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Effect of plant geometry on growth and yield of papaya (*Carica papaya* L.) CV. GJP-1

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Abstract
The experiment was conducted at Madhadibaug, Fruit Research Station, Department of Horticulture, Junagadh Agricultural University, Junagadh (Gujarat). There were nine treatment combinations replicated thrice in a randomized block design. The results revealed that the minimum plant height (144.87 cm) was recorded in treatment T_1 (Normal – 1.8 x 1.8 m) followed by treatments T_5, T_2 T_3 and T_7. Among different spacing, the maximum stem girth (25.10 cm), number of leaves (29.49) and minimum days to flowering (80.04 days), bearing height (57.16 cm) and days to first fruit harvesting (208.67) were observed in treatment T_1 (Normal- 1.8 x 1.8 m) followed by treatment T_3. The highest number of fruits per plant and fruit yield per ha (114.78 t/ha) was obtained in treatment T_3 (Paired row Zig-zag - 1.5 x 1.5 x 2 m).

Keywords: Papaya, yield, growth, geometry, Cv. GJP-1

Introduction
Papaya (*Carica papaya* L.) produces fruits throughout the year. It requires less area for tree, comes to fruiting in a year, is easy to cultivate and provide more income/ha next to banana. It is a member of dicotyledonous family caricaceae and has chromosome number 2n=18. It has a high nutritive and medicinal value. Papain prepared from dried latex of its immature fruits is used in meat tendering, manufacture of chewing gum, cosmetics, for degumming natural silk and to give shrink resistance to wool. Besides, it is also used in pharmaceutical industries, textile and garment cleaning paper and adhesive manufacture, sewage disposal etc. Papayais a very wholesome fruit. It ranks second only to mango as a source of the precursor of vitamin A. While this vitamin is generally associated with carotene, the yellow pigment in the papaya is not carotene but caricaxanthin. Papaya also called pawpaw, is a quick growing, typically single-stemmed, short-lived, large perennial herb. Branching may occur with age or if the apical growing point is damaged and can bear fruits for more than 20. Though not economical from commercial point of view. It is a highly problematic, complicated and interesting fruit crop from botanical, genetical, cytogenetical and horticultural points of view.

India is the largest producer of papaya with an annual production of 59.89 lakh MT from an area of 1.38 lakh hectares followed by Brazil, Nigeria, Mexico, Ethiopia with the highest productivity of 72.7 metric tonnes per hectare in Indonesia (Anonymous a, 2018). In Gujarat area of papaya during the year 2019-20 was highest in Kutch (2532 ha) followed by Vadodara (2068 ha), Tapi (1717 ha) and highest production in Kutch (2.14 lakh MT) followed by Vadodara (1.18 lakh MT), Tapi (1.05 lakh MT). In Gujarat it occupies area of 18.127 thousand ha and 11.15 lakh MT production with 61.51 MT/ha productivity (Anonymous b, 2019). The varieties of papaya like Madhu Bindu, Coorg Honeydew, Pusa Nanha, Taiwan and GJP-1 are under cultivation in Gujarat.

Plant geometry is the pattern of distribution of plant over the ground or the shape of the area available to the individual plant in a crop field. It also refers to the shape of the space available for individual plants. If the spacing is inadequate, the fruit trees will grow poorly, produce small quantity of fruits of inferior quality and suffer from various diseases and insect pests. The cultural practices of the orchards are also greatly hindered. Weeds and grasses grow in abundance and rob off the vitality of the trees, resulting in their early decline and premature death. The single row planting, the distance within the row is close, whereas the distance between the rows is wide. This system allows good aeration to plant canopy, allowing wet leaves to dry more rapidly, reducing fungal disease severity. In this, less number of trees occupied in the field and yield will automatically reduce. In double row planting, a wider spacing is given after every two rows.

Whereas in three row planting, a wider spacing is given after every three rows. By using paired row system intercultural operations can be carried out easily and cost of drip irrigation is decreased.

Material and Methods

The experiment was conducted at Fruit Research Station, Madhadi Baugh, Department of Horticulture, College of Horticulture, Junagadh Agricultural University, Junagadh (Gujarat). The experiment was laid out with different spacing in Randomized Block Design with three replications. The experiment comprising of nine treatments including: T1 (Normal- 1.8 x 1.8 m), T2 (Paired row - 1.5 x 1.5 x 2 m), T3 (Paired row zig-zag - 1.5 x 1.5 x 2 m), T4 (Three row- 1.5 x 1.5 x 1.5 x 2 m), T5 (Three row zig-zag - 1.5 x 1.5 x 1.5 x 2 m), T6 (Paired row – 1 x 1 x 2 m), T7 (Paired row zig-zag – 1 x 1 x 2 m), T8 (Three row – 1 x 1 x 1 x 2 m) and T9 (Three row zig-zag – 1 x 1 x 1 x 2 m).

The selected plants were marked with metal tag for recording observation. The observations like plant height, number of leaves, stem girth, reproductive parameters like days to first flowering, bearing height, days to first fruit harvesting, yield parameters like number of fruits per plant, fruit yield (kg/plant & t/ha) parameters were recorded. Plant height and stem girth were recorded with measuring tape. The number of fruits per plant were recorded at the time of harvesting from the marked plants. The total fruit yield per plant was obtained through the number of fruits retained by the trees and weighing the fruits by electronic balanced. The data was statistically analysed by method of analysis of variance using RBD as described by Panse and Sukhatme (1985) [8].

Results and Discussion

Growth parameters

The effect of different spacing on growth parameter like plant height (cm), stem girth (cm) and number of leaves per plant were found significant during the period of investigation. Plant height (cm) was significantly influenced by various treatments. The minimum plant height (144.87 cm) was recorded in treatment T_1 (Normal – 1.8 x 1.8 m) which was at par with treatments T_5, T_2, T_3 and T_7. Plant height decreased significantly with increasing levels of spacing. It is quite natural that when more plants per unit area are retained, mutual shading was more, which tended the plants to grow taller. The decrease in plant height with wider spacing can also be due to competition for light under inadequate spacing (Bhatia *et al*. 2017) [4] in strawberry. The maximum stem girth (25.10 cm) was noted in treatment T_1 (Normal -1.8 x 1.8 m) but which was found at par with T_3, T_2, T_4 and T_5. The minimum stem girth (18.90 cm) was observed intreatment T_8 (Three row - 1 x 1 x 1 x 2 m). Number of leaves per plant differed significantly by different spacing. The highest number of leaves (29.49) was observed under treatment T_1 (Normal- 1.8 x 1.8 m), which was at par with the treatment T_3 and T_2. This might be due to the plants of wider spacing could receive more light, nutrients and other resources than the plants of closer spacing.

Reproductive parameters

The minimum days to first flower (80.04 days) was recorded in treatment T_1 (Normal- 1.8 x 1.8 m). However, it was found at par with T_3 and T_2. The minimum bearing height (57.16 cm) was found in treatment T_1 (Normal- 1.8 x 1.8 m) but it was at par with T_3, T_5 and T_2. The result indicated that with increase in spacing, the height of the first flower from ground level also decreased and *vice versa*. These results are in conformity with Rajasekaran (1975) [10] reported that increase of spacing decreased the height of flowering. the minimum days required to first fruit harvesting (208.67) was observed in treatment T_1 (Normal- 1.8 x 1.8 m), which was at par with treatment T_3. The maturity was delayed in close spacing which might be due to lower interception of light and low microclimatic temperature due to more shading. (Kavino *et al.*, 2004) [6] in banana.

Table 1: Effect of plant geometry on growth parameters on papaya cv. GJP-1

Treatments	Plant height (cm)	Stem girth (cm)	Number of leaves per plant	Days to first flowering	Bearing height (cm)	Days to first fruit harvesting
T_1	144.87	25.10	29.49	80.04	57.16	208.67
T_2	157.43	23.80	26.33	88.04	60.65	224.67
T_3	159.67	24.26	28.47	82.73	58.65	215.00
T_4	169.00	22.71	25.43	92.54	64.82	226.67
T_5	154.67	21.86	23.53	89.64	60.00	225.33
T_6	162.67	20.27	22.60	92.06	63.39	230.67
T_7	160.00	20.40	22.16	90.72	64.93	228.00
T_8	174.33	18.90	21.93	94.37	71.22	234.00
T_9	171.00	19.46	22.97	92.99	66.29	230.83
S.Em. ±	5.353	1.248	1.447	3.014	1.893	4.649
C. D at 5%	15.24	3.55	4.12	8.58	5.39	13.23
CV %	5.74	9.89	10.12	5.84	5.20	3.58

Yield parameters

The analyzed data (Table 2) pertaining to the yield parameters was found significantly different among the different spacings. The maximum number of fruits per plant (31.33) was observed under treatment T_3 (Paired row zig-zag - 1.5 x 1.5 x 2 m), which was at par with the treatment T_1. This may be due to reduced number of plants under wider spacing undergone less inter or intra plant competition which caused an increased number of fruits per plants. Similar results were reported by Ghanta *et al.* (1994) [5] and Singh *et al.* (1999) [11] in papaya, Patel *et al*. (2018) [9] and Badway*et al.* (2010) in banana. The maximum fruit yield (30.13 kg/plant) was recorded in treatment T_3 (Paired row zig-zag – 1.5 x 1.5 x 2 m). The plant population per unit area increased, yield per plant decreased. Lower number of flower bud and fruits per plant in closely spaced plants seems to be due to lesser photosynthetic activity, while higher yield per hectare with close spaced plants may be due to more plants accommodated per unit area in guava (Kumawat *et al.*, 2014) [7]. The highest fruit yield (114.78 t/ha) was noted in treatment T_3 (Paired row zig-zag - 1.5 x 1.5 x 2 m). Number of plants per hectare increased with increasing planting densities therefore maximum estimated yield per hectare obtained from closest spacing.

Table 2: Effect of plant geometry on yield parameters on papaya cv. GJP-1

Treatments	Number of fruits per plant	Fruit yield (kg/plant)	Fruit yield (t/ha)	Percentage increase over control	Benefit cost ratio
T_1	28.33	21.53	66.44	-	1:2.18
T_2	26.00	20.13	76.69	15.43	1:2.37
T_3	31.33	30.13	114.78	72.76	1:3.25
T_4	26.29	19.72	78.87	18.71	1:2.24
T_5	24.34	17.56	70.24	5.72	1:2.03
T_6	21.13	13.17	87.82	32.17	1:2.00
T_7	22.33	13.46	89.72	35.04	1:1.93
T_8	20.33	12.54	94.24	41.84	1:1.88
T_9	21.00	13.28	99.81	50.23	1:1.98
S.Em. ±	1.471	1.128	5.232		
C. D at 5%	4.19	3.21	14.89		
CV %	10.37	10.88	10.48		

Conclusion

On the bases of above study and observations, it is can be concluded that the maximum stem girth, number of leaves per plant, fruit girth and minimum days to first flowering, bearing height and days to first fruit harvesting were observed in plant geometry (3086 plants/ha) with T_1 -Normal- 1.8 x 1.8 m. Whereas, the highest numbers of fruit per plant, Fruit yield (t/ha), yield percentage over normal spacing (72.76) and net realization were obtained in plant geometry (3809 plants/ha) with paired row zig-zag- 1.5 x 1.5 x 2 m in papaya cv. GJP-1.

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