HIGH DENSITY PLANTING IN PAPAYA *(Carica papaya L.)*

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DECLARATION

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

Vellayani,
25-04-2005.

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CERTIFICATE

Certified that this thesis entitled "**High density planting in papaya** (*Carica papaya* **L.**)" is a record of research work done independently by Mrs. Juliya Mathew (2002-12-08) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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LIST OF ABBREVIATIONS

BCR	–	Benefit cost ratio
cc	–	Cubic centimetre
CD	–	Critical difference
cm	–	Centimetre
cv.	–	Cultivar
et al.	–	and others
FIB	–	Farm Information Bureau
Fig.	–	Figure
g	–	Gram
ha	–	Hectare
ha^{-1}	–	Per hectare
kg	–	Kilogram
LAI	–	Leaf area index
m	–	Metre
MAP	–	Months after planting
mg	–	Milligram
mm	–	Millimetre
NHB	–	National Horticultural Board
$Plant^{-1}$	–	Per plant
Rs/ha	–	Rupees per hectare
t	–	Tonnes
TSS	–	Total soluble solids

INTRODUCTION

1. INTRODUCTION

Papaya (*Carica papaya* L.) is one of the most commonly cultivated fruits of the tropical region. It is one of the few fruits which yields throughout the year, gives quick returns and adapts itself to diverse agro-climatic conditions. The crop was introduced from Central America to Asia. Papaya has now emerged from the status of a home garden crop to that of a commercial orchard crop. It gives one of the highest production of fruits per hectare. Fruits are very wholesome with high nutritive and medicinal values. The fruit is rich in vitamins, especially vitamin A, C and E. Papaya is rich in minerals like calcium, phosphorus and iron. A piece of papaya after the meal takes care of the action of bowel and helps to dispose the waste after digestion without any difficulty. Regular intake of papaya will prevent constipation. Fruit is also beneficial for the treatments of piles, dyspepsia, disorders of liver, spleen etc. It is used for the preparation of jam, jelly, nectar, tooty-fruity and crystallized fruits. Papaya yields a valuable proteolytic enzyme papain used in meat tenderization and preparation of certain digestive medicine. Papain also finds extensive application in leather industry, cosmetics and production of chewing gum.

Major papaya growing countries are Hawaii, India, Ceylon, South Africa, Tropical America, Indonesia and The Philippines. In India papaya cultivation is mainly concentrated in Karnataka, Gujarat, Orissa, West Bengal, Assam, Kerala and Madhya Pradesh. India is the largest producer of papaya in the world with an annual production of 16.85 lakh tonnes (NHB, 2004). Important varieties cultivated in India are Honeydew, Coorg Honeydew, Washington, Pusa Delicious, Pusa Majesty, Pusa Dwarf, CO-1 to CO-7, Pusa Nanha etc. In Kerala papaya is usually grown as homestead crop. The area and production in the state are 16,016 ha and

72,009 t (FIB, 2004). Recently, isolated attempts have been made by some progressive farmers for commercial cultivation of papaya.

One of the major production constraints encountered in papaya is the difficulty in maximizing yield within unit area. One way of enhancing productivity is to go for high density orcharding. Spacing plays a vital role on plant growth, yield and fruit quality. Optimum spacing will increase the yield per unit area with minimal loss of market acceptability. It is quite obvious that when the spacing is reduced, the yield per plant may be decreased. However, due to the higher number of plants, the total yield per unit area will increase.

The spatial arrangement of plants in an orchard is very important and usually involves a choice between physiological efficiency and practical suitability. The jurisdiction of such planting thus lies at a level where competition between plants is minimum, the total yield is maximum and quality is optimum. In Kerala conditions no systematic attempts have been made on the determination of optimum spacing under high density planting system. The present study was thus undertaken to determine the optimum spacing for maximum growth, yield and quality in papaya under high density planting system.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Papaya has long been known and cultivated by the people of tropics. The fruits are an important and economical source of vitamins and minerals. Besides the table uses, it is highly priced for its medicinal properties. In Kerala papaya is grown as a homestead crop. Recently, isolated attempts have been made by some progressive farmers for commercial cultivation of papaya. Optimum spacing play a vital role to obtain maximum yield per unit area with minimal loss of market acceptability. The current experiment was laid out to determine the optimum spacing for papaya under Kerala condition. The review of research works on the effect of different plant densities on papaya is presented in relation to the following aspects:

Biometric characters

Physiological characters

Yield characters

Quality characters

Incidence of pests and diseases

Economics of cultivation

2.1 BIOMETRIC CHARACTERS

Singh *et al.* (1967) recommended planting distance of 2.5 to 3.0 m each way for papaya. Rajasekharan (1975) evaluated the effect of spacing and pinching on Co-2 papaya. The results showed that increased spacing decreased the height of the plants and also the height of flowering.

Papaya varieties PR6-65 and PR 7-65 planted at 1.8 x 1.8 m in Puerto Rico produced significantly larger plants than those at a closer spacing of 1.2 x 1.2 m (Perez and Vargas, 1977). Purohit (1981) suggested 1.8 x 1.8 m spacing for papaya cvs. Co-1, Co-2 and Solo, while 2.4 x 2.4 m for Coorg Honeydew and Washington.

Camejo and Alvarez (1983) noted that the highest planting density decreased plant height and stem width of papaya. According to Arango *et al.* (1986) tree height and flowering generally increased and stem diameter and leaf number decreased as the planting distance of papaya decreased. It was also noted that the planting distance had no effect on number of nodes to first flower and period of time from transplanting to flowering. Biswas *et al.* (1989) observed an increase in plant height and number of leaves per plant with increasing plant density in papaya cultivar Ranchi, whereas basal girth, plant spread, and petiole length and diameter decreased.

Singh (1990) reported that in India the usual practice is to plant papaya at a spacing of 1.8 m either way accommodating about 3090 plants ha^{-1}. Ghanta (1994) evaluated the performance of papaya cv. Ranchi and noted that an increase in plant population from 1600 to 4444 per hectare increased the plant height at flowering by 4.08 cm to 18.84 cm. The girth of the plant, length of the petiole (5^{th} leaf) and number of leaves per plant at flowering, however decreased with the increase in plant population. A marked variation was also noted among the different plant spacings, in the days required for the first flowering. Plants with 2.5 x 2.5 m spacing resulted in early flowering at about eight days compared to spacing of 1.5 x 1.5 m.

According to Kist and Manica (1995) spacing had no effect on stem diameter, plant height and average fruit weight of papaya in the first productive year. Reddy (1995) reported that plant height and girth of papaya cv. Coorg Honeydew did not differ with density.

According to Ghosh (1996) a spacing of 1.8 x 1.8 m is normally followed in most of the places and is optimum for Co-1, Co-2 and Solo in

Bangalore conditions. The spacing of 1.4 x 1.4 m or 1.6 x 1.4 m is ideal for Pusa Delicious in Bihar. For the dwarf variety of papaya Pusa Nanha, a closer spacing of 1.25 x 1.25 m has been found satisfactory. In papaya cv. Maradol Roja stem circumference and plant height were significantly lowered when grown at a spacing of 4.0 x 1.5 m (Arce *et al.*, 1997).

Singh *et al.* (1999) reported that papaya plants of closer spacings (1.5 x 1.5 m, 2.0 x 1.5 m) were observed to be taller than the widely spaced (3.0 x 2.5 m, 2.5 x 2.5 m and 2.0 x 2.0 m) plants and it was found to be significantly superior to rest of the treatments. Maximum plant height of 242 cm was recorded in 1.5 x 1.5 m spacings followed by 2.0 x 1.5 m and minimum in 3.0 x 2.5 m. Maximum increase in plant girth was in 3.0 x 2.5 m spacing and minimum in 1.5 x 1.5 m.

According to Shukla *et al.* (2001) papaya variety Pusa Delicious attained maximum height under the spacing 1.25 x 1.25 m whereas girth was maximum under 2.0 x 2.0 m.

According to Kawarkhe *et al.* (2002) maximum plant height and leaves per plant of papaya was observed in closer spacing of 1.8 x 1.8 m while minimum plant height and leaves per plant was recorded in wider spacing (2.5 x 2.5 m). The basal girth and spread of papaya were maximum under 2.5 x 2.5 m and minimum under the closer spacing of 1.8 x 1.8 m.

Ravitchandirane *et al.* (2002) observed lesser stem girth under closer spacing of 1.8 x 1.8 m in papaya. Among the spacing treatments, 2.4 x 2.4 m followed by 2.1 x 2.1 m registered the maximum number of leaves. The closer spacing resulted in reduced number of leaves. The widest spacing of 2.4 x 2.4 m resulted in the plants with the lowest first flower height, while the closest spacing of 1.8 x 1.8 m increased the first flowering as well as first bearing height. Double row system can also be used if needed, providing a spacing of 1.8 m between rows and 3.0 – 3.5 m between paired row to ease farm operations (Soorianathasundaram, 2002).

2.2 PHYSIOLOGICAL CHARACTERS

There are no literature available on the effect of spacing on physiological characters of papaya. The results obtained in other fruit crops in similar lines are presented below.

Reddy (1982) in an experiment with 'Robusta' banana found that biomass production per plant increased with increase in planting distance. He recorded the maximum biomass production per plant at the spacing of 2.1 x 2.1 m (24.74 kg dry weight) and minimum at the spacing 1.2 x 1.2 m (22.083 kg dry weight). Stover (1984) reported that in "Valery" bananas the leaf area index increased as the plant density increased. Anil (1994) reported that the biomass accumulation in tissue culture banana cv. Nendran was higher at wider spacings compared to closer ones.

Nalina *et al.* (2000) observed that in banana cv. Robusta, leaf area index (LAI) is an ideal factor to determine the effect of planting density in banana and that high density planting always resulted in more LAI. Athani and Hulmani (2001) reported that in banana cv. Rajapuri significantly high leaf area was observed in control plants (2.4 x 2.4 m) and minimum in 1.0 x 1.2 m spacing.

2.3 YIELD CHARACTERS

In papaya variety CO-2, the fruit set was higher at wide spacing (Rajasekaran, 1975). Papaya grown in Brazil at a spacing of 3.0 m between the rows and 2.5, 2, 1.5 and 1.0 m within the rows respectively yielded highest at the closest spacing (De Carvalho *et al.*, 1976). Coloncovas (1977) reported that increased height of papaya plants increased the yield. The larger height of papaya varieties PR 6-65 and PR 7-65 at 1.8 x 1.8 m spacing was also reflected in the increase in fruit yield (Perez and Vargas, 1977).

Agnilar *et al.* (1980) did not find any decrease in papaya yield with increasing the plant population upto 1666 plants ha^{-1}. Purohit (1980) revealed that height and girth of papaya seedlings at transplanting were poorly correlated with yield whereas height and girth six months after transplanting were positively and highly correlated with yield.

According to Camejo and Alvarez (1983) yield per plant decreased form 40.8 to 22.1 kg as planting density of papaya was increased from 1250 to 2500 plants ha^{-1}. Yield ha^{-1} were the highest at the intermediate planting density (2500 plants ha^{-1}) and were the lowest at the lowest planting density (1250 plants ha^{-1}). Planting density had no effect on fruit weight. Kulasekaran *et al.* (1983) reported that papaya varieties Co-3 and Co-4 planted at a spacing of 1.8 x 1.8 m yielded upto 150 t ha^{-1} and 200 t ha^{-1}.

Arango *et al.* (1986) observed that yields were the highest with papaya trees planted 2 m apart in rows. Kohli *et al.* (1986) reported that optimum spacing for papaya variety Coorg Honey Dew is 1.33 x 1.33 m and yield per tree and per hectare at this spacing were 28.59 kg and 1630.76 q respectively. Olalde *et al.* (1986) reported that yields were highest (27-28 t ha^{-1}) in trees planted at 2 x 2 m (2500 plants ha^{-1}).

According to Biswas *et al.* (1989) increasing the planting density of papaya cultivar Ranchi delayed flowering, reduced the number of fruits $plant^{-1}$, average fruit weigh and fruit yield $plant^{-1}$. However yield ha^{-1}. increased with increasing plant density, with the highest yield being obtained at the 1.85 x 1.85 m spacing. Pulp thickness increased with decreasing plant density. Kumar *et al.* (1989) tabulated the effects of spacing, cultivar and their interactions on plant characteristics and fruit yield in papaya. The results showed that a spacing of 1.5 x 1.5 m with 4444 plants ha^{-1} gave the highest yields.

The papaya varieties 'Pusa Delicious' followed by CO-2 recorded the highest yield at a spacing of 1.4 x 1.4 m (5, 102 plants ha^{-1}) (ICAR, 1990). According to Ghanta *et al.* (1994), widely spaced papaya plants produced more number of fruits per plant as compared to closely spaced plants. The total yield per plant (33.5 kg plant^{-1}) was also higher at wider spacing (1600 plants ha^{-1}). However, the highest per hectare yield (98.73 t ha^{-1}) was recorded with maximum plant population (4444 plants ha^{-1}). Individual fruit weight, fruit size and pulp thickness were reduced at higher plant population. The average number of seeds per fruit increased with the increase in plant population.

Kist and Manica (1995) reported that the seedlings of papaya cv. Tainung-2 planted at six spacings namely 1.8 x 2.0, 2.0 x 2.0 m, 2.2 x 2.0 m, 2.4 x 2.0 m, 2.6 x 2.0 m, 2.8 x 2.0 produced highest yield at 2.0 x 2.0 m (14.74 kg plant^{-1} and 36.02 t ha^{-1}) followed by 2.2 x 2.0 m (17.02 kg plant^{-1} and 38.18 t ha^{-1}) and 2.4 x 2.0 m (17.29 kg plant^{-1} and 36.38 t ha^{-1}). Reddy (1995) observed that in papaya cv. Coorg Honeydew the number of fruits per hectare and fruit yield per hectare increased with density.

Auxcilia and Sathiamoorthy (1996) reported that the fruit weight, flesh thickness, number and weight of seeds influenced the fruit yield in papaya. Ghosh (1996) recorded fruit yield of 98.7 t ha^{-1} under a spacing of 1.5 x 1.5 m with papaya variety Ranchi. In papaya variety CO-6 a spacing If 1.6 x 1.6 m was found to give higher papain yield (ICAR, 1996).

For papaya cv. Maradol Roja, fruit yields were highest at a staggered spacing of 4.0 m x 2.0 m (155.4 t ha^{-1}) or 3.0 m x 1.5 m (145.7 t ha^{-1}). The former spacing was recommended since a 4.0 m space facilitates easiness in cultivation and harvesting (Arce *et al.*, 1997).

According to Singh *et al.* (1999) yield per plant of papaya either in number or in weight is higher with widely spaced plant (3 x 2.5 m) which produced 17 fruit weighing 24 kg per plant than the closely spaced (1.5 x 1.5 m) plants. On the other hand, the medium spacing was considered to be the best for producing highest yield per hectare. The spacing (2.0 x 2.0 m) has produced highest yield (382.8 kg ha^{-1}) which has given 32.91 per cent more yield than widely spaced plant (3.0 x 2.5 m) which has yielded

288 kg ha^{-1}. The minimum yield (280 kg ha^{-1}) however was noted in 2.5 x 2.5 m spaced plants followed by 3 x 2.5 m.

Kumar *et al.* (2000) recorded that the widest spacing of 2.1 x 2.1 m produced highest yield of papaya (170.36 and 99.77 kg ha^{-1}). Shukla *et al.* (2001) reported maximum fruit yield with spacing 2.0 x 2.0 m in papaya. According to Kawarkhe *et al.* (2002) in papaya variety Co-2 average fruit weight was increased with decrease in plant population. Significantly heavier fruits was obtained under wider spacing (1.08 kg) of 2.5 x 2.5 m as compared to closer spacing. Significantly higher number of fruits (74.4 per plant) were harvested from plants spaced at 2 x 2 m than other planting distance. Although the yield per plant was increased under wider spacing; decrease in spacing increased the fruit yield ha^{-1}. The maximum fruit yield ha^{-1} (158.29 t) was obtained under the spacing of 2 x 2 m

Ravitchandirane *et al.* (2002) observed that the widest spacing of 2.4 x 2.4 m registered the maximum fruit yield per plant (199.57 kg) compared to the closest spacing of 1.8 x 1.8 m for papaya cv. CO-2. Increase in the fruit yield per plant with lesser plant density was observed in papaya. Also, the widest spacing recorded the maximum fruit weight than the closest spacing. Rodriguez-Pastor (2002) concluded that the highest density 2.5 x 1.5 m of papaya cv. Baixinho de Santa Amalia gave the best performance and fruit yield and lowest percentage of rejected fruit.

2.4 QUALITY CHARACTERS

Arango *et al.* (1986) reported that for papaya, planting distance had no effect on the fruit quality. Biswas *et al.* (1989) observed that TSS and total sugar content of papaya fruits increased with decreasing planting density.

According to Singh *et al.* (1999) the papaya fruits from different space treatments showed no significant variation in pulp, peel, TSS, total sugar and vitamin C content. Kumar *et al.* (2000) also reported that different spacing had little or no significant effects on quality parameters of papaya.

2.5 INCIDENCE OF PESTS AND DISEASES

Willers and Neething (1994) reported that spiral nematodes (mainly *Helicotylenchus dihystera*) were found associated with papaya orchards of high density.

2.6 ECONOMICS OF CULTIVATION

Reddy (1995) reported that for papaya cv. Coorg Honey Dew, net profit was higher (Rs. 77,520 ha^{-1}) at 4444 plants ha^{-1}. Cost : benefit ratio was highest (2.44) at the lowest density.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present investigation on "High density planting in papaya (*Carica papaya* L.)" was conducted at the Department of Pomology and Floriculture, College of Agriculture, Vellayani, Thiruvananthapuram during 2003-2004. The site of the experiment is situated at 8° 5' North latitude 77° 1' East longitude and at an altitude of 29 m above the mean sea level. Soil of the experimental site is red loam belonging to Vellayani series, texturally classified as sand clay loam.

Two months old seedlings of papaya var. CO-7 were planted in November 2003. The plants were maintained as per the Package of Practices Recommendations of Kerala Agricultural University for papaya except in spacing (KAU, 2002).

The experimental design adopted was Randomised Block Design (RBD) with five spacings as treatments, including the present recommended spacing of 2 x 2 m, each with four replications. Minor variation in plot sizes were made to accommodate all spacing treatments. Each replication consisted of four experimental plants from which observations were recorded. Two additional plants were maintained for destructive sampling. The details of various treatments imposed are furnished below.

Table 1. Details of various treatments imposed

Treatments	Spacing	Number of plants / ha	Plot size	Number of experimental plants / plot
T_1	2.25 x 2.25 m	1975	4 x 4 m	4
T_2	2.0 x 2.0 m	2500	4 x 4 m	4
T_3	1.75 x 1.75 m	3265	4 x 4 m	9
T_4	1.50 x 1.50 m	4444	4 x 4 m	9
T_5	1.25 x 1.25 m	6400	4 x 4 m	16

The following observations were recorded to evaluate the performance of the treatment plants under varying spacings.

3.1 BIOMETRIC OBSERVATIONS

3.1.1 Plant Height and Girth

Height of plant (cm) was recorded from the soil level to the tip of the growing plant. Observations were started five months after field planting and continued at two months interval. Then the average were worked out.

Girth of plant (cm) was recorded at 10 cm above the ground level at two months interval and expressed in centimetre.

3.1.2 Number of Leaves per Plant

Number of fully opened leaves per plant was recorded at two months interval from all the observational plants.

3.1.3 Time for First Flowering (days)

Time taken for flowering was recorded from the date of transplanting till the opening of first flower and expressed in days.

3.1.4 Height at which First Flower Appears

Height at which first flower appeared (cm) was measured from the soil level.

3.1.5 Time for Harvest (days)

Time taken for harvest was recorded as the number of days taken from transplanting to the harvest of first formed fruit in each plant.

3.1.6 Root Spread

Two plants were uprooted from each plot and the maximum root length was measured in the horizontal direction. Then taking it as the radius the area was calculated.

3.2 PHYSIOLOGICAL OBSERVATIONS

3.2.1 Leaf Area Index

The leaf area index was calculated using the following formula suggested by Watson (1952).

$$LAI = \frac{\text{Leaf area per plant}}{\text{Area occupied per plant}}$$

Leaf area was measured using leaf area metre.

3.2.2 Biomass Partitioning

The uprooted plant immediately after harvest was separated into shoot, root and leaves and their weights were recorded. Fruit was also weighed. These weights were added together to get total weight. Out of the samples, 500 g of each part was dried in hot air oven and dry weight was calculated. Biomass per hectare was calculated by multiplying biomass of individual plant with total plants ha^{-1}.

3.2.3 Root : Shoot Ratio

The fresh weight of both shoot and root was taken and the ratio was calculated.

3.3 YIELD CHARACTERS

3.3.1 Number of Fruits per Plant

The total number of fruits was counted from each plant and the average worked out.

3.3.2 Number of Marketable Fruits per Plant

The total number of fruits without any deformation and marketable size was counted from each plant and the average was calculated.

3.3.3 Fruit Weight

Four fruits were taken from each observational plant and the average fruit weight was worked out and expressed in grams.

3.3.4 Fruit Length and Girth

Length of fruit was measured from stalk end to the floral end of the selected fruits separately and mean length was recorded in centimetres. Girth at the middle of the fruit was measured and the average was recorded in centimetres.

3.3.5 Fruit Volume

A container filled with water was taken and placed inside another container. The selected fruits were taken individually and immersed completely. The volume of water displaced by the fruit was measured with the help of a measuring cylinder and the value was expressed in cubic centimeters.

3.3.6 Volume of Fruit Cavity

The selected fruits were cut longitudinally and seeds were removed. Then the cavity was filled with water. The volume of water contained in the fruit cavity was measured with the help of measuring cylinder and the value was expressed in cubic centimeters.

3.3.7 Seed Content

From each observational plants four fruits were taken and seeds of these fruits were weighed and the average seed weight was expressed in grams.

3.3.8 Pulp Percentage

Weight of fruit was recorded before and after peeling and removing seeds and pulp percentage was calculated by the following formula:

$$\text{Pulp percentage} = \frac{\text{Weight of pulp (g)}}{\text{Weight of fruit (g)}} \times 100$$

3.3.9 Total Yield per Plant

Weight of total number of fruits obtained from each plant was recorded and expressed in kilogram per plant.

3.3.10 Total Yield per Hectare

Total yield per plant was multiplied with total number of plants in one hectare.

3.4 QUALITY CHARACTERS

3.4.1 Total Soluble Solids (TSS)

Total soluble solids of the pulp was measured using Erma hand refractometer (pocket type) and expressed in percentage.

3.4.2 Acidity

Titrable acidity of the fruit was estimated following the method proposed by Ranganna (1977) and expressed as per cent anhydrous citric acid.

3.4.3 Total Carotenoids

The estimation of total carotenoids was done as per the method described by Jensen (1978) and expressed in percentage.

3.4.4 Ascorbic Acid

Estimation of ascorbic acid was done as per the method described by Sadasivam and Manikam (1992) and expressed as mg per 100 gram of pulp.

3.4.5 Total Sugars

The total sugars on fresh weight basis was estimated as per the method described by Ranganna (1977) and expressed in percentage.

3.4.6 Reducing Sugar

The estimation of reducing sugars was done as per the method described by Ranganna (1977) and expressed in percentage on fresh weight basis.

3.4.7 Non-reducing Sugar

The non-reducing sugar content was obtained by deducting the value for reducing sugars from the value of total sugars (Ranganna, 1977).

3.4.8 Firmness of Pulp

Firmness of fully ripe fruit was assessed with the help of a panel of judges for organoleptic evaluation. Fully ripe fruits were utilized for the evaluation.

3.4.9 Organoleptic Qualities

The panel members for sensory analysis at the laboratory level were selected from a group of teachers and students. Ten judges were selected through triangle test as suggested by Mahony (1985).

The sensory analysis of panel members were done using the scoring method and scoring was done as suggested by Swaminathan (1974). The major quality attributes included in the score were appearance, colour, texture, flavour and taste. Scores of overall acceptability was obtained by determining the average mean scores for each character.

3.4.10 Shelf-life at Ambient Condition

Days for which papaya fruit remains without decaying and retaining edible qualities at normal atmosphere conditions was recorded and average was worked out.

3.5 INCIDENCE OF PESTS AND DISEASES

The plants were observed for incidence of pests and diseases at monthly intervals.

3.6 ECONOMICS OF CULTIVATION

The economics of cultivation of the crop was worked out considering all aspects of cost of cultivation and the income derived from the plant. Then the net income and benefit-cost ratio (BCR) was calculated as follows.

Net income (Rs/ha) = Gross income – Cost of cultivation

$$BCR = \frac{\text{Gross income}}{\text{Cost of cultivation}}$$

3.7 STATISTICAL ANALYSIS

The data collected on different characters were analysed by applying the technique of analysis of variance for randomised block design following Panse and Sukhatme (1967).

RESULTS

4. RESULTS

The present experiment was conducted at the Department of Pomology and Floriculture, College of Agriculture, Vellayani during 2003-2004 with an objective of studying the response of different spacing on growth, yield and quality of papaya and also to standardise the optimum spacing for papaya under Kerala conditions. The results of the study are presented below.

4.1 BIOMETRIC CHARACTERS

4.1.1 Plant Height

Plant height as influenced by different spacings at different stages of growth are presented in Table 2 and Fig. 1. The different spacings tried were found to have significant influence on the height of plants at all stages of growth.

At five months after planting, the maximum plant height was recorded in T_5 (117.88 cm) followed by T_4 (115.81 cm) and T_3 (113.63 cm) and these treatments were statistically on par. The treatment T_4 in turn was on par with T_3 and T_1 (109.94 cm). The lowest height of plants recorded in T_2 (106.81 cm) did not differ significantly from T_1 and T_3.

At seven months after planting treatment T_5 (158.75 cm) recorded the highest value for plant height which was significantly superior to all other treatments. This was followed by T_4 (137.50 cm) and T_3 (132.50 cm) which were statistically on par. The lowest value for plant height recorded in T_1 (115.51 cm) did not differ significantly from T_2 (121.13 cm).

At nine months after planting the treatment T_5 recorded significantly higher value for plant height (265.64 cm) compared to other treatments. This was followed by T_4 (209.91 cm) which was significantly superior to all other treatments except T_5. The treatments T_3 (181.01 cm)

Table 2. Effect of different spacing on height of papaya plants

Treatments	Height of plant (cm)		
	5 MAP	7 MAP	9 MAP
T_1	109.94	115.51	154.29
T_2	106.81	121.13	177.28
T_3	113.63	132.50	181.01
T_4	115.81	137.50	209.91
T_5	117.88	158.75	265.64
CD (0.05)	7.26	7.85	4.67

MAP – Months after planting

Table 3. Effect of different spacings on the girth of papaya plants

Treatments	Girth of plant (cm)		
	5 MAP	7 MAP	9 MAP
T_1	12.97	16.55	31.33
T_2	13.81	16.06	25.31
T_3	14.34	14.76	21.94
T_4	13.81	14.25	20.01
T_5	11.97	13.08	17.94
CD (0.05)	0.69	1.39	1.18

MAP – Months after planting

and T_2(177.28 cm) which followed T_4 were statistically on par. The lowest value for plant height recorded in T_1 (154.29 cm) was significantly lower compared to all the treatments.

The results thus indicated that in all stages of growth, closer spacing increased the height of plants. In general, in the spacing upto T_3 level (1.75 x 1.75 m), the plant height was reasonable while in further closer spacings the plants grow taller.

4.1.2 Plant Girth

The results of the study are presented in Table 3 and Fig. 1. The spacing was found to have significant influence on plant girth. The highest plant girth five months after planting was recorded in T_3 (14.34 cm) followed by T_2 (13.81 cm) and T_4 (13.81 cm). All the three treatments were statistically on par. The lowest plant girth was recorded in T_5 (11.97 cm) followed by T_1 (12.97 cm) which was found to differ significantly from T_5.

The plant girth was the highest in T_1 (16.55 cm) followed by T_2 (16.06 cm) seven months after planting; both the treatments being statistically on par. However T_2 was found to be statistically on par with T_3 (14.76 cm). The lowest value for plant girth was observed for T_5 (13.08 cm) followed by T_4 (14.25 cm) both being statistically on par. Treatments T_4 and T_3 were found to be statistically on par.

Observations recorded nine months after planting showed the highest plant girth in T_1 (31.33 cm) followed by T_2 (25.31 cm) and T_3 (21.94 cm). The lowest value for plant girth was observed in T_5 (17.94 cm) followed by T_4 (20.01 cm). All the treatments differed significantly from one another.

The results indicated that in the early stages of growth upto seven months, closer spacing upto 1.75 x 1.75 m can produce reasonably good plant girth. In the later stages of growth wider spacing increased the plant girth significantly upto 2 x 2 m. Still closer spacings had a negative influence on the girth of plants.

4.1.3 Number of Leaves per Plant

Number of leaves as influenced by different spacings at different stages of growth are presented in the Table 4 and Fig. 1. Spacing had significant influence on number of leaves at all stages of plant growth.

At five months after planting the highest number of leaves was observed in T_3 (21.56) followed by T_4 (19.69), T_2 (19.58) and T_1 (18.81); all the four treatments being statistically on par. The lowest number of leaves was recorded in T_5 (14.88) which was found to differ significantly from the other treatments.

Observations taken seven months after planting showed highest number of leaves in T_3 (22.50) followed by T_4 (20.21), T_2 (20.00) and T_1 (19.25). All these treatments were found to be statistically on par; whereas T_5 having the lowest mean value (16.58) differed significantly from the above treatments.

At nine months after planting the highest number of leaves was in T_1 (28.64) which differed significantly from T_2 (23.64). The lowest number of leaves was observed in T_5 (17.13) which differed significantly from T_4 (22.15). However T_2, T_3 (23.25) and T_4 are statistically on par.

From the results it can be concluded that in general, there was reduction in the number of leaves produced with decrease in spacing. Considering the number of leaves produced during the different stages of growth, a spacing upto T_4 level (1.5 x 1.5 m) did not have very harmful effects. In still closer spacing of 1.25 x 1.25 m there was significant reduction in leaf production.

4.1.4 Time for First Flowering

Data on the influence of different spacings on the duration for the first flowering are presented in Table 5 Fig. 2. Different spacings tried

Table 4. Effect of different spacings on the number of leaves produced in papaya plants

Treatments	Number of leaves per plant		
	5 MAP	7 MAP	9 MAP
T_1	18.81	19.25	28.64
T_2	19.58	20.00	23.64
T_3	21.56	22.50	23.25
T_4	19.69	20.21	22.15
T_5	14.88	16.58	17.13
CD (0.05)	3.34	3.69	3.86

MAP – Months after planting

Table 5. Effect of different spacings on the time taken for flowering in papaya

Treatments	Time taken for first flowering (days)
T_1	122.55
T_2	125.69
T_3	153.34
T_4	155.75
T_5	182.81
CD (0.05)	7.17

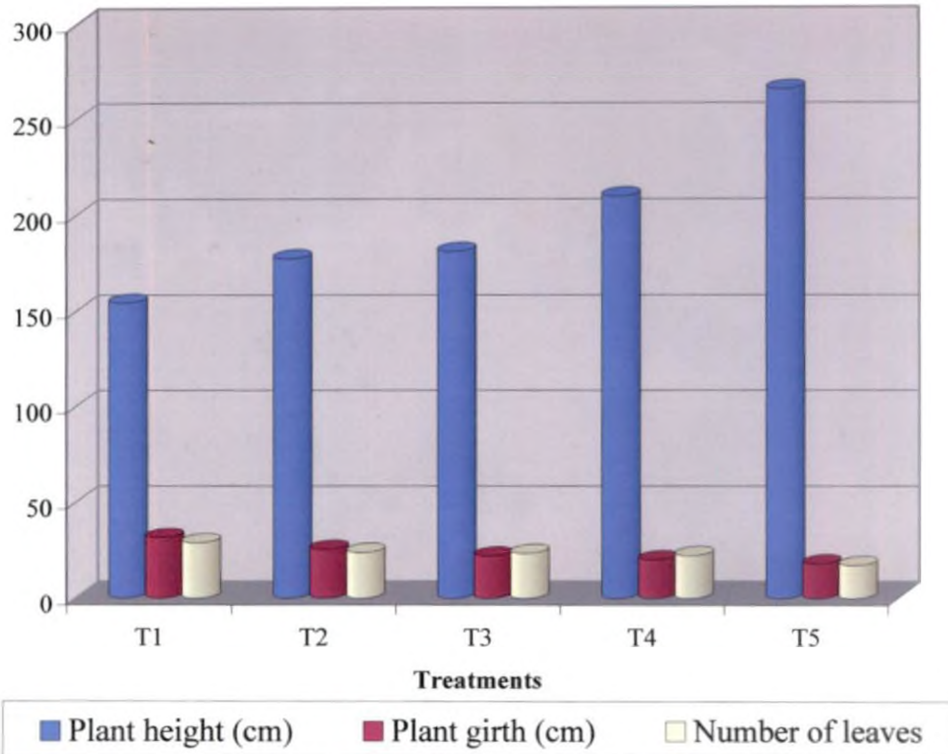

Fig. 1. Effect of different spacings on plant height, girth and number of leaves of papaya

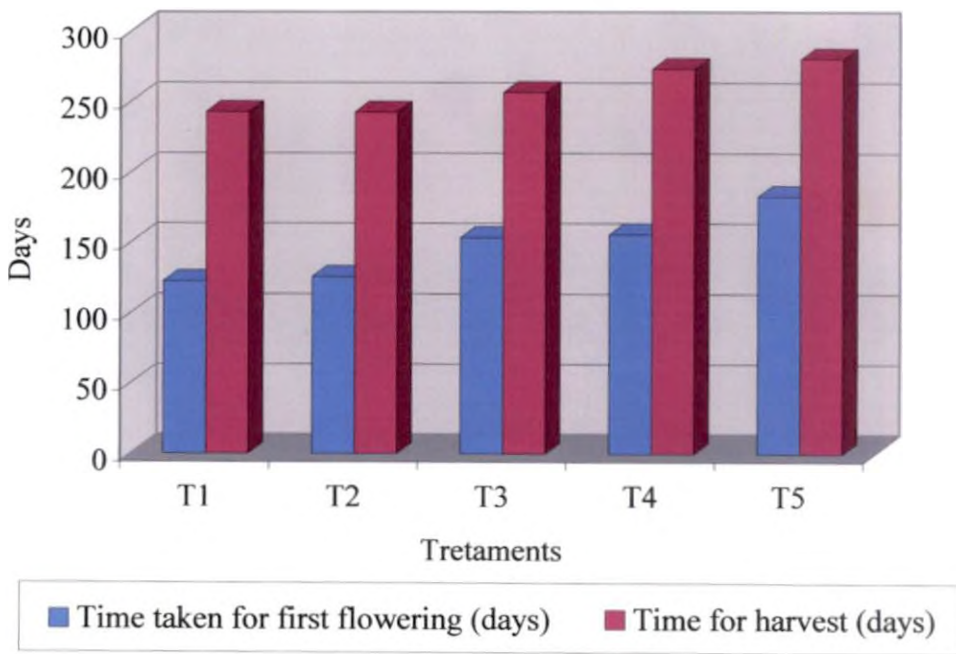

Fig. 2. Effect of different spacings on time for first flowering and time for harvest in papaya

were found to significantly influence the time taken for first flowering in the papaya plants.

The lowest time for first flowering was observed for T_1 (122.55 days) followed by T_2 (125.69 days). Both the above treatments were statistically on par. The highest value was recorded in T_5 (182.81 days) which differed significantly from all other treatments. Treatments T_4 (155.75 days) and T_3 (153.34 days) which followed T_5 were on par.

The above results indicated that time taken for first flowering in papaya plants decreased with wider spacings. The lowest period for flowering was in the widest spacing of 2.25 x 2.25 m followed by 2 x 2 m. There was an increase of 28-30 days for flowering in closer spacing of 1.25 x 1.25 and 1.5 x 1.5 m.

4.1.5 Height of First Flowering

Data on the height at first flowering as influenced by different spacings are presented in the Table 6. The lowest height at which flowering occurred was observed in T_1 (85.88 cm) followed by T_2 (92.00 cm) and both these treatments were statistically on par. This was followed by T_3 (95.44 cm) which was on par with T_2. Maximum height was recorded for T_5 (124.35 cm) followed by T_4 (107.44 cm) and T_3 (95.44 cm). These three treatments were found to differ significantly from the other treatments.

The results indicated that with increase in spacing, the height at which first flower appeared decreased. Upto T_3 level (1.75 x 1.75 cm) the plants could be considered to be flowering at lower levels.

4.1.6 Time for Harvest

Time for harvest as influenced by different spacings are presented in the Table 7 and Fig. 2. Different levels of spacings had significant influence on time for harvest. The lowest time for harvest was recorded in T_2 (242.50 days) followed by T_1 (242.56 days): both being statistically on par.

Table 6. Effect of spacings on height of first flowering

Treatments	Height of first flowering (cm)
T_1	85.88
T_2	92.00
T_3	95.44
T_4	107.44
T_5	124.35
CD (0.05)	9.28

Table 7. Effect of different spacings on time for harvest from transplanting

Treatments	Time for harvest (days)
T_1	242.56
T_2	242.50
T_3	256.75
T_4	273.31
T_5	280.38
CD (0.05)	7.05

This was followed by T_3 (256.75 days) which differed significantly from other treatments. Treatments T_5 (280.38 days) recorded the highest period for harvest followed by T_4 (273.31 days). These two treatments differed significantly from one another and all other treatments.

The results indicated that the time taken for harvest decreased in wider spacings. Upto T_2 level (2 x 2 m) there was marked reduction in the time for harvest of fruits.

4.1.7 Root Spread

The data on root spread influenced by different spacings are presented in Table 8. The root spread was found to be significantly influenced by different treatments. The maximum root spread was observed in T_1 (4.19 m^2) followed by T_2 (3.65 m^2); both the treatments being on par and significantly superior to others. The lowest value was seen with T_5 (1.21 m^2) followed by T_4 (1.39 m^2); both the treatments being statistically on par. The treatment T_4 was found to be statistically on par with T_3 (2.15 m^2).

The data revealed that as the plant population increased the root spread decreased. Spacing treatments T_1 (2.25 x 2.25 m) and T_2 (2 x 2 m) had better root spread compared to other treatments.

4.2 PHYSIOLOGICAL OBSERVATIONS

4.2.1 Leaf Area Index

Data on the leaf area index during different growth stages are presented in the Table 9.

The data revealed that leaf area index (LAI) was influenced by the treatments in all the stages. During the fifth month after planting, the treatment T_3 which recorded a LAI value of 1.14 was significantly superior to all other treatments. This was followed by T_4 (0.92), T_5 (0.85) and T_2 (0.81). These three treatments were statistically on par.

Table 8. Effect of spacings on root spread of papaya

Treatments	Root spread (m^2)
T_1	4.19
T_2	3.65
T_3	2.15
T_4	1.39
T_5	1.21
CD (0.05)	0.82

Table 9. Effect of spacings on leaf area index of papaya

Treatments	Leaf area index		
	5 MAP	7 MAP	9 MAP
T_1	0.63	0.65	0.96
T_2	0.81	0.84	0.98
T_3	1.41	1.88	1.23
T_4	0.92	0.94	1.04
T_5	0.85	0.85	0.88
CD (0.05)	0.188	0.161	0.175

The lowest value recorded in T_1 (0.63) was found to be statistically on par with T_2.

During seven months after planting also the highest LAI was recorded in T_3 (1.88) which found to be significantly superior to all other treatments. This was followed by T_4 (0.94), T_5 (0.85) and T_2 (0.84). These three treatments were statistically on par. The lowest LAI was recorded for T_1 (0.65) which was significantly lower than all other treatments.

During the ninth month after planting maximum LAI was recorded for T_3 (1.23) which showed significantly superior to all other treatments. The lowest LAI was recorded in T_5 (0.88) followed by T_1 (0.96), T_2 (0.98) and T_4 (1.04); four treatments being statistically on par.

The data indicated that leaf area index in general was lower in wider spacings. Increase in plant density consequent to decrease of spacing resulted in higher leaf area index.

4.2.2 Biomass Partitioning

Data on the influence of different spacings on dry matter production and biomass partitioning are presented in Table 10.

The total dry matter production showed that the treatments influenced this character significantly. The highest dry matter production was observed in T_2 (7.08 t ha^{-1}) followed by T_3 (7.01 t ha^{-1}), T_1 (6.75 t ha^{-1}) and T_5 (6.65 t ha^{-1}); all the treatments being statistically on par. The lowest dry matter production recorded in T_4 (6.08 t ha^{-1}) was statistically on par with T_5.

The biomass partitioning between the vegetative and economic part did not show any significant difference in relation to the different spacings tried.

The data thus indicated that in general there was more dry matter production when the spacing was wider upto 1.75 x 1.75 m. However, this

Table 10. Effect of spacings on biomass partitioning in papaya

Treatments	Dry weight / ha (t ha^{-1})	Biomass partitioning (per cent)
T_1	6.75	37.06
T_2	7.08	39.52
T_3	7.02	38.85
T_4	6.08	35.59
T_5	6.65	40.71
CD (0.05)	0.659	NS

Table 11. Effect of spacings on root : shoot ratio of papaya

Treatments	Root : shoot ratio
T_1	0.036
T_2	0.029
T_3	0.039
T_4	0.062
T_5	0.095
CD (0.05)	0.0081

did not significantly influence the biomass partitioning between the vegetative and economic part.

4.2.3 Root : Shoot Ratio

Data on the influence of different spacings on root : shoot ratio are presented in Table 11. The root : shoot ratio was influenced by various treatments imposed. The highest ratio was observed in T_5 (0.095) followed by T_4 (0.062); the two treatments showing significant difference from one another and the rest of the treatments. This was followed by T_3 (0.039) which was statistically on par with T_1 (0.036). The lowest ratio recorded in T_2 (0.029) did not differ significantly from T_1.

From the data it was inferred that the root : shoot ratio increased significantly with decrease in the spacing and the consequent increase in the plant density.

4.3 YIELD CHARACTERS

4.3.1 Number of Fruits per Plant

Data on the effect of different spacings on number of fruits per plant are presented in Table 12.

Number of fruits was not significantly affected by various treatments. Though highest mean number of fruits per plant was in T_1 (14.20) followed by T_2 (12.89) and T_3 (11.88) and the lowest value in T_5 (11.31) followed by T_4 (11.38), the treatments did not differ significantly from another.

The results indicated that the different spacings tried did not influence the number of fruits produced per plant during the initial bearing period. The mean values showed that in general, more number of fruits were produced at wider spacing.

Table 12. Effect of spacings on number of fruits $plant^{-1}$ and number of marketable fruits $plant^{-1}$

Treatments	Number of fruits $plant^{-1}$	Number of marketable fruits $plant^{-1}$
T_1	14.20	12.51
T_2	12.89	11.00
T_3	11.88	10.14
T_4	11.38	9.80
T_5	11.31	10.00
CD (0.05)	NS	NS

Table 13. Effect of spacings on fruit weight, fruit length and fruit girth of papaya

Treatments	Fruit weight (g)	Fruit length (cm)	Fruit girth (cm)
T_1	1282.50	16.13	44.94
T_2	1105.00	15.38	45.19
T_3	921.25	15.06	43.31
T_4	736.25	14.38	39.44
T_5	633.75	13.63	30.31
CD (0.05)	62.52	0.913	1.41

4.3.2 Number of Marketable Fruits Plant^{-1}

Number of marketable fruits as influenced by different spacings are presented in Table 12. The highest number of marketable fruits was recorded in T_1 (12.51) followed by T_2 (11.00) and lowest value is for T_4 (9.80) followed by T_5 (10.00) and T_3 (10.14). But there was no significant difference observed among the treatments.

From the above results it can be concluded that the market acceptance of fruits was not influenced by the spacings tried during the initial bearing period.

4.3.3 Fruit Weight

Data on fruit weight, as influenced by different spacings are presented in Table 13 Fig. 3. Different spacings had significant influence on mean fruit weight. Highest fruit weight was recorded inT_1 (1282.50 g) followed by T_2 (1105.00 g) and T_3 (921.25 g). The lowest value was in T_5 (633.75 g) followed by T_4 (736.25 g). All the treatments differed significantly from one another with respect to weight of fruits.

From the above data, it can be inferred that the individual fruit weight increased markedly with wider spacings. Spacings below 1.75 x 1.75 m resulted in low weight of fruits.

4.3.4 Fruit Length

Fruit length as influenced by different spacings are presented in the Table 13. Spacing was found to have significant influence on fruit length. The highest fruit length was recorded in T_1 (16.13 cm) followed by T_2 (15.38 cm); both the treatments being statistically on par. The treatment T_3 (15.06 cm) which followed these was on par with T_2. The lowest fruit length was in T_5 (13.63 cm) followed by T_4 (14.38 cm). Both the treatments were statistically on par. The treatment T_4 was on par with T_3.

Plate 1 Papaya fruits from different spacing treatments

From the above results, it can be concluded that length of fruit increased with increase in spacing. The spacing upto T_3 (1.75 x 1.75 m) can be considered to result in good fruit length.

4.3.5 Fruit Girth

The results of the study are presented in Table 13. Difference in spacings had significant influence on fruit girth. The maximum fruit girth was recorded in T_2 (45.19 cm) followed by T_1 (44.94 cm); both the treatments being statistically on par. This was followed by T_3 (43.31 cm) which differed from all other treatments significantly. The lowest fruit girth (30.31 cm) was recorded in T_5 followed by T_4 (39.44 cm). These treatments differed significantly from one another as well as from all other treatments.

The results indicated that with increase in spacing, the girth of fruits increased. The wider spacings T_1 (2.25 x 2.25 m) and T_2 (2 x 2 m) gave maximum fruit girth followed by T_3 level (1.75 x 1.75 m).

4.3.6 Fruit Volume

The data on the influence of spacings on fruit volume are presented in Table 14 and Fig. 3. Different spacings had significantly influenced the volume of fruits.

The highest fruit volume was recorded in T_1 (1542.50 cc) followed by T_2 (1432.50 cc) and T_3 (1152.50 cc). The fruit volume was the lowest in T_5 (542.50 cc) followed by T_4 (906.25 cc). All the treatments differed significantly from one another.

The data indicate that there was significant reduction in volume of fruits with decrease in spacing. Spacing below T_3 (1.75 x 1.75 m) showed marked reduction of fruit volume.

Table 14. Effect of different spacings on fruit volume of papaya

Treatments	Fruit volume (cc)
T_1	1542.50
T_2	1432.50
T_3	1152.50
T_4	906.25
T_5	542.50
CD (0.05)	27.33

Table 15. Effect of spacings on volume of fruit cavity

Treatments	Cavity volume (cc)	Cavity index
T_1	323.81	476.82
T_2	311.50	459.92
T_3	232.50	496.86
T_4	131.81	688.62
T_5	70.81	766.23
CD (0.05)	10.33	34.89

4.3.7 Volume of Fruit Cavity

The data on the influence of spacings on cavity index are presented in the Table 15. The highest value on cavity index was observed in T_5 (766.23) followed by T_4 (688.62) and T_3 (496.86); all the three treatments being statistically different. The lowest value for cavity index was noted in T_2 (459.92) followed by T_1 (476.82); both being statistically on par. The treatments T_1 and T_3 were also found to be statistically on par.

The data showed that the cavity index decreased with decrease in spacing. It indicates that the cavity volume per unit volume of fruit decreased with decrease in spacing.

4.3.8 Seed Content

Effect of different spacings observed on seed content are presented in Table 16. Seed content of fruit was significantly influenced by different treatments. The highest seed content was recorded in T_1 (14.19 g) followed by T_2 (41.87 g). Both the treatments were statistically on par. This was followed by T_3 (40.38 g) which was on par with T_2. The lowest seed content was recorded in T_5 (13.30 g) followed by T_4 (18.25 g). These two treatments differed from one another and from other treatments significantly.

The observations revealed that as the plant population increased, the seed content decreased in the fruits. Upto T_3 level (1.75 x 1.75 m) the seed content was high.

4.3.9 Pulp Percentage

The data on pulp percentage under the influence of different spacings are given in Table 16.

The data revealed that the pulp percentage was highest in T_5 (89.99 per cent) followed by T_4 (85.29 per cent). These treatments differed significantly from one another and from all other treatments. The treatment T_2 (83.17 per cent) which followed did not differ significantly

Table 16. Effect of spacings on seed content and pulp percentage of papaya fruits

Treatments	Seed content (g)	Pulp percentage
T_1	44.19	80.97
T_2	41.87	83.17
T_3	40.38	82.43
T_4	18.25	85.29
T_5	13.30	89.99
CD (0.05)	3.08	1.01

Table 17 Effect of spacings on yield per plant and yield hectare^{-1} of papaya

Treatments	Yield plant^{-1} (kg)	Yield hectare^{-1} (t)
T_1	17.94	31.22
T_2	14.02	35.19
T_3	10.89	34.13
T_4	8.14	36.09
T_5	7.14	45.40
CD (0.05)	2.66	8.88

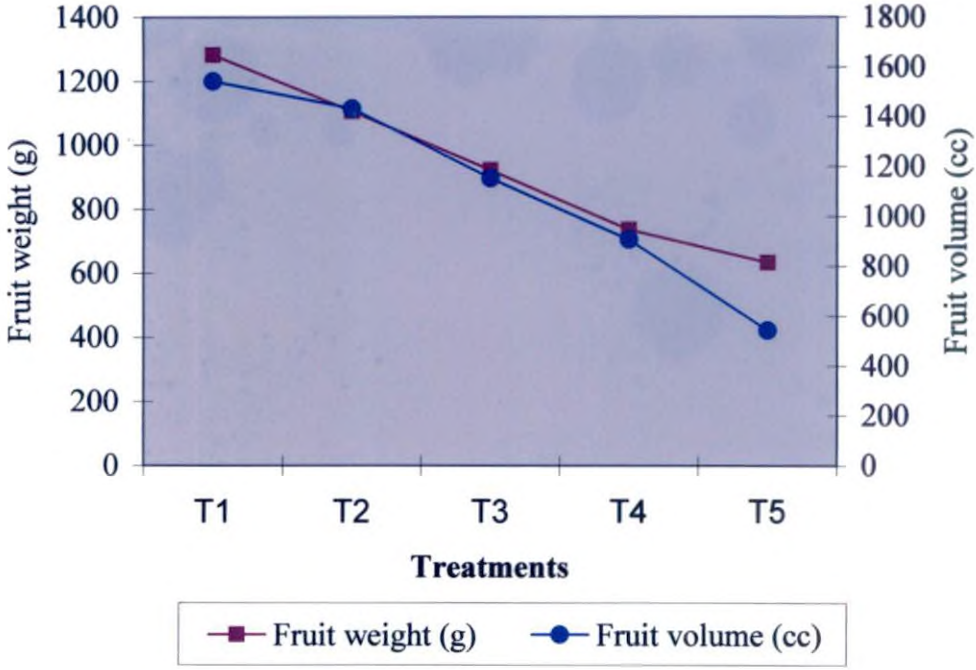

Fig. 3. Effect of different spacings on fruit weight and fruit volume of papaya

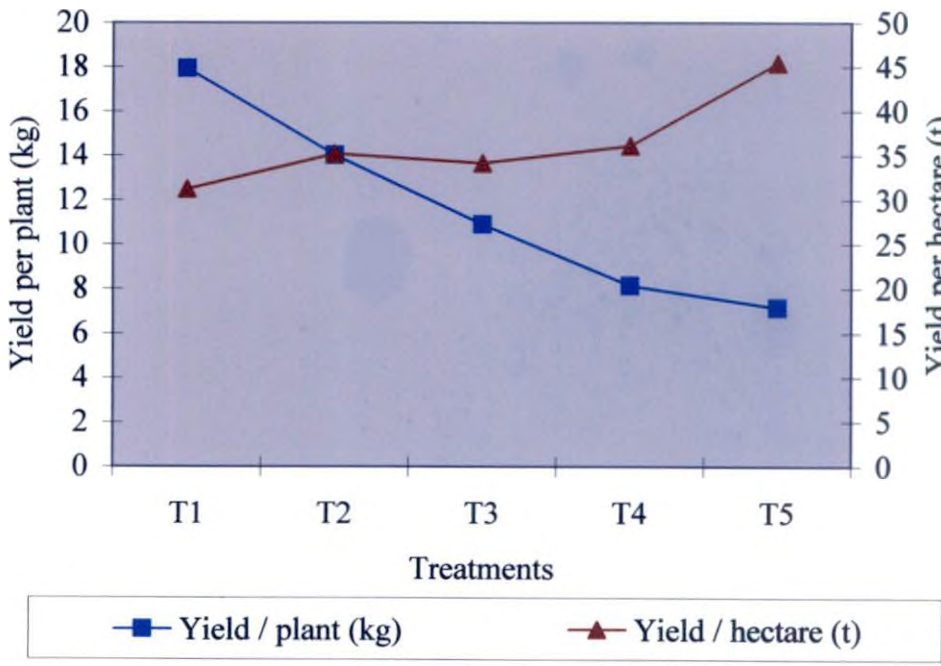

Fig. 4. Effect of different spacings on yield of papaya

form T_3 (82.43 per cent). The lowest pulp percentage was recorded in T_1 (80.97 per cent) which differed significantly from all other treatments.

The results indicated that there was increase in the pulp percentage with decrease in spacing. Pulp percentage was high the closer spacings upto T_4 (1.5 x 1.5 m spacing). Spacing levels T_2 (2 x 2 m) and T_3 (1.75 x 1.75 m) gave reasonable good pulp percentage.

4.3.10 Yield Plant^{-1}

The data on the influence of spacings on yield per plant are presented in Table 17 and Fig. 4. The mean yield per plant was influenced by the different spacings tried. The highest yield was recorded in T_1 (17.94 kg) followed by T_2 (14.02 kg) and T_3 (10.89 kg). These three treatments were significantly different and superior to other treatments. The yield was lowest in T_5 (7.14 kg) followed by T_4 (8.14 kg) and these two treatments did not show significant difference between them.

The data indicated that the yield per plant decreased significantly with decrease in spacing. There was no significant reduction in per plant yield in the spacing below 2 x 2 m.

4.3.11 Yield per Hectare

The effect of spacing on per hectare yield are given in Table 17 and Fig. 4. The data revealed that the character was influenced by the treatments imposed. The highest yield per hectare recorded in T_5 (45.4 t) was significantly superior to all other treatments. This was followed by T_4 (36.09 t), T_2 (35.19 t), T_3 (34.13 t) and T_1 (31.22 t). The latter four treatments were significantly on par.

The results indicated that the total yield per hectare increased significantly as the spacing decreased. The data also revealed that there was no significant reduction in yield per hectare between the wider spacings. However, the difference yield between T_4 and T_1 was 4.87 t ha^{-1} while between T_3 and T_1 was 2.91 t ha^{-1} and between T_2 and T_1 was 3.97 t ha^{-1}.

4.4 QUALITY CHARACTERS

The effect of different spacings observed on quality of papaya fruits are presented in Table 18, Table 19 and Fig. 5.

The TSS content of fruit was influenced by the treatments. The highest TSS (10.72 per cent) was observed in T_1 followed by T_2 (10.60 per cent) and these two treatments were statistically on par, but significantly superior to others. This was followed by T_3 (8.89 per cent). The lowest TSS values were observed in T_5 (7.34 per cent) followed by T_4 (7.88 per cent) and these three treatments differed significantly from one another.

Acidity of fruits was also affected by the treatments. The acidity was lowest in T_1 (0.157 per cent) followed by T_2 (0.169 per cent), T_3 (0.191 per cent), T_4 (0.255 per cent) and T_5 (0.267 per cent). All these treatments differed significantly from one another.

The data revealed that the treatments did not significantly influence the total carotenoids. However, the mean value showed that the total carotenoids was the highest in T_1 (2.53 mg/100 g) followed by T_2 (2.52 mg/100 g), T_3 (2.48 mg/100 g), T_4 (2.44 mg/100 g) and T_5 (2.42 mg/100 g); indicating that the total carotenoids of fruits increased with increase in spacing.

The ascorbic acid content of the fruits showed significant variation between treatments. The highest ascorbic acid content was observed in T_5 (46.09 mg/100 g) followed by T_4 (45.19 mg/100 g); both the treatments being statistically on par. The treatment T_3 (40.57 mg/100 g) followed the above two treatments. The lowest levels of ascorbic acid was noted in T_1 (38.51 mg/100 g) followed by T_2 (38.93 mg/100 g). The treatments T_1 and T_2 did not show any significant difference between them.

The total sugar content of the fruit also showed variation in different treatments. The highest total sugar content was observed in T_1 (14.46 per cent) followed by T_2 (14.16 per cent); the treatments being

Table 18. Effect of different spacings on TSS, acidity, carotenoids and ascorbic acid of papaya fruits

Treatments	TSS (%)	Acidity (%)	Total carotenoids (mg/100 g)	Ascorbic acid (mg/100g)
T_1	10.72	0.157	2.53	38.513
T_2	10.60	0.169	2.52	38.93
T_3	8.89	0.191	2.48	40.57
T_4	7.88	0.255	2.44	45.19
T_5	7.34	0.267	2.42	46.09
CD (0.05)	0.46	0.007	NS	1.22

Table 19. Effect of different spacings on sugar content and shelf-life of papaya fruits

Treatments	Total sugars (%)	Reducing sugar (%)	Non-reducing sugar (%)	Shelf-life (days)
T_1	14.46	11.91	2.48	5.31
T_2	14.16	11.75	2.42	5.18
T_3	13.20	10.87	2.29	5.06
T_4	12.21	10.38	2.13	4.75
T_5	11.58	9.61	2.04	4.50
CD (0.05)	0.48	0.55	0.15	0.435

statistically on par and significantly superior to other treatments. These treatments were followed by T_3 (13.2 per cent), T_4 (12.21 per cent) and T_5 (11.58 per cent). The three treatments differed significantly from one another.

The reducing sugar content of fruits was the highest in T_1 (11.91 per cent) followed by T_2 (11.75 per cent) and these two treatments were statistically on par. Treatment T_4 (10.38 per cent) and T_3 (10.87 per cent) which followed these treatments were statistically on par. The lowest reducing sugar content was observed in T_5 (9.61 per cent) which was significantly lower than the other treatments.

The non-reducing sugar content of the fruits was the highest in T_1 (2.48 per cent) followed by T_2 (2.42 per cent); the two treatments being statistically on par and significantly superior to others. The lowest content of non-reducing sugar was observed in T_5 (2.04 per cent) followed by T_4 (2.13 per cent) and T_3 (2.29 per cent). The treatments T_5 and T_4 were statistically on par.

The shelf life of fruits kept at room temperature also varied significantly with treatments. The highest mean value was noted in T_1 (5.31 days) followed by T_2 (5.18 days) and T_3 (5.06 days); all the three treatments were statistically on par. The lowest value was observed for T_5 (4.5 days) followed by T_4 (4.75 days); both the treatments being statistically on par. However, the treatments T_2 and T_3 were also statistically on par.

It was observed from the data that the TSS, total sugars, reducing sugars, non-reducing sugars, total carotenoids and shelf life increased with increase in spacing. The acidity and ascorbic acid content decreased with increase in spacing. In general, it was observed that the quality of fruits was superior in the wider spacings upto T_2 level (2 x 2 m). In T_3 level (1.75 x 1.75 m) the fruit quality decreased slightly and this trend continued with still closer spacings.

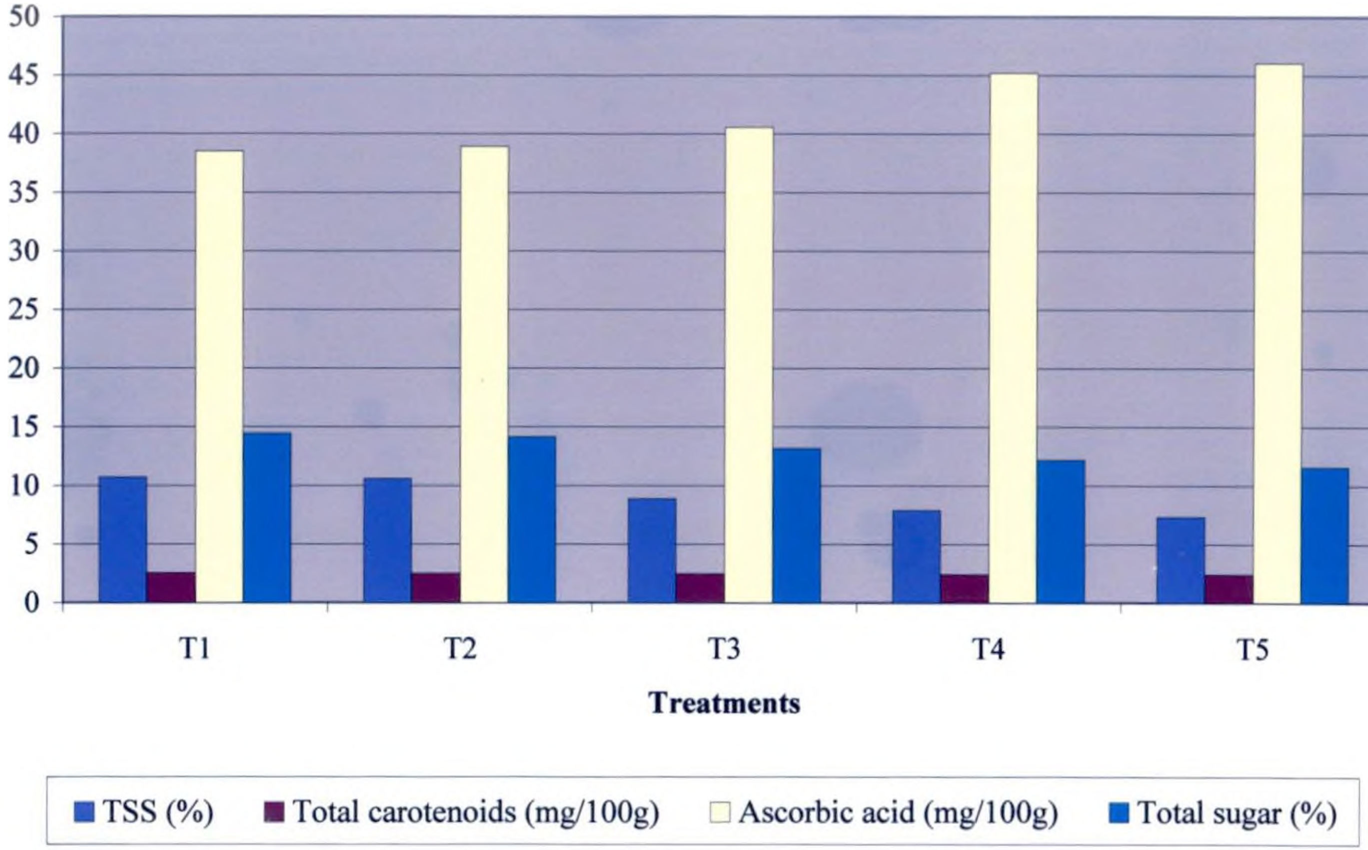

Fig. 5. Effect of different spacings on quality of papaya

Organoleptic Characters

The results of the organoleptic evaluation are presented in Tables 20 to 25 which indicates the percentage of score given by judges.

The score on appearance of fruits (Table 20) indicated that T_2 treatment was very good in the opinion of the majority of the judges (85.70 per cent) followed by T_3 (57.00 per cent) and T_1 (42.80 per cent). The treatment T_4 was considered as very good only by 14.20 per cent of the judges while T_5 was not considered very good by any of the judges.

The fruit colour (Table 21) in T_2 was most acceptable according to 85.70 per cent followed by T_3 (57.00 per cent), T_1 (42.80 per cent) and T_5 (14.20 per cent). None of the judges considered the colour as most acceptable in the case of T_4; it was considered as acceptable by all the judges.

Flavour (Table 22) of the fruit was most acceptable for T_1, T_2, T_3 and T_4 for 42.80 per cent of the judges while only 28.50 per cent considered T_5 as most acceptable. In T_1, T_2 and T_3 majority of the judges (57.00 per cent) considered the flavour as acceptable only.

Among the panel of judges, 71.40 per cent considered the taste (Table 23) of fruits in T_2 and T_3 as very good followed by T_1 (57.00 per cent). The treatments T_4 and T_5 were not very good in taste, according to them.

According the panel of judges in the case of texture (Table 24) of fruit flesh, the high quality was achieved in T_2 (85.70 per cent) followed by T_1 (71.40 per cent) and T_3 (64.30 per cent). Only 42.80 per cent of the judges considered T_4 and 28.50 per cent of the judges considered T_5 as having firm, crisp and melting pulp.

According to 85.70 per cent of judges, papain odour (Table 25) was not at all present in T_4. Treatment T_2 (78.60 per cent) and T_3 (71.40 per cent) followed this. Only 35.70 per cent judges considered T_5 as having no

Table 20 Effect of spacings on organoleptic characters (Appearance) of papaya fruits

Score	T_1	T_2	T_3	T_4	T_5
Very good – 4	42.80	85.70	57.00	14.20	-
Good – 3	57.00	14.20	42.80	42.80	28.50
Fair – 2	-	-	-	42.80	71.40
Poor – 1	-	-	-	-	-

Table 21 Effect of spacings on organoleptic characters (Colour of flesh) of papaya fruits

Score	T_1	T_2	T_3	T_4	T_5
Most acceptable – 4	42.80	85.70	57.00	-	14.20
Acceptable – 3	57.00	14.20	42.80	100.00	28.50
Fairly acceptable – 2	-	-	-	-	57.00
Not acceptable – 1	-	-	-	-	-

Table 22 Effect of spacings on organoleptic characters (Flavour) of papaya fruits

Score	T_1	T_2	T_3	T_4	T_5
Most acceptable – 4	42.80	42.80	42.80	42.80	28.50
Acceptable – 3	57.00	57.00	57.00	28.50	42.80
Fairly acceptable – 2	-	-	-	28.50	28.50
Not acceptable – 1	-	-	-	-	-

Table 23 Effect of spacings on organoleptic characters (Taste) of papaya fruits

Score	T_1	T_2	T_3	T_4	T_5
Very good – 4	57.00	71.40	71.40	-	-
Good – 3	42.80	28.50	28.50	71.40	14.20
Fair – 2	-	-	-	28.50	85.70
Poor – 1	-	-	-	-	-

Table 24 Effect of spacings on organoleptic characters (Texture) of papaya fruits

Score	T_1	T_2	T_3	T_4	T_5
Firm, crisp and melting – 4	71.40	85.70	64.30	42.80	25.80
Firm, crisp – 3	14.20	14.20	35.70	28.50	57.00
Fairly firm – 2	14.20	-	-	28.50	14.20
Too soft – 1	-	-	-	-	-

Table 25 Effect of spacings on organoleptic characters (Papain order) of papaya fruits

Score	T_1	T_2	T_3	T_4	T_5
Not at all present – 4	42.80	78.60	71.40	85.70	35.70
Very mildly present – 3	57.00	21.40	28.50	14.20	64.30
Mildly present – 2	-	-	-	-	-
Strongly present – 1	-	-	-	-	-

papain odour. However, the papain odour was very mild in T_5 and T_1 according to 64.30 per cent and 57.00 per cent the judges.

Considering the results of evaluation of organoleptic characters, it can be concluded that in all the characters considered, the treatments T_1, T_2 and T_3 were superior to T_4 and T_5. Thus, it can be concluded from the result that in wider spacing upto T_3 level (1.75 x 1.75 m), the organoleptic qualities of fruit were acceptable. In the closer spacings T_4 (1.5 x 1.5 m) and T_5 (1.25x 1.25 m), the organoleptic qualities showed reduction.

Firmness of the Pulp

The data on the effect of different spacings on the firmness of pulp is presented in Table 26.

The fruit pulp was considered very firm in T_1, T_2 and T_3 and firm in T_4 and T_5 treatments.

4.5 INCIDENCE OF PESTS AND DISEASE

No major pests of disease attack was observed during the course of the experiment. The plants were healthy and did not show any symptoms of diseases or pest attack.

4.6 ECONOMICS OF CULTIVATION

The effect of different spacings observed on the net profit and Benefit : cost ratio of papaya are presented in Table 27.

The net profit did not differ markedly among the treatments imposed. However, the mean values showed that the highest net profit (Rs. 38060) was attained in T_3 followed by T_1 (Rs. 37403) and T_2 (Rs. 34289). In the treatment T_4 only very low net profit (Rs. 367) was recorded while in T_5 only loss was observed.

The benefit : cost ratio was the highest in T_1 (1.43) which was followed by T_2 (1.42); the two treatments being on par. T_2 was in turn

Table 26. Effect of spacings on firmness of the pulp

Treatments	Firmness of the pulp
T_1	Very firm
T_2	Very firm
T_3	Very firm
T_4	Firm
T_5	Firm

Table 27 Effect of spacings on net profit and benefit : cost ratio of papaya

Treatments	Net profit per hectare	Benefit : cost
T_1	37403	1.43
T_2	34289	1.42
T_3	38060	1.15
T_4	367	1.005
T_5	-6487	0.968
CD (0.05)		0.27

on par with T_3 (1.15). The treatment T_3 did not differ significantly from T_5 (0.968) and T_4 (1.005) which recorded the lowest values of B : C ratio.

From the above observations indicate that the highest net profit was obtained with the spacing of 1.75 x 1.75 m. This treatment involves higher cost of cultivation resulting in low benefit : cost ratio compared to wider spacings.

DISCUSSION

5. DISCUSSION

Papaya is a major tropical fruit suited for both nutrition gardens and commercial orcharding. Due to year round availability of fruits, high nutritive value, reasonably high returns per unit area, easiness in management and scope for processing, this fruit has attained a place of prominence in tropical fruit orchards. Optimum spacing plays a vital role on plant growth, yield and fruit quality. Hence the present experiment was conducted with an objective of studying the response of different spacing on growth, yield and quality of papaya. Standardisation of optimum spacing for papaya under Kerala conditions is also aimed at. The results of the experiment conducted with the above objectives are discussed hereunder.

5.1 BIOMETRIC CHARACTERS

The results of the present study indicated that in all the stages of growth plant height increased with closer spacings while the girth of the plants decreased. It was observed that upto a spacing of 1.75 x 1.75 m the plants were less tall compared to further closer spacings. In similar studies Rajasekaran (1975) observed that increased spacing resulted in decreased plant height of papaya variety CO-2. Experiments conducted by Arango *et al.* (1986) also revealed the same trend. Biswas *et al.* (1989) from similar studies observed decrease in plant girth with an increase in population density. Ghanta (1994), Singh *et al.* (1999), Shukla *et al.* (2001) and Kawarkhe *et al.* (2002) also observed increase in plant height and decrease in plant girth with increase in plant populations. However, the studies of Kist and Manica (1995) and Reddy (1995) did not reveal any difference in stem diameter as well as plant length in papaya in relation to differences in spacing. According to Singh (1990) as well as Ghosh (1996) the optimum spacing vary with the varieties. Thus the results of the present study agree with the studies conducted in similar lines.

From the results of the present study it was inferred that the number of leaves produced per plant decreased with a reduction in the spacing. Considering the number of leaves produced during different growth stages, it was observed that the number of leaves was not very severely affected upto a spacing of 1.5 x 1.5 m. As the spacing decreased, root spread also decreased. The wider spacings upto 2 x 2 m had better root spread. These findings are in agreement with the studies on the effect of plant population on growth of papaya conducted by Ghanta (1994) and Ravitchandirane *et al.* (2002). In their studies also the number of leaves produced per plant was found to decrease when the plant density increased. According to Kawarkhe (2002) the number of leaves per plant and spread were maximum under wider spacings.

The time taken for the appearance of the first flower in papaya was found to decrease with increase in spacing tried in the current experiment. The height at which the first flower appeared decreased with increase in spacing upto 1.75 x 1.75 m. The present studies indicated that the time taken for harvest decreased with the wide spacings upto 2 x 2 m wherein the harvest was about two weeks earlier compared to still closer spacings. According to Rajasekaran (1975) also increase of spacing decreased the height of flowering. Arango *et al.* (1986) also observed a decrease in the height of first flowering with an increase in spacing. However, it was observed that the time for first flowering was not influenced by plant density. Biswas *et al.* (1989 also observed delay in flowering due to decrease in spacing. Ghanta (1994) also found that the time for first flowering decreased with wider spacings in papaya. Ravitchandirane *et al.* (2002) also observed a similar trend. The above results are in line with the findings from the present investigations.

5.2 PHYSIOLOGICAL CHARACTERS

The present study showed that the leaf area index in general was lower in wider spacings. With decrease in spacing, higher leaf area index was noted. Stover (1984) observed that the leaf area index increased as the plant density increased in 'Valery' bananas. Anil (1994) also observed the same trend in tissue culture banana cv. Nendran. Similar studies in banana cv. 'Robusta' by Nalina *et al.* (2000) revealed that high planting density resulted in more leaf area index.

From the results of the current experiment it was concluded that in general, there was more dry matter production when the spacing was upto 1.75 x 1.75 m However, this did not significantly influence the biomass partitioning between the vegetative and economic parts. The root: shoot ratio increased significantly with decrease in the spacing. In the present studies it was noted that growth in terms of plant height, girth and number of leaves, fruit production and fruit size was reasonably high upto this spacing. However, yield per hectare was higher in closer spacings. This might have resulted in higher biomass production in spacing upto 1.75 x 1.75 m, but little difference in biomass partitioning. Closer spacing had higher proportion of roots. Anil (1994) also observed that biomass accumulation was higher at wider spacings in tissue culture banana cv. Nendran.

5.3 YIELD CHARACTERS

Different spacings tried did not influence the number of fruits produced per plant during the initial bearing period of the present studies. The mean values showed that in general, more number of fruits were produced at wider spacing. The market acceptance of fruits was not markedly influenced by the spacings tried during the initial bearing period. This is in agreement with the studies on the effect of plant population on fruit production per plant of papaya conducted by Biswas *et al.* (1989). According to Ghanta *et al.* (1994), widely spaced papaya produced more number of fruits per plant compared to closely spaced plants. Singh *et al.* (1999) also observed that the number of fruits per plant increased with wider spacing. Rodriguez-Paster (2002) also did not find difference in the number of rejected fruits upto the level of intermediate spacing.

The individual fruit weight increased markedly with wider spacings. Spacings below 1.75 x 1.75 m resulted in low fruit weight. The length of fruit increased with increase in spacing. Spacing upto 1.75 x 1.75 m could be considered to attain good fruit length. With increase in spacing, the girth of fruits increased. The wider spacings gave maximum fruit girth followed by 1.75 x 1.75m. There was significant reduction in volume of fruits with decrease in spacing. In spacings below 1.75 x 1.75 m marked reduction of fruit volume was observed. From similar studies Biswas *et al.* (1989) also observed that increasing the planting density of reduced the average fruit weight. Ganta *et al.* (1994) observed that the fruit weight and fruit size were reduced at higher plant population. Singh *et al.* (1999) and Kawarkhe *et al.* (2002) also observed similar trend due to the influence of spacing in papaya.

With decrease in spacing the cavity index decreased which indicates that the cavity volume per unit volume of fruit decreased with decrease in spacing. The experiment revealed that as the plant population increased, the seed content decreased. There was also an increase in pulp percentage with decrease in spacing. The yield per plant decreased significantly with decrease in spacing. Camejo and Alvarez (1983) reported that yield per plant decreased as planting density of papaya was increased. Biswas *et al.* (1989) also observed that increasing the planting density of papaya reduced the yield per plant. According to Ghanta *et al.* (1994) the total yield per plant was higher at wider spacing. Singh *et al.*

(1999), Kawarkhe *et al.* (2002) and Ravitchandirane *et al.* (2002) also agree to the same result. Thus the results of the present study, thus agree with the studies conducted in similar lines.

The total yield per hectare increased significantly as the spacing decreased. The difference in yield between the best treatment with respect to tonnage, 1.25 x 1.25 m and lowest treatment 2.25 x 2.25 m was around 14 t ha^{-1}. According to Biswas *et al.* (1989) increased plant population increased the yield per hectare. Kumar *et al.* (1989) and Ghanta *et al.* (1994) also observed that a spacing of 1.5 x 1.5 m gave the highest yield compared to the other spacings tried.

Reddy (1995), Kumar *et al.* (2000) and Ravitchandirane *et al.* (2002) also observed similar trend. Thus the experimental results are in agreement with the research findings in similar lines.

5.4 QUALITY CHARACTERS

The quality of the fruits in terms of TSS, sugar content , acidity, carotenoids and ascorbic acid content was superior in wider spacings upto 2 x 2 m. In lower spacing (1.75 x .175 m) the fruit quality decreased slightly. The evaluation of organoleptic characters also proved that fruits under wider spacings were superior. In closer spacings, the organoleptic qualities showed reduction. Biswas *et al.* (1989) also reported that TSS and total sugar content of papaya fruits increased with decreasing planting density. However, the studies of Arango *et al.* (1986), Singh *et al.* (1999) and Kumar *et al.* (2000) did not reveal any significant difference on quality parameters of papaya.

5.5 INCIDENCE OF PESTS AND DISEASES

No major pests or disease attack was observed during the course of the experiment and the plants were healthy without any symptoms of disease or pests attack. However, Willer's and Neething (1994) observed the incidence of spiral nematodes in high density orchards.

5.6 ECONOMICS OF CULTIVATION

The highest net profit was obtained when the spacing was 1.75 x 1.75 m. This treatment involved higher cost of cultivation resulting in low benefit : cost ratio compared wider spacings. Reddy (1995) also reported that the cost : benefit ratio was higher when plant density was lower.

The results of the current experiment showed that plant growth in terms of height, girth, number of leaves per plant, height of first flowering and dry matter production was better in wider spacings upto 1.75 x 1.75 m compared to further closer spacings. However, time for flowering and harvest was earlier in wider spacing upto 2 x 2 m.

On assessing the yield characters the number of fruits per plant or the number of marketable fruits were not significantly influenced by the spacings, whereas the fruit size and pulp percentage was better upto 1.75 x 1.75 m compared to further closer spacings.

The quality of the fruits in terms of TSS, acidity, carotenoids, sugar content, ascorbic acid etc. were better under wider spacing upto 2 x 2 m. However, under the spacing 1.75 x 1.75 m the fruit quality was reasonably good.

Though the closest spacing (1.25 x 1.25 m) resulted in highest tonnage per hectare, the highest net profit was in 1.75 x 1.75 m spacing. The benefit : cost ratio, however was higher in wider spacings upto 2 x 2 m, due to comparatively less cost of cultivation.

Thus it can be concluded that for papaya a spacing of 1.75 x 1.75 m was suitable for good yield and highest net profit under Kerala conditions. But for better fruit quality and early yield a spacing of 2 x 2 m was suitable.

SUMMARY

6. SUMMARY

The present investigations on "High density planting in papaya (*Carica papaya* L.)" was conducted in the Department of Pomology and Floriculture, College of Agriculture, Vellayani, Thiruvananthapuram during the year 2003-2004, to find out the optimum spacing for papaya, so as to increase the number of marketable fruits per unit area without affecting the yield and quality of fruit. During the course of the experiment, plant growth, yield and quality of the produce under different spacings were critically observed. The salient findings of the study are summarized below:

The results of the present study indicated that in all stages of growth, closer spacing increased the height of papaya plants. In general, in the spacing upto 1.75 x 1.75 m, the plant height was reasonable while in further closer spacings the plants grew taller.

In the early stages of growth upto seventh months, the spacing of 1.75 x 1.75 m produced reasonably good plant girth. Still closer spacings had a negative influence on the girth of the plants. In the later stages of growth increase in the spacing upto 2 x 2 m increased the plant girth.

In general, there was a reduction in the number of leaves produced with decrease in spacing. Considering the number of leaves produced during the different stages of growth, a spacing upto T_4 level (1.5 x 1.5 m) did not have very harmful effects. In still closer spacing of 1.25 x 1.25 m there was significant reduction in leaf production.

The time taken for first flowering in papaya plants decreased with wider spacing. The lowest period for flowering was in the widest spacing of 2.25 x 2.25 m followed by 2 x 2 m. There was an increase of 28–30 days for flowering in closer spacings below 2 x 2 m.

The results of the experiment showed that with increase in spacing, the height at which first flower appeared decreased. Upto T_3 level (1.75 x 1.75 m), the plants could be considered to be flowering at lower levels.

The time taken for harvest decreased in wider spacings. Upto T_2 level (2 x 2 m) there was a reduction of about two weeks in the time for harvest of fruits.

As the plant population increased the root spread decreased. The wider spacings, T_1 (2.25 x 2.25 m) and T_2 (2 x 2 m) had better root spread compared to other treatments.

The leaf area index in general was lower in wider spacings. With increase in plant density consequent to decrease of spacing higher leaf area index was noticed.

In general there was more dry matter production when the spacing was wide upto 1.75 x 1.75 m. However, this did not significantly influence the biomass partitioning between the vegetative and economic parts.

The root : shoot ratio increased significantly with decrease in the spacing and the consequent increase in the plant density. Closer spacings had higher proportion of roots.

The different spacings tried did not influence the number of fruits produced per plant during the initial bearing period. The mean values showed that in general, more number of fruits were produced at wider spacing.

Market acceptance of fruits was not markedly influenced by the spacings tried during the initial bearing period.

The individual fruit weight increased markedly with wider spacings. At the same time, spacings below 1.75 x 1.75 m resulted in low weight of fruits.

The length of fruits increased with increase in spacing. The spacing upto T_3 (1.75 x 1.75 m) could be considered to attain good fruit length.

With the increase in spacing, the girth of fruits also increased. The wider spacings T_1 (2.25 x 2.25 m) and T_2 (2 x 2 m) gave maximum fruit girth followed by T_3 level (1.75 x 1.75 m).

There was significant reduction in the volume of fruit with decrease in spacing. In spacings below T_3 (1.75 x 1.75 m) marked reduction of fruit volume was observed.

With decrease in spacing the cavity index also decreased indicating that the cavity volume per unit volume of fruit decreased with decrease in spacing.

As the plant population increased per unit area, the seed content decreased in the fruits. In the wider spacings upto T_3 level (1.75 x 1.75 m) the seed content was highest.

There was increase in the pulp percentage with decrease in spacing. Pulp percentage was the highest in the closer spacing upto T_4 level (1.5 x 1.5 m spacing). Wider spacings *viz.*, T_2 (2 x 2 m) and T_3 (1.75 x 1.75 m) levels gave reasonably good pulp recovery.

The data indicted that the yield per plant decreased significantly with decrease in spacing. There was no significant reduction in the yield per plant yield in the spacing below 2 x 2 m.

The total yield per hectare increased significantly as the spacing decreased. The data also revealed that there was no significant reduction in yield per hectare between the wider spacings. However, the difference in yield between the best treatment T_5 (1.25 x 1.25 m) and the lowest treatment T_1 (2.25 x 2.25 m) was around 14 t ha^{-1}. The difference in yield between T_4 and T_1 was 4.87 t ha^{-1} while between T_3 and T_1 was 2.91 t ha^{-1} and between T_2 and T_1 was 3.97 t ha^{-1}.

In general it was observed that the quality of fruits was superior in the wider spacings upto T_2 level (2 x 2 m). In T_3 level (1.75 x 1.75 m) and in still closer spacings, the fruit quality decreased slightly.

With respect to the organoleptic characters, the treatments T_1, T_2 and T_3 were superior to T_4 and T_5. Thus, it can be concluded that in wider spacing upto T_3 level (1.75 x 1.75 m), the organoleptic qualities of fruit was acceptable.

No major pests or disease attack was observed during the course of the experiment and the plants were healthy without any symptoms of diseases or pest attack.

The highest net profit was obtained when the spacing was 1.75 x 1.75 m. This treatment involved high cost of cultivation also resulting in low benefit : cost ratio compared to wider spacings.

Overall assessment of the performance of the papaya plants under different spacings showed that plant growth in terms of height, girth, number of leaves per plant, height of first flowering and dry matter production was better in wider spacings upto 1.75 x 1.75 m compared to further closer spacings. However, time for flowering and harvest was earlier in wider spacings upto 2 x 2 m.

With respect to the yield characters the number of fruits per plant or the number of marketable fruits were not significantly influenced by the treatments imposed. However, in general the fruit size and pulp percentage was better upto 1.75 x 1.75 m spacing compared to the closer spacing tried.

Wider spacing upto 2 x 2 m attained better quality of fruits in terms of TSS, sugar content, acidity, carotenoids, ascorbic acid etc. However, the fruit quality was reasonably good upto 1.75 x 1.75 m spacing level.

Eventhough the closest spacing of T_5 (1.25 x 1.25 m) resulted in the highest tonnage per hectare, the highest net profit was in 1.75 x 1.75 m spacing. The benefit : cost ratio, however was higher in wider spacings upto 2 x 2 m due to comparatively lesser cost of cultivation.

From the above results it can be concluded that a spacing level of 1.75 x 1.75 m can be considered suitable for good yield and net profit from papaya under Kerala condition. For better fruit quality and early yield a spacing of 2 x 2 m was suitable.

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7. REFERENCES

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APPENDICES

APPENDIX – I

Score card for organoleptic qualities of papaya

Sl No.	Criteria		Treatments				
			T_1	T_2	T_3	T_4	T_5
1.	Appearance						
	Very good	– 4					
	Good	– 3					
	Fair	– 2					
	Poor	– 1					
2.	Colour						
	Most acceptable	– 4					
	Acceptable	– 3					
	Fairly acceptable	– 2					
	Not acceptable	– 1					
3.	Flavour						
	Most acceptable	– 4					
	Acceptable	– 3					
	Fairly acceptable	– 2					
	Not acceptable	– 1					
4.	Taste						
	Very good	– 4					
	Good	– 3					
	Fair	– 2					
	Poor	– 1					
5.	Texture						
	Firm, crisp and melting	– 4					
	Firm, crisp	– 3					
	Fairly firm	– 2					
	Too soft	– 1					
6.	Papain odour						
	Not at all present	– 4					
	Very mildly present	– 3					
	Mildly present	– 2					
	Strongly present	– 1					

APPENDIX – II

Evaluation card for triangle test

In the triangle test three sets of sugar solution of different concentrations were used. Of the three sets, two solutions were of identical concentrations and the members were asked to identify the third sample which was of different concentration.

Name of product : Sugar solution

Note : Two of the three samples are identical, identify the odd sample.

Sl. No.	Code No. of the samples	Code No. of the identical samples	Code No. of the odd samples
1	XYZ		
2	ABC		

APPENDIX – III

Weather data prevailed during the cropping period

Year and Month	Maximum temperature (°C)	Minimum temperature (°C)	Total rainfall (mm)	Total day length (hours)	Relative humidity (%)
2003					
August	30.9	24.3	100.5	6.0	80.8
September	31.4	23.9	10.3	9.1	76.5
October	30.4	23.6	515.9	5.8	84.0
November	30.5	23.2	169	4.5	82.5
December	31.2	21.6	-	8.2	77.1
2004					
January	31.5	21.7	6.8	9.0	76.9
February	32.2	22.1	0.4	9.4	75.3
March	33.1	24.1	1.2	8.8	76.7
April	33.3	24.9	126	8.0	78.3
May	31.0	23.9	447.6	5.3	83.1
June	30.2	23.3	243.3	5.6	83.7
July	29.8	23.1	321	5.2	85.2
August	30.2	23.1	89.5	7.2	80.6

HIGH DENSITY PLANTING IN PAPAYA *(Carica papaya L.)*

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Abstract of the
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ABSTRACT

An experiment was conducted in the Department of Pomology and Floriculture, College of Agriculture, Vellayani during 2003-2004 to study the effect of different spacings on growth, yield and quality of papaya and to standardise the optimum spacing. The experiment was conducted in randomised block design with five treatments and four replications.

The results of the study indicted that the vegetative characters were influenced by the spacings tried. As the plant spacing decreased, the plant height also increased and upto the spacing 1.75 x 1.75 m it was reasonable. The girth and number of leaves per plant decreased with decrease in spacing. Closer spacings upto 1.75 x 1.75 m resulted in reasonably good plant girth. Closer spacings upto 1.5 x 1.5 m did not have very harmful effects on the number of leaves produced. Wider spacings upto 2 x 2 m showed early flowering. The spacing upto 1.75 x 1.75 m could be considered to be flowering at lower height. The time taken for harvest decreased with increase in spacing upto 2 x 2 m. The root spread also increased with increase in spacing. Leaf area index and root : shoot ratio increased with decrease in spacing. Dry matter production increased under wider spacing upto 1.75 x 1.75 m.

The number of fruits per plant and market acceptance of the fruits were not influenced by the spacing. Fruit weight increased as the spacing increased and was high under wider spacing upto 2 x 2 m. Fruit length, fruit girth, seed content and cavity index were high upto 1.75 x 1.75 m. Pulp percentage increased as the spacing decreased and it was reasonable upto the spacing of 1.75 x 1.75. Yield per plant was higher under wider spacing. The yield per hectare increased as the plant population increased. The closest spacing of 1.25 x 1.25 m gave the highest tonnage per hectare.

Quality of the fruits was also affected by the spacings tried. TSS, total sugars and shelf-life increased under wider spacing and was superior upto the wider spacing of 2 x 2 m. Acidity and ascorbic acid showed a reduction as the spacing increased. Carotenoids was not significantly affected by different spacings.

Organoleptic evaluation indicted that the spacings upto 1.75 x 1.75 m were superior than further closer spacings.

The highest net profit was observed for spacing 1.75 x 1.75 m. But the cost of cultivation increased with increase in plant population and hence the benefit : cost ratio was the highest under wider spacings upto 2 x 2 m.

From the results it can be concluded that a spacing of 1.75 x 1.75 m was suitable for papaya cultivation in commercial scale under Kerala conditions. However, for better fruit quality, spacing of 2 x 2 m and above was suitable.