ofrecommended dose of N and K2O) and T3 (1.25 m x 1.25 m spacing + 100 % of recommended dose of N and K2O). Meanwhile, the least number of flowers per cluster was recorded in the control treatment T7. Maximum number of flowers per plant, number of fruits per plant, fruit weight, and yield per plant were recorded under the widest spacing treatment, whereas estimated yield per ha showed an increasing trend with increasing plant density in guava cv. L49 under ultra-high-density planting under Rajasthan conditions (Kumawat *et al.*, 2014). Similarly, Shanmukhi *et al.* (2018) discovered that fertigation with higher doses of fertilizers increased the number of flowers per cluster when compared to fertigation with lower doses.

For obtaining early profit from the papaya orchards, the number of days from flowering to harvest should be shorter, indicating that, induction of early bearing will help to get early yield and early profit. The statistical data on the number of days to harvest showed a significant difference among the treatments. The treatment T6 (1.50 m x 1.50 m spacing+ 100 % of recommended dose ofN and K2O) took the lower number of days to harvest. It was followed by T2 (1.25 m x 1.25 m spacing+ 80 % ofrecommended dose ofN and K2O), T3 (1.25 m x 1.25 m spacing+ 100 % ofrecommended dose ofN and K2O), and T4 (1.50 m x 1.50 m spacing + 60 % of recommended dose of N and K2O) for the first harvest. While the highest number of days were taken by treatments T1 (1.25 m x 1.25 m spacing + 60 % of recommended dose of N and K2O) and T7 (control treatment with soil application as per KAU PoP).

Application of drip irrigation during the experimentation period effectively increased vegetative growth parameters over basin irrigation, as continuous availability of water to the plants might have favourably influenced the vegetative growth of the plant. Drip irrigation is found to maintain the soil moisture at an optimum level, eliminating water stress on the plant and resulting in greater vigour (Subramanian *et al.*, 1997). Bhardwaj *et al.* (1995) and Maas and Van (1996) reported that the vegetative growth of the plants was found to be favourably influenced by the uniform distribution of water in the soil through drip irrigation in young fruit trees.

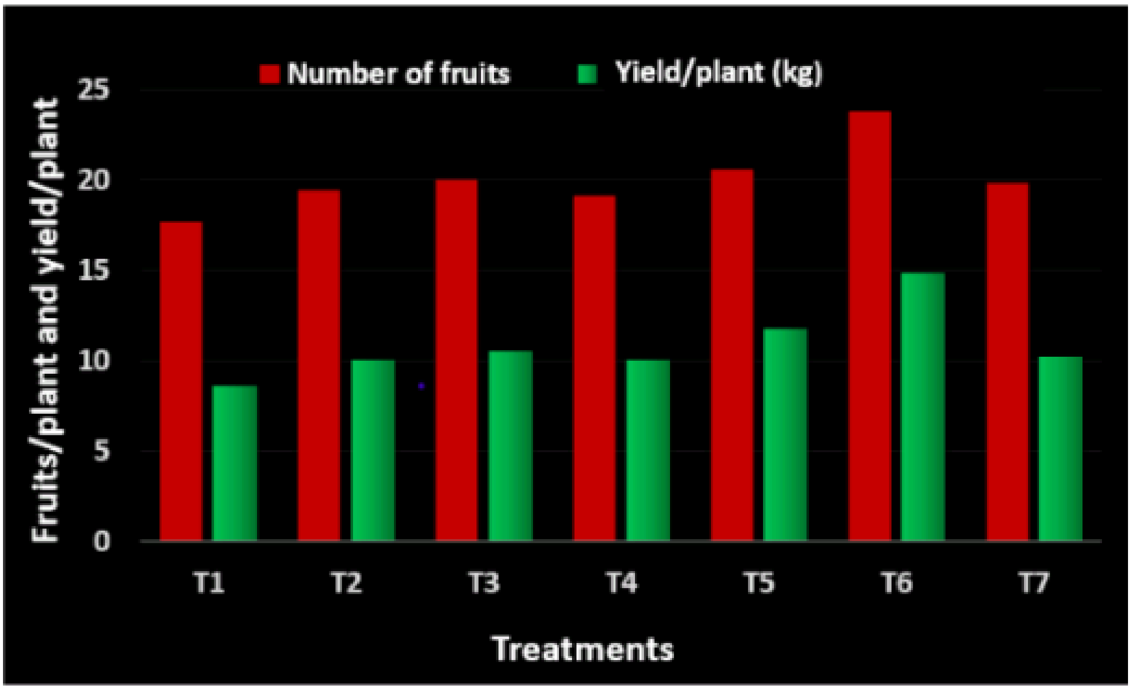

Fig 9. Effect of fertigation and spacing on number of fruits per plant and yield per plant of papaya

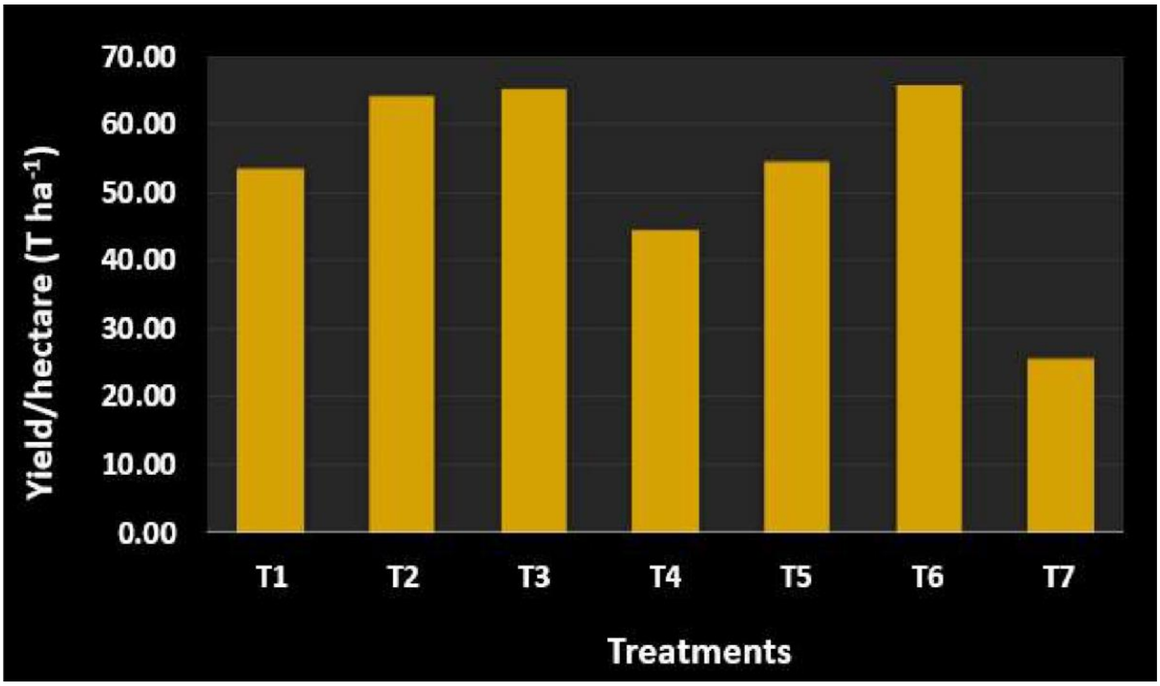

Fig 10. Effect of fertigation and spacing on yield per hectare of papaya

5.1.2. Yield characters

The most important criteria of evaluation for selecting the best treatment is that, the treatment could offer higher yield with quality fruits. All the fertigation treatments were found to differ significantly with regard to yield characters.

With regard to fruit weight, the maximum fruit weight was recorded for treatment T6 (1.50 m x 1.50 m spacing + 100 % of recommended dose of N and K2O), followed by treatments T3 and T5 (respectively), and then by other treatments T7, T2, Tl, and T4, respectively. Fruit weights were found to be in the range of 657.08-498.52 g for the treatments under study. The effect of different fertigation levels (100, 80, and 60 % ofRDF) on the fruit weight of papaya cv. Red Lady were assessed by Jadhav *et al.* (2016). The findings from their study indicated that plants receiving 100 % RDF produced fruits with the highest average fruit weight (1.12 kg), while the lowest average fruit weight (0.83 kg) was noted in plants receiving 60 % RDF. According to Godi *et al.* (2020), the fruit weight of papaya cv. Red Lady increased as the level of fertigation dose increased. The maximum fruit weight was observed in plants supplied with fertigation. Also, the fruit weight of the papaya variety Ranchi increased with a wider spacing, while the lowest was recorded in closely spaced plants. This reduction in fruit weight may be due to the increased competition for water and nutrients and the lesser availability of sunlight and carbon dioxide for photosynthesis among the closely spaced plants (Kumar *et al.*, 1989).

The longest fruits were found in treatments T6 (1.50 m x 1.50 m spacing+ 100 % of recommended dose of N and K2O) and T3 (1.25 m x 1.25 m spacing+ 100 % ofrecommended dose ofN and K2O), while the shortest ones were found in treatment T7 (control treatment with soil application as per KAU PoP). Treatment T5 was found to be on par with treatment T7 for fruit length. On comparing the fruit girth, treatment T6 was reported to have the maximum fruit girth, which was on par with treatments T5, T3 and T4 (1.50 m x 1.50 m spacing+ 60 % ofrecommended dose of N and K2O). However, the minimum fruit girth was observed in control treatment T7. Regarding the fruit volume, the highest value, was recorded for treatment T6, followed by treatment T5. Thick fruit flesh was observed for treatment T6, followed by T5 (1.50 m x 1.50 m spacing + 80 % of recommended dose ofN and K2O), T7 (control treatment with soil application as per KAU PoP), and T4 (1.50 m x 1.50 m spacing+ 60 % ofrecommended dose of N and K2O).

Deshmukh and Hardaha (2014) observed that the application of 100 % CPE and 100 % RDF increased the length and diameter of the fruits along with the yield in papaya cv. Red Lady. According to Jadhav *et al.* (2016), adoption of 100 % RDF (200g N, 200g P2O, and 250g K2O) through fertigation resulted in significantly longer fruits (22.93 cm) in papaya cv. Red Lady, whereas plants obtaining 60 % RDF through fertigation produced shorter fruits (18.63 cm). According to the findings from the experiment conducted by Mathew (2005), it was reported that an increase in plant spacing increased the length, girth, and volume of papaya fruits. Taking into consideration the effect of fertigation on the fruit volume of papaya var. Madhu Bindu, Valji (2011) observed that the highest fruit volume (1357.05 cc) was recorded by the plants receiving fertigation at 100 % RD of N and K2O. Meanwhile, the plants supplied with N and K2O at 60 % of RD were reported to have the minimum fruit volume (1027.44) among the other treatments.

According to Biswas *et al.* (1989), the flesh thickness of papaya cv. Ranchi increased with closer spacing, Accommodating more plants per hectare than the wider spaced ones. Jadhav *et al.* (2016) found that plants receiving 100 % RDN through fertigation had the highest pulp thickness (3.33 cm), whereas plants receiving 60 % RDN had the lowest pulp thickness (3.06 cm) among the other treatments.

With regard to the yield characters, T6 (1.50 m x 1.50 m spacing+ 100 % ofrecommended dose ofN and K2O) was observed to have the maximum number of fruits, followed by T5 (1.50 m x 1.50 m spacing + 80 % of recommended dose of N and K2O), whereas treatment Tl (1.25 m x 1.25 m spacing + 60 % of recommended dose ofN and K2O) was found to produce the minimum number of fruits among the treatments. Similar results were recorded by Singh *et al.* (2008), who studied the effect of spacing levels on the growth and yield of papaya. They observed that the number of fruits increased with an increase in plant spacing in papaya. This can be attributed to the increased availability of sunlight and an increase in the C:N ratio of widely spaced papaya plants. According to Babaji (2013), highest number of fruits per plant was noticed in the plants supplied with 100 per cent RDF ofN and K20 through fertigation in the papaya variety Red Lady, while the lowest number of fruits per plant was recorded in the treatment plants receiving N and K20 at 60 per cent RDF.

Split application of fertilizers to papaya were found to favour better nutrient availability across the growth period, leading to increased growth attributes accompanied by more absorption of photosynthetically active radiation reflected in a higher photosynthetic rate. The photosynthates thus synthesised were effectively translocated towards fruit formation, finally resulting in an increase in fruit number and weight (Chandrakumar *et al.*, 2001).

The results on the fruit yield per plant showed markable significance for the treatment T6 (1.50 m x 1.50 m spacing+ 100 % of recommended dose ofN and K20), followed by T5 (1.50 m x 1.50 m spacing + 80 % of recommended dose of N and K20), which was on par with the treatment T3 (1.25 m x 1.25 m spacing + 100 % of recommended dose ofN and K20), while the maximum per hectare yield was observed for T6, T3, and T2 (1.25 m x 1.25 m spacing+ 80 % of recommended dose of N and K20). The reports from the study of Anil (1994) clearly stated that in tissue culture banana cv. Nendran, a wider plant spacing showed a higher biomass Accumulation as compared to the closer spacing. Deshmukh and Hardaha (2014) found that there was a significant difference in the yield of papaya cv. Red Lady when it was subjected to different levels of fertigation. The maximum yield per plant was observed in the plants that received 100 per cent RDF ofN and K20 (73.97 kg/plant), followed by 75 per cent RDF ofN and K20 (62.21 kg/plant) and control treatment with soil application of fertilizers (55.70 kg/plant). The plants supplied with 50 per cent RDF ofN and K20 (62.21 kg/plant) marked the minimum yield per plant (45.56 kg/plant) among the treatments. According to Sebastian (2021), among the fertigation treatments, the 100 per cent RD of N and K20 was reported to have the highest yield per plant (23.62 kg/plant), while the lowest yield per plant was noticed in the fertigation level of75 per cent RD ofN and K20 (16.21 kg/plant).

According to the reports of Deshrnukh and Hardaha (2014), the highest yield per hectare of papaya was reported in drip irrigation at 100 % CPE with 100 % RDF (225.10 T ha^{-1}), followed by 80 % and 60 % RDF (197.30 T ha^{-1} and 181.70 T ha^{-1}, respectively) at 100 % CPE. Hence, Godi *et al.* (2020) concluded that the number of fruits per plant, yield per plant, and yield per hectare increased directly proportional to the amount of fertilizer applied in all the treatment plants, with the highest value recorded by the fertigation level of 125 % RDF, followed by 100 % RDF. According to a study conducted by Camejo and Alvarez (1983), as the planting density of papaya increased from 1250 to 2500 plants ha^{-1}, yield per plant declined from 40.8 to 22.1 kg. The highest yield (kg ha^{-1}) was obtained at a closer spacing with an intermediate planting density of 2500 plants ha^{-1}, while the lowest yield was obtained at a wider spacing with a planting density of 1250 plants ha^{-1}.

The number of days from flowering to fruit maturity should be minimum so that the total crop duration is not extended unduly. The minimum number of days to fruit maturity were observed for treatments T6 (1.50 m x 1.50 m spacing+ 100 % ofrecommended dose ofN and K20) and T3 (1.25 m x 1.25 m spacing+ 100 % of recommended dose of N and K20), while the maximum number of days taken for the fruits to mature was exhibited by treatment Tl (1.25 m x 1.25 m spacing+ 60 % ofrecommended dose ofN and K20)

Jadhav *et al.* (2016) observed that plants supplied with a fertigation level of 100 % RDF took a lesser number of days to fruit maturity in the papaya cv. Red Lady. According to Parag *et al.* (2016), papaya cv. Red Lady took a minimum number of days to reach fruit maturity (260.99 days) after receiving 100% RDF through fertigation. Meanwhile, it took more days for fruit maturity (276.90 days) in those plants receiving 60 % RDF.

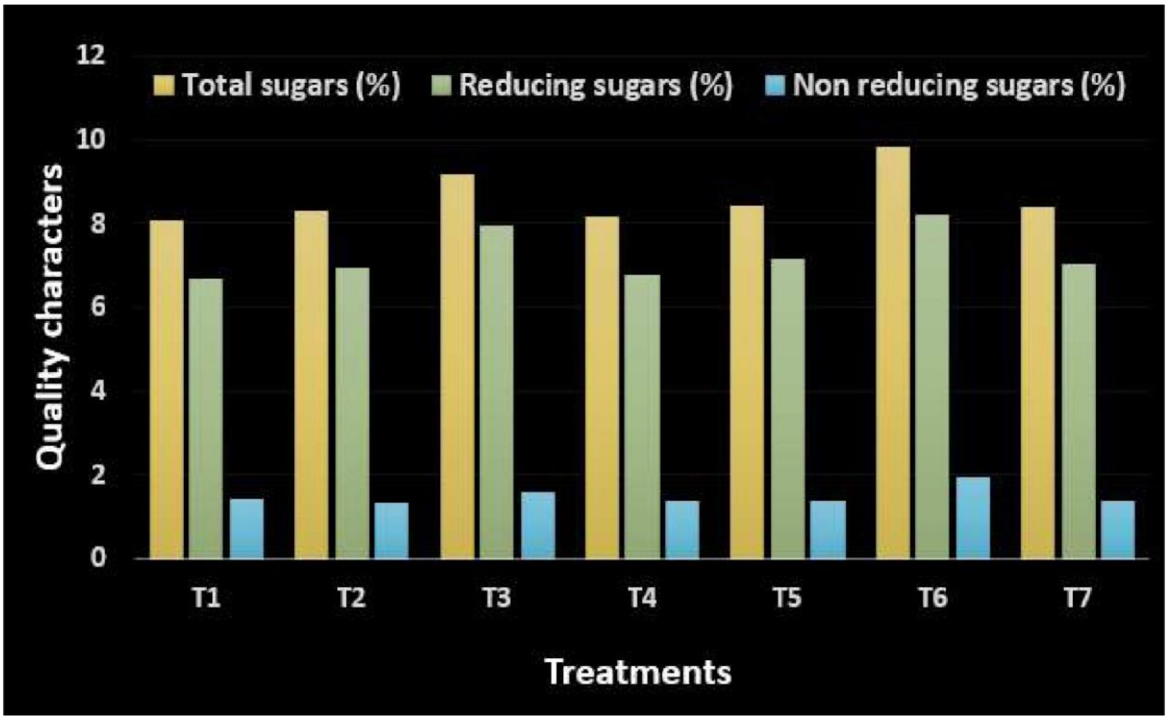

Fig 11. Effect of fertigation and spacing on sugar content of papaya

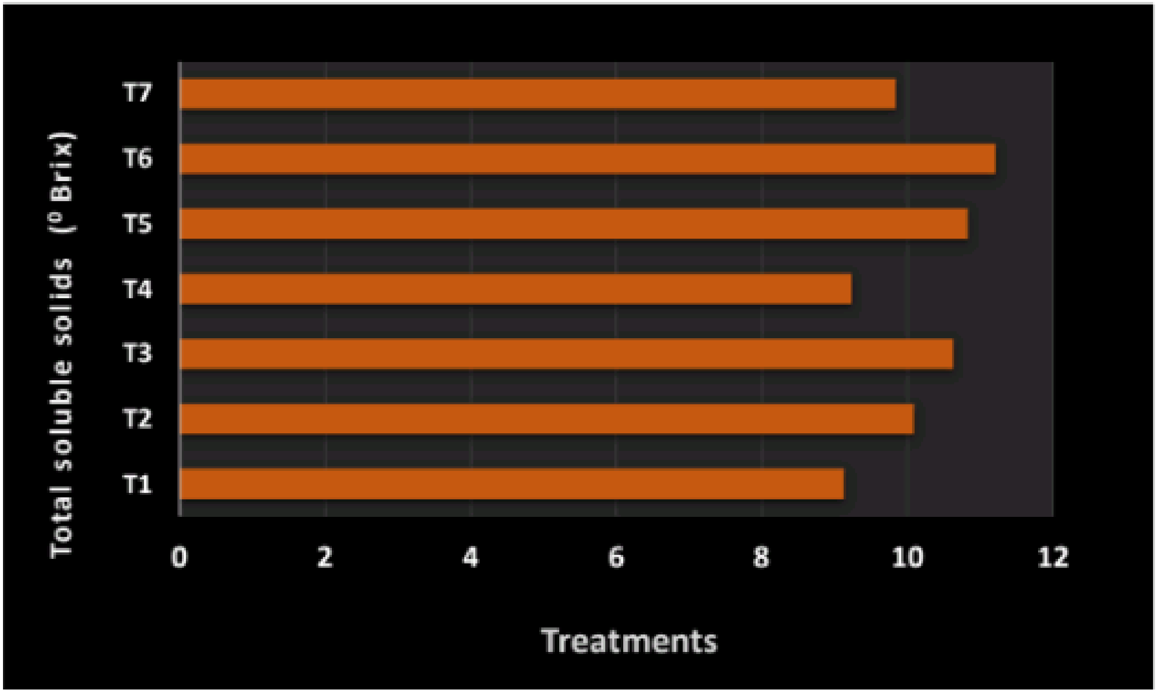

Fig 12. Effect of fertigation and spacing on total soluble solids of papaya

Broad casting of fertilizers generally tends to cause uneven distribution of fertilizers in the root zone. Alternatively, if soluble N, **P** and K fertilizer can be applied via fertigation through a drip system, it will help to obtain proper distribution of the fertilizer in the soil. This will in turn help for the longer availability of nutrients, where nutrients were applied to match the nutrient uptake by the crop. This will enhance the current photosynthesis for fruit development, leading to the development of fruit to marketable size and producing a greater number of fruits per plant and fruit weight in fertigation treatments compared to soil application treatments (Kumar *et al.*, 2013).

5.1.3. Fruit quality characters

The genotypes exhibited significant variation for fruit quality characters like TSS, sugars, and titrable acidity. The highest TSS, total sugars, reducing sugars and non-reducing sugars was recorded by treatment T6 (1.50 m x 1.50 m spacing+ 100 % of recommended dose of N and K2O). While, the lowest titrable acidity was observed for the treatment T6 (0.16 %) and the highest for treatment Tl (0.20 %).

Ascorbic acid exhibited a significant difference among the treatments. It was highest in treatment T6, followed by treatment T5. Beta carotene is the precursor molecule of vitamin A. The highest content of total carotenoids was observed in T4 (1.50 m x 1.50 m spacing+ 60 % of recommended dose ofN and K2O), which was on par with treatments T7, Tl, and T5.

Arango *et al.* (1986) observed that planting distance did not affect the fruit quality of papaya fruits, whereas Biswas *et al.* (1989) reported that total soluble solids and total sugar concentration in papaya fruits increased with a wider plant spacing. Jeyakumar *et al.* (2010) also studied the effect of fertigation on quality attributes of papaya cv. CO 7 and noticed that drip irrigation with 100 per cent RDF ofN and K2O resulted in maximum total soluble solid content (11.4 %), total sugars (8.85 %), and minimum titrable acidity (0.14 %) in the papaya fruits. In a study conducted in papaya cv. Red Lady, Babaji (2013) observed, low total soluble solid and reducing sugar content (5.96 °Brix and 6.89 %, respectively) in plants receiving fertigation@ 60% RD ofN and K2O, whereas application ofN and K20 at 100% RD of N and K2O resulted in the highest total soluble solids (7.47 °Brix) and reducing sugar (8.44 %)

In a study under different fertigation levels, the use of 100 % RDF ofN, P, and K led to higher TSS, total sugars, total carotenoids, and ascorbic acid levels **in** mango var. Alphonso, whereas the use of 50 % RDF recorded the lowest value with respect to these parameters (Prakash *et al.*, 2015). Adequate doses ofN, **P,** and K fertilizers are important to obtain better fruit quality in mango. Likewise, Colapietra (1987) and Sadarunnisa *et al.* (2010) observed similar behaviour with grapes and papaya, respectively.

Among the treatments evaluated, the highest rank for appearance of fruits was given to treatment T6, followed by treatments T3 and *TS.* For colour, the highest rank was again given to treatment T6, followed by treatments T3, *TS,* and T2. The highest rank for overall acceptability was also observed for treatment T6, followed by T3 and *TS.* The analysis of organoleptic characteristics indicated the superiority of fruits grown with wider spacing. The organoleptic characteristics of papaya fruits decreased as plant spacing decreased (Juliya, 2005). According to Haneef *et al.* (2014), fertigation with 125% RDN in pomegranate cv. Bhagwa recorded the highest overall organoleptic score of7.52, followed by fertigation with 100% RDN (7.46). The lowest score was obtained with 50% RDN (6.94) through drip.

The data on soil analysis after the experiment showed considerable variation for pH, EC, organic carbon, nitrogen, phosphorous, and potassium among the treatments. The treatment T6 (1.50 m x 1.50 m spacing+ 100 % of recommended dose of N and K2O) showed the highest pH, EC, organic carbon, nitrogen, phosphorous, and potassium. It was followed by treatment T3 (1.25 m x 1.25 m spacing+ 100 % ofrecommended dose ofN and K2O) for pH, EC, organic carbon, nitrogen, phosphorous, and potassium. Meanwhile, the minimum value for all these soil parameters was observed for the control treatment T7 (control treatment with soil application as per KAU PoP), which was on par with the treatment Tl (1.25 m x 1.25 m spacing+ 60 % of recommended dose of N and K20).

Tank and Patel (2013) observed that the plots that were treated with higher levels of fertiliser recorded higher levels of available N and K and that the phosphorus status of the soil after various treatments was not significantly different. Similarly, Sebastian (2021) observed a similar trend in the nutrient status of soil subjected to fertigation and foliar sprays, wherein she observed that phosphorous content did not show any significant variation with respect to different levels of fertigation supplied to the papaya plants.

The data of different treatments on the leaf analysis before flowering and after harvest, varied significantly for plant nutrients like N, P, K, Ca, Mg, S, Zn and B. The report of leaf analysis before flowering showed that the highest nitrogen content was observed for treatment T6 (1.50 m x 1.50 m spacing + 100 % of recommended dose of N and K20), followed by treatment T3 (1.25 m x 1.25 m spacing + 100 % of recommended dose of N and K20). Meanwhile, the lowest nitrogen content was observed in the leaves of treatment Tl (1.25 m x 1.25 m spacing + 60 % of recommended dose of N and K20). The highest content of phosphorous was also recorded for treatment T1 and control T7 (control treatment with soil application as per KAU PoP), followed by T4 (1.50 m x 1.50 m spacing+ 60 % ofrecommended dose ofN and K20), whereas the lowest value was recorded for treatment T3. The potassium content was found to be highest in treatment T6, followed by treatment T3. There was no significant difference in the calcium and magnesium content among the treatments before flowering. A similar trend was observed for zinc and boron content of the leaves of the treatment plants. The highest sulphur content was recorded for treatment T6, followed by T3.

The fertigation and spacing levels were found to have a significant effect on the absorption of nutrients by the plant system. After the harvest, significant variation was observed among the treatments for nitrogen, phosphorous, and potassium content. The maximum leaf nitrogen was recorded for treatment T6 (1.50

m x *I.SO* m spacing + 100 % of recommended dose of N and K20), followed by treatment *TS (I.SO* m x *I.SO* m spacing + 80 % of recommended dose of N and K20), while the minimum nitrogen was found in control treatment T7 (control treatment with soil application as per KAU PoP). On comparing the phosphorous content, treatments T2 and T6 recorded the highest value, which was on par with treatment *TS.* The potassium content in the index leaf of the treatments showed maximum content for treatment T6, followed by treatment T3 (1.2S m x *l.2S* m spacing + 100 % of recommended dose of N and K20). The lowest potassium content was noted in the treatment T1 (l *.2S* m x 1.2S m spacing + 60 % of recommended dose of N and K20), followed by the control T7. The treatment varied significantly for calcium content, and the highest percentage of calcium was observed in the index leaf of treatment T3, which was on par with treatments T2 and *TS,* while the lowest value was noticed in treatment T6. The maximum magnesium content was recorded in treatment T6, followed by treatments T3 and *TS,* while the minimum magnesium content was noticed in treatments T4 and T7. The statistical data on sulphur content revealed that there was significant variation among the treatments, and the maximum value was noted for treatment T6, followed by T3. Meanwhile, the minimum sulphur content was noted in treatment Tl.

The highest percentage of zinc was exhibited by treatment T6 (I *.SO* m x *I.SO* m spacing+ 100 % ofrecommended dose ofN and K20), which was found to be on par with treatment T3 (1.2S m x 1.2S m spacing + 100 % of recommended dose ofN and K20). However, the minimum zinc content was observed for control treatment T7 (control treatment with soil application as per KAU PoP), which was on par with Tl (1.2S m x *l.2S* m spacing+ 60 % of recommended dose ofN and K20). The data on boron content showed the maximum value for treatment T3, which was observed to be on par with T6. While the lowest boron content was observed for treatment T7, which was found to be on par with treatment Tl.

Jeyakumar *et al.* (2010) investigated variations in the leaf nutrient content of papaya cv. CO 7 following application of various doses of fertigation. The maximum leafN and leaf K were obtained with 100 % RD ofN and K2O by drip irrigation (1.72 % and 2.91 %, respectively). The leaf N and K content of control plants (full dose of fertilizers through soil application) were 1.37 % and 2.46 %, respectively. Plants receiving 50 % RD ofN and K2O through drip had the lowest leaf N and K levels (1.28 % and 2.23 %, respectively). Valji (2011) came to the conclusion that various fertigation treatments considerably affected the leaf nitrogen content of papaya *(Carica papaya* L.) var. Madhu Bindu. Highest content of nitrogen (1.82%), potassium (2.91%), and phosphorus (0.43%) were found in the papaya leaves of plants receiving drip irrigation at 0.8 PEF coupled with N and K2O at 100% RD. The papaya plants grown under drip irrigation at 0.4 PEF and N and K2O at 60% RD was found to have minimum nitrogen (1.15%), potassium (2.25%), and phosphorus content (0.38%) in the leaves. Similar results were noted by Sebastian (2021), suggesting no significant difference in the phosphorous content of papaya leaves subjected to different fertigation and foliar sprays, The analysis of the nutritional status of papaya leaves revealed that fertigation had significant effect on the nitrogen and potassium levels of papaya leaves but not on the phosphorus content (Tank and Patel, 2013).

The data on economic analysis of papaya revealed that treatment T6 recorded the highest values for gross income, net income, and B:C ratio among the seven treatments. Singh *et al.* (2006) observed that fertigation led to greater fruit development and maturation in pomegranate cv. Ganesh, which resulted in well-developed fruits that can fetch a decent price in the market. In comparison to other treatments, the 100 % RDF treatment generated the highest net returns of Rs. 89137.29 ha-^{1} and a B:C ratio of2.19 (Kumar *et al.*, 2013). The study conducted by Pandey *et al.* (2013) gave an insight into the influence of drip irrigation, fertigation, and dripper spacing on the cost of papaya cultivation. They found that closer dripper spacing increased the yield and income of the papaya orchard, while a wider dripper spacing improved the water saving percentage and reduced the disease and weed incidence in the orchard.

Hence, from the present study on the effect of fertigation and spacing levels in papaya under high-density planting system, it could be concluded that the treatment T6 (1.50 m x 1.50 m spacing + 100 % of recommended dose of N and K2O) was found to be the most suitable treatment with respect to the biometric, flowering, and fruit quality parameters. It was followed by treatments T3 (1.25 m x 1.25 m spacing+ 100 % of recommended dose ofN and K2O) and *TS* (1.50 m x 1.50 m spacing + 80 % of recommended dose of N and K2O). So, the plants spaced at 1.50 m x 1.50 m receiving 100 % RDF of N and K2O are found to be the best under the HDP system of papaya cultivation under Kerala conditions.

Summary

6. SUMMARY

The study entitled "Genotype evaluation and production technology development for high density planting system in papaya *(Carica papaya* L.)" was conducted in the college orchard attached to the Department of Fruit Science, College of Agriculture, Vellanikkara, during 2021-2022. It was aimed at evaluating the genotypes suitable for table purpose and standardising the spacing and fertilizer levels for growth, yield, and quality of papaya under high density planting system in Kerala. The salient findings of experiments I and II are summarised as follows.

EXPERIMENT 1

1. The papaya variety CO 7 recorded the lowest, plant height throughout the observation period. The plant height of the twenty-five genotypes ranged from 249.39 cm to 342.48 cm.

2. A significant variation was observed for the collar girth among the genotypes throughout the period of observation. The highest plant girth was recorded for the variety CO 6 at the final observation. The plant girth of the genotypes ranged from 43.24 cm to 66.64 cm.

3. At the final stage of observation, the highest number of leaves were observed for genotypes CPV 4 (local type from Malappuram) and CPV 7 (local type from Kottayam).

4. With respect to petiole length, and colour of mature, leaf petioles, variations, were observed among the genotypes. The longest petiole was recorded for CPV 2 (local type from Emakulam), while the shortest petiole was found in Arka Prabhath. The colour of the leaf petiole, of the genotypes was observed to exhibit, four different colours viz., normal green, pale green, green, and shades ofred purple and red purple.

5. The papaya variety CO 7 and local genotype CPV 16 (local type from Thrissur) exhibited, the lowest height at first flowering, while the, maximum height at first flowering was observed for the variety CO 6. With respect to the number of days to flower, CPV 2 (local type from Ernakulam) flowered early among the genotypes. The genotype CPV 2 took the lowest number of days to harvest and was statistically on par with the variety CO 7.

6. On comparing the sex expression of the genotypes, there were mainly two types: gynodioecious and dioecious types. The papaya genotypes, CPV 1, CPV 3, CPV 5, CPV 6, CPV 7, CPV 8, CPV 10, CPV 11, CPV 15, CPV 16, Arka Prabhath, CO 3,
CO 7 and Red Lady were gynodioecious, whereas CPV 2, CPV 4, CPV 9, CPV 12, CPV 13, CPV 14, CO 1, CO2, CO 4 and CO 6 were dioecious in nature.

7. A comparison of the colour of the flesh revealed that the genotypes produced fruits of different colours, viz., light yellow, bright yellow, deep yellow to orange, and reddish orange. Similarly, the fruit shapes of these genotypes showed variation, viz., club shape, elongate, elliptic, oblong-ellipsoid, pear shape, acron, globular, oval and lengthened cylindrical.

8. The heavier fruits were observed for TNAU papaya variety CO 6, and were statistically on par with CO 4 and CO 1. The longest fruits were recorded for CPV 1 (local type from NBPGR, Vellanikkara), whereas the broadest fruits were found in the variety CO 6. The fruit flesh thickness was superior in the varieties CO 6 and CO 4, while the thinnest flesh was observed in CPV 1.

9. Higher number of fruits were recorded for CPV 2 (local type from Ernakulam), followed by CPV 3 (local type from Ernakulam), and Red Lady. Meanwhile, the highest yield per plant was exhibited by CO 4 and CO 6. Also, the maximum yield per hectare was superior in the varieties CO 4 and CO 6. On comparing the days to fruit maturity, the minimum number of days was observed for CPV 5 (local type from Malappuram), which was statistically on par with CPV 11 (local type from Kottayam).

10. The fruit quality characters like total soluble solids, total sugars and reducing sugars were recorded highest for CO 7. Four local genotypes (CPV 9, CPV 2, CPV 12, and CPV 15) were found to be on par with CO 7 for fruit quality characters like total soluble solids, total sugars and reducing sugars. The lowest titrable acidity was recorded for CO 7, while the highest ascorbic acid content was exhibited by CPV 9 (local type from Kottayam), followed by CPV 10 (local type from Palakkad). With respect to total carotenoids, the red fleshed varieties CO 7 and Arka Prabhath were found to be superior.

11. From the sensory evaluation, the TNAU papaya variety CO 7 was found to be the most promising type with respect to flavour, taste and overall acceptability. The genotypes CPV 15, CPV 9, CPV 2 and CPV 12 were noted to be on par with CO 7.

EXPERIMENT II

1. In experiment II, the treatment plants with 1.25 m x 1.25 m spacing that received 100 % recommended dose ofN and K2O (T3) exhibited the highest value for plant height at the final stage of observation. Whereas, it was lowest in the plants subjected to treatment Tl (1.25 m x 1.25 m spacing+ 60 % ofrecommended dose of N and K2O).

2. With respect to the plant girth at final observation, treatment T6 (1.50 m x 1.50 m spacing + 100 % of recommended dose of N and K2O) recorded the highest value. Meanwhile, treatment T1 (1.25 m x 1.25 m spacing + 60 % of recommended dose of N and K2O) was noted to have the lowest plant girth at the final stage of observation.

3. The number of leaves was superior in treatments T6 (1.50 m x 1.50 m spacing+ 100 % of recommended dose of N and K2O), T7 (control treatment with soil application as per KAU PoP), T5 (1.50 m x 1.50 m spacing+ 80 % ofrecommended dose of N and K2O), and T3 (1.25 m x 1.25 m spacing + 100 % of recommended dose of N and K2O).

4. The treatments showed a positive effect on the height at first flowering and days to flowering. The lowest height at first flowering was observed in treatment T6, followed by T3 (1.25 m x 1.25 m spacing+ 100 % ofrecommended dose ofN and K20) while early flowering was observed in treatment T6 (1.50 m x 1.50 m spacing + 100 % ofrecommended dose ofN and K20).

5. The data on the number of days to harvest showed a significant difference among the treatments. The treatment T6 (1.50 m x 1.50 m spacing + 100 % of recommended dose ofN and K20) took the minimum number of days to harvest.

6. Superiority with respect to the fruit length was exhibited by the treatments (1.50 m x 1.50 m spacing+ 100 % of recommended dose ofN and K20) and T3 (1.25 m x 1.25 m spacing+ 100 % of recommended dose ofN and K20). While the broadest fruits were observed for treatment T6, it was found to be statistically on par with treatments T5 (1.50 m x 1.50 m spacing + 80 % of recommended dose of N and K20), T3 (1.25 m x 1.25 m spacing+ 100 % ofrecommended dose ofN and K20) and T4 (1.50 m x 1.50 m spacing + 60 % of recommended dose of N and K20). Similarly, the thickest fruit flesh was exhibited by treatment T 6, followed by T5.

7. All the fertigation treatments were found to differ significantly with regard to yield characters. Heavier fruits were recorded for treatment T6 (1.50 m x 1.50 m spacing+ 100 % of recommended dose ofN and K20). Fruit weights were found to be in the range of 657.08-498.52 g for the treatments under study.

8. With regard to the yield characters, T6 (1.50 m x 1.50 m spacing+ 100 % of recommended dose ofN and K20) was observed to have the maximum number of fruits and yield per plant, followed by T5 (1.50 m x 1.50 m spacing + 80 % of recommended dose of N and K20). The per hectare yield was superior in the treatments T6 (1.50 m x 1.50 m spacing+ 100 % of recommended dose of N and K20), T3 (1.25 m x 1.25 m spacing+ 100 % ofrecommended dose ofN and K20), and T2 (1.25 m x 1.25 m spacing+ 80 % ofrecommended dose ofN and K20).

9. The minimum number of days to fruit maturity were observed for treatments T6 (1.50 m x 1.50 m spacing+ 100 % of recommended dose ofN and K20) and T3 (1.25 m x 1.25 m spacing+ 100 % ofrecommended dose ofN and K20)

10. With respect to the quality parameters, the highest TSS, total sugars, reducing sugars and non-reducing sugars were recorded for the treatment T6 (1.50 m x 1.50 m spacing + 100 % of recommended dose of N and K20). Similarly, the lowest titrable acidity was observed for the treatment T6, followed by T5 (1.50 m x 1.50 m spacing+ 80 % ofrecommended dose ofN and K20). The ascorbic acid content in the treatment T6 marked the highest value, followed by T5 whereas, the highest content of total carotenoids was observed in T4 (1.50 m x 1.50 m spacing+ 60 % ofrecommended dose ofN and K20), which was statistically on par with treatments T7 (control treatment with soil application as per KAU PoP), Tl (1.25 m x 1.25 m spacing + 60 % of recommended dose of N and K20), and T5 (1.50 m x 1.50 m spacing+ 80 % of recommended dose ofN and K20).

11. The sensory evaluation of organoleptic parameters of the fruits recorded the highest mean score for all the parameters like appearance, colour, flavour, odour, taste, aftertaste and overall acceptability for the treatment T6 (1.50 m x 1.50 m spacing+ 100 % of recommended dose ofN and K20), followed by T3 (1.25 m x 1.25 m spacing + 100 % of recommended dose of N and K20) and T5 (1.50 m x 1.50 m spacing+ 80 % ofrecommended dose of N and K20).

12. Improvements in soil and leaf nutrient content were observed for all the treatment plants under study.

13. The computation of the economics of cultivation under experiment II marked the highest values for gross income, net income, and B:C ratio in the treatment T6 (1.50 m x 1.50 m spacing+ 100 % ofrecommended dose of N and K20).

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GENOTYPE EVALUATION AND PRODUCTION TECHNOLOGY DEVELOPMENT FOR HIGH DENSITY PLANTING SYSTEM IN PAPAYA (*Carica papaya* L.)

by

AMRITA MANOHAR
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Abstract of the Thesis

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

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Genotype evaluation and production technology development for high density planting system in papaya *(Carica papaya* L.)

Abstract

Papaya (*Carica papaya* L.) is an evergreen, tropical, herbaceous fruit crop valued for its taste, medicinal, and dietary benefits. Lack of suitable high-yielding dessert purpose papaya genotypes, scarcity of irrigation water, high cost of fertilisers and limitation with respect to land area available for cultivation are the major factors limiting commercial cultivation of papaya in Kerala. In this background, the present investigation on "Genotype evaluation and production technology development for high density planting system in papaya (*Carica papaya* L.)" was undertaken at the college orchard attached to the Department of Fruit Science, College of Agriculture, Vellanikkara, during 2021-2022.

The study consisted of two separate experiments, experiment I and experiment II. In experiment I, evaluation of genotypes for table purpose under Kerala conditions was carried out in RBD using 25 genotypes. The seeds were collected from research stations and homesteads in Kottayam, Emakulam, Thrissur, Palakkad, and Malappuram districts. The nutrient management was done as per PoP recommendations for papaya (KAU, 2016).

The genotypes showed wide variation in plant height, ranging from 249.39 cm in CO 7 to 342.47 cm in CPV 15 at 12 months after planting (MAP). The girth of the plant was found to be highest in CO 6 (66.64 cm), while the maximum number ofleaves was recorded for CPV 4 (33.30). With respect to the height at first flowering, the genotypes CO 7 and CPV 16 (82.32 cm and 82.69 cm, respectively) exhibited the shortest height, whereas early blooming was noticed in CPV 2 (52.89 days), followed by CPV 14 (53.56 days). Among the genotypes, CO 7 was found to have the highest number of flowers per cluster (7.92), CPV 9 recorded the maximum fruit set percentage (79.74 %), CPV 2 and CO 7 took the minimum number of days to first harvest (196.60 days and 201.56 days, respectively), and CPV 5 took the least number of days to fruit maturity. The papaya varieties Red Lady and Arka Prabhath exhibited maximum shelf life among the genotypes evaluated.

The varieties CO 6 and CO 4 were found to be on par with respect to fruit weight (1908.20 g and 1779.72 g, respectively) and flesh thickness (3.26 cm and 3.18 cm, respectively), while the fruit girth was highest for the variety CO 6 (35.01 cm). The highest yield per plant (33.59 kg), and yield per hectare (83.97 T ha^{-1}) was observed for the variety CO 4, which was followed by CO 6. Whereas, the number of fruits was found to be the highest in

CPV 2 (29.25), followed by CPV 3 (23.75) and Red Lady (23.63), while the fruit volume was highest in CPV 10 (1178.62 cm^3), which was on par with CO 4 (1105.23 cm^3).

Papaya genotypes exhibited significant variation with respect to fruit quality characters. The highest total soluble solids (TSS), reducing sugars and total sugars, and lowest titrable acidity were recorded for CO 7 (13.11 °Brix, 9.79 % and 11.13 %, 0.14 %, respectively). The papaya genotypes CPV 2, CPV 15, CPV 9, and CPV 12 were found to be on par for all these quality characters. It was noticed that Arka Prabhath had the highest percentage of non-reducing sugars, while the ascorbic acid content of fruits was the highest for CPV 9 (85.77 mg 100 g^{-1}). In organoleptic evaluation, variety CO 7 exhibited the highest mean score for colour, taste, and overall acceptability, and was on par with CPV 2, CPV 15, CPV 9, and CPV 12.

In experiment II, the effect of fertigation and spacing levels on papaya under high density planting system was carried out with the IIHR papaya variety Arka Prabhath. The experiment was laid out in RBD with seven treatments replicated thrice. The treatments were in combination of two levels of spacing (S1-1.25 m x 1.25 m and S2- 1.50 m x 1.50 m) and three levels offertigation, viz. 60 %, 80 % and 100 % recommended doses of fertilizers (RDF) of, N (169.04, 225.38, and 281.73 g/plant/year) and K (340.99, 454.66, and 568.33 g/plant/year) respectively, based on the soil test data. This was compared with the control treatment (spacing: 2 m x 2 m), which was supplied with fertilizers based on the KAU PoP recommendation for papaya (240:240:480 g NPK/plant/year). Farmyard manure, lime, and rock phosphate were uniformly supplied as a basal dose to all the treatments. Fertigation was initiated at 1 MAP using urea and muriate of potash (MOP) as sources of N and K fertilizers, respectively. Urea and MOP were provided to the treatment plants in equal splits on a weekly basis, starting from 4 weeks (1 MAP) up to 48 weeks (12 MAP) based on the fertigation levels (60 %, 80 % and 100 %).

The spacing and fertigation levels significantly influenced the biometric, yield, and quality parameters of papaya. The tallest plants were noted in treatment T3 (297. 29 cm- 1.25 m x 1.25 m spacing+ 100 % of recommended dose ofN and K2O), followed by T6 (272.18 cm- 1.50 m x 1.50 m spacing+ 100 % ofrecommended dose ofN and K2O), while the shortest plants were found in treatments Tl (1.25 m x 1.25 m spacing+ 60 % ofrecommended dose of N and K2O) and T2 1.25 m x 1.25 m spacing + 80 % of recommended dose of N and K2O (242.91 cm and 243.66 cm, respectively). Higher collar girth (45.49 cm) and number of leaves (22.62) were found in treatment T6. Also, the shortest height at first flowering, highest fruit set percentage, and minimum days to first flowering and days to harvest were observed for treatment T6 (78.62 cm, 72.11%, 67.77, and 207.33 days, respectively).

The fruit parameters like fruit length, fruit girth, fruit volume, flesh thickness, and yield parameters like fruit weight (657.08 g), fruits per plant (23.71), yield per plant (14.82 kg), and yield per hectare (65.97 T ha^{-1}) were the highest for treatment T6 (1.50 m x 1.50 m spacing+ 100 % of recommended dose of N and K20). Also, the highest content of TSS, total sugars, reducing sugars, ascorbic acid (11.21 °Brix, 9.81%, 8.18 %, and 82.34 mg 100 g^{-1}, respectively) and the lowest titrable acidity (0.16 %) were observed for T6.

The combined effect of fertigation and spacing on the shelf life of papaya revealed that maximum shelf life was observed for higher doses of fertilizers in treatment T6 (8.20 days). The organoleptic scoring of papaya showed the highest mean value for appearance, colour, taste and overall acceptability for the plants receiving 100 % RDF of N and K20 planted at a spacing of 1.50 m x 1.50 m (T6). Index leaf analysis before flowering showed small variations among the treatments. The highest nitrogen, potassium, and sulphur content was observed in the treatment T6 (1.75 %, 2.82 % and 0.44 %, respectively), followed by T3 (1.61 %, 2.79 % and 0.36 %). Calcium, magnesium, zinc, and boron did not vary significantly among the treatments before flowering. The nutrient content of the index leaf varied significantly after harvest. The maximum content of nitrogen, potassium, sulphur, magnesium, and zinc (1.73 %, 2.77 %, 0.41 %, 0.39 % and 20.94 ppm) were noticed in T6, while maximum calcium and boron content were noted in treatment T3 (0.46 % and 18.12 ppm). Treatment T6 showed the highest gross income (Rs. 13,17,345/ha), net income (Rs. 7,88,084/ha) and B:C ratio (2.5).

It can be concluded that papaya variety CO 7 was found to be the most suitable table purpose variety with respect to short plant stature, early flowering, and fruit quality parameters. In addition to CO 7, the local genotypes CPV 2, CPV 9, CPV 12, and CPV 15 were found to have comparable quality parameters of fruits as that of CO 7. Under HDP system, a closer spacing of 1.50 m x 1.50 m along with application of 100 % recommended dose of fertilizers (N and K20 @ 240 and 480 g/plant/year, respectively) can be recommended for higher yield (65.97 T ha^{-1}), fruit quality and net profit.

Appendices

Appendix i

Nutrient properties of soil before the experiment

Experiment I	
Parameter	**Concentration**
pH	4.41
EC (dS m^{-1})	0.04
QC(%)	1.52
N (kg ha^{-1})	193.47
P (kg ha^{-1})	34.93
K (kg ha^{-1})	256.19

Appendix ii

Weather data during the period of study (January 2022-May)

Month/year	Temperature (° C)		Relative humidity (%)	Mean evaporation (mm)	Monthly rainfall (mm)	Mean Sunshine (hr/day)
	Maximum	Minimum				
Jan 2021	32.30	21.30	64.00	4.30	45.70	6.60
Feb 2021	34.60	21.60	54.00	5.50	0	9.20
Mar 2021	36.80	23.00	59.00	5.30	31.80	8.60
Apr 2021	34.90	23.60	73.00	3.70	72.40	6.30
May 2021	32.70	22.90	83.00	2.70	550.50	4.50
Jun 2021	31.20	23.70	84.00	2.70	473.00	4.30
Jul 2021	29.80	23.50	87.00	2.10	626.90	2.40
Aug 2021	30.20	23.40	86.00	2.20	409.10	2.50
Sep 2021	30.70	23.90	83.00	2.60	291.70	4.00
Oct 2021	31.30	23.60	86.00	2.00	593.20	3.50
Nov 2021	31.00	23.40	81.00	2.10	364.20	2.40
Dec 2021	32.50	23.30	67.00	4.00	19.20	8.20
Jan 2022	33.30	22.60	64.00	4.30	0	9.10
Feb 2022	34.80	23.30	58.00	5.10	0	8.30
Mar 2022	36.10	24.70	74.00	5.00	1.70	6.90
Apr 2022	34.20	25.10	77.00	3.20	84.30	5.90
May 2022	31.10	24.00	85.00	2.70	422.00	3.00

Appendix-iii

Score card for organoleptic evaluation Name of the judge:

Date:

Characteristics	Scores					
			T_3	**T_4**	Ts	
Appearance						
Colour						
Flavour						
Texture						
Odour						
Taste						
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

Signature

Appendix iv

Analytical methods adopted in plant analysis

Element	Method adopted	Reference
N	Digestion- H_2SO_4 Microkjeldahl distillation	Jackson, 1958
P	Digestion- Nitric-perchloric acid (9:4) Spectophotometry	Jackson, 1958
K	Digestion- Nitric-perchloric acid (9:4) Flamephotometry	Jackson, 1958
Ca	Digestion- Nitric-perchloric acid (9:4) Inductively coupled plasma spectrometry (ICP)	Piper (1967)
Mg		
S	Turbidimetry	Chesnin and Yien, 1950
Zn	Digestion- Nitric-perchloric acid (9:4) Inductively coupled plasma spectrometry (ICP)	Jackson, 1958
B	Azomethane- H method	Gupta, 1967

Appendix-v

Economic analysis of papaya variety CO 7

Genotype	Gross Income (Rs ha-')	Net Income (Rs ha-')	B:C ratio
C07	944872.60	604342.87	2.7

Appendix-vi

Market price of papaya fruit is Rs 20 per kg of fruit

Appendix-vii

Nutrient properties of soil before the experiment

Experiment II	
Parameter	**Concentration**
pH	4.34
EC (dS m^{-1})	0.03
QC(%)	1.32
N (kg ha^{-1})	180.10
P (kg ha^{-1})	49.29
K (kg ha^{-1})	224.47