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Effect of transplanting dates and crop geometry on growth, quality, yield and profitability of papaya (*Carica papaya* L.) cv. Red Lady-786

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Abstract

Field experiments were conducted at four adjoining farmer's field in district Sirohi of Rajasthan during 2012-13 and 2013-14. The experiments comprised of three transplanting dates *i.e.* first week of March (Temp. 30°C, RH 42%), first week of July (Temp. 35°C, RH 60%), first week of September (Temp. 32°C, RH 70%)] and three crop geometries followed were 3m x 3m (1111 plants ha^{-1}), 2m x 2m (2500 plants ha^{-1}), 2.5m x 1.6m (2500 plants ha^{-1}). The experiments were replicated four times in a Randomized Block Design. Results revealed that the maximum seedling survival per cent at 20 DAT (89.30%) and 30 DAT (81.45%) was recorded in T_9 treatment (1st September + 2.5m x 1.6m). The combination of crop geometry of 3m x 3m and transplanting date in first week of March (T_1) resulted maximum plant height (289.61 cm), stem girth (50.76 cm), number of leaves (42.45), number of fruits plant^{-1} (82.46), highest average fruit weight (1.98 kg) and fruit yield plants^{-1} (163.28 kg). However, maximum fruit set (57.70 %), fruit retention (75.50 %), yield ha^{-1} (2372.47 q in two year of experimentation) and quality parameters viz., TSS (11.80°Brix), ascorbic acid (58.35 mg 100g^{-1} fruit pulp), pulp thickness (3.20 cm), overall quality score of fruit (8.36) and low acidity (1.30%) with highest net return (10.689 lakh ha^{-1} in two years of experimentation) and benefit: cost ratio (4.54) was found in the combination of crop geometry of 2.5m x 1.6m and transplanting date in first week of March (T_3). This led to lower virus incidence (leaf curl & ring spot virus), sun scald and frost injury symptoms.

Key word: Papaya ring spot virus, Days After Transplanting, crop geometry, diurnal fluctuation, Dates of transplanting

Introduction

Papaya (*Carica papaya* L.) is an important quick growing delicious and nutritious fruit crop. It is not only needed as a fresh fruit but also used for processing of fruits and as vegetable for cooking. It contains high amount of vitamin A, vitamin C and iron (Rashid *et al* 1987). Papaya is available round the year and grown easily in the homesteads as well as large scale farms in India (Bhardwaj et al 2013). India leads the world in papaya production with an annual output of about 4.1 million tones. Rajasthan state occupied 9,000 ha area with production 16,010 tones, Sirohi is leading districts in papaya cultivation (Anonymous, 2013). Among gynodiocious varieties, Red Lady is a choicest variety which fetches high price in the market for good shape, size, delicious taste and long self life. Though South Western Rajasthan is naturally blessed with suitable condition for growing papaya, yet the average yield of papaya is not satisfactory compared to many other states in India due to lack of systematic management practices especially adequate spacing on proper plant population per unit area and date of transplanting. However, the availability of cultivable land is decreasing day by day, the solution lies in resorting to maintain proper crop geometry and it not only provides economic use of land but also helps in efficient utilization of resources or inputs (solar energy, water, fertilizer, pesticides etc.) for higher yield. Because Red Lady variety is a new plant type, as imported hermaphrodite short duration hybrid (F_1) there is an urgent need to find out suitable transplanting dates and crop geometry for higher production, induce mechanization for reduction of labour cost. Optimum crop geometry is one of the important factors for higher production, by efficient utilization of underground resources (plant nutrient and water) and converges maximum solar radiation and in turn better photosynthate formation (Bhardwaj and Agrawal, 2014). Ideal crop geometry was also minimizing the effect of unfavorable climatic condition (Sun scald and frost) and disease indecency on crop. According to bench mark survey report of Sirohi district for papaya cultivation reported that significant increase in papaya fruit yield with cost minimizing by increase row to row spacing upto 2.5 meter for initial weeding by tractor operated cultivator and reduce plant spacing next to 1.6 meter for maintained maximum plant population upto 2500 ha^{-1} (Bhardwaj et al 2013).

Appropriate time of seedling transplanting not only increases the productivity and quality of fruit but also helps in synchronized, uniform growth and development (flowering and fruiting) of plants, reduce weed and disease infection (leaf curl virus and papaya ring spot virus). Enhancing better growth in plant by providing optimum growing period through manipulation of planting time may offer the most promising approach for increasing production and reducing the virus incidence in papaya (Singh and Singh, 1998). Leaf curl and ring spot virus disease plays havoc in papaya production and there being no effective control measures, the only alternative approach in the absence of virus resistant varieties is to escape the infestation through cultural manipulation, i.e. to avoid the infestation by checking the vector population at its active stage or planting at such a time when vectors are not active (Chadha, 1992).

Information on seedling transplanting dates and crop geometry for production of papaya cv. Red Lady in Rajasthan is lacking and it is desirable to obtain precise information in this aspect. Hence, keeping this in view the present study was undertaken to find out the best time for transplanting and crop geometry for higher yield, quality of fruits and economic returns from papaya cultivation.

Materials and Methods

The effect of transplanting dates and crop geometry on the growth, yield and quality of papaya cv. Red Lady-786 was investigated at four adjoining fields of farmers during two consecutive years i.e., 2012-13 and 2013-14 in district Sirohi (Rajasthan). The abiotic factors viz., average minimum and maximum temperatures were 28.0°C ± 5.0°C and 38.0°C ± 5.0°C, relative humidity of 58.0 ± 25.0 per cent and total rainfall 585.0 mm per annum were recorded during the experimentation (24 months). Treatment comprised of nine combinations consisting by three transplanting dates and three crop geometry viz., (T_1) Transplanted in first week of March + 3m x 3m (1111 plants ha^{-1}), (T_2) Transplanted in first week of March + 2m x 2m (2500 plants ha^{-1}), (T_3) Transplanted in first week of March + 2.5m x1.6m (2500 plants ha^{-1}), (T_4) Transplanted in first week of July + 3m x 3m (1111 plants ha^{-1}), (T_5) Transplanted in first week of July + 2m x 2m (2500 plants ha^{-1}), (T_6) Transplanted in first week of July + 2.5m x1.6m (2500 plants ha^{-1}), (T_7) Transplanted in first week of September + 3m x 3m (1111 plants ha^{-1}), (T_8) Transplanted in first week of September + 2m x 2m (2500 plants ha^{-1}) and (T_9) Transplanted in first week of September + 2.5m x1.6m (2500 plants ha^{-1}). The experiment was laid out in Randomized Block Design with four replications in 10m x 10m plot size and accommodated plants at 3m x 3m (9 plants), 2m x 2m (25 plants) and 2.5m x 1.6 m (25 plants) per $plot^{-1}$ for each replication. The beds were prepared and pits measuring 50 × 50 × 50 cm were dug 15 days prior to transplanting. The 45 days old disease free seedlings were transplanted in the main plot as per treatments. First half recommended dosage of organic matter and fertilizer (10 kg Farm Yard Manure + 150 g nitrogen + 150 g phosphorus + 250 g potash) were applied at the time of transplanting in pits and remaining half quantity of organic matter and fertilizer was applied in four splits dosage *i.e.*3 month, 6 month, 9 month and 12 month after transplanting by ring method near root zone. The intercultural operations (weeding, irrigation, mulching, insecticide spray etc.) were followed as and when required.

All the observations were taken from randomly selected five plants of each replication throughout the investigation period at appropriate time by adopting standard methodology. Seedling survival per cent (after transplanting in main field recorded at 10, 20 and 30 DAT) was recorded by following formula:

$$\text{Survival per cent} = \frac{\text{Survival plants}}{\text{Total transplanted plants}} \times 100$$

The plant height was measured three-monthly starting after third months of planting upto 24 months (at last harvesting). Plant height was measured from the ground level to the highest point of plant in centimeters (at 3, 6, 9, 12, 15, 18, 21 & 24 months after transplanting). Stem girth was determined 15 cm above ground by a vernear caliper in centimeters. Number of functional leaves was counted which were green and photosynthetically active at the time of observations. While leaf area was determined by tracing the leaves on a graph paper and calculating the areas covered and expressed in square meter. Days taken to first flower initiation, number of flowers $plant^{-1}$ number of fruits $plant^{-1}$ and days taken fruit setting to harvesting was calculated by simple counting method. Fruit set and retention were recorded from randomly selected five tagged plants by using following formulae:

$$\text{Fruit set (\%)} = \frac{\text{Total number of fruit set plant}^{-1}}{\text{Total number of flowers plant}^{-1}} \times 100$$

$$\text{Fruit retention (\%)} = \frac{\text{Total number of fruit gets maturity plant}^{-1}}{\text{Total number of fruit set plant}^{-1}} \times 100$$

Fruit yield and fruit weight was recorded after 10 months from the date of planting to 24 months age of plants, which was a first spell of complete fruiting and expressed in kg $fruit^{-1}$. The total fruit yield $plant^{-1}$ and $hectare^{-1}$ were calculated by weighing total marketable fruits during successive harvesting obtained from each plant, per plot and per hectare estimated by multiplied yield per plant to planting density and expressed in kg and quintal, respectively. Further, the net return was calculated by subtracting cost of each treatment from gross return. The gross return was calculated from yield multiplied by average market rate during the period of investigation. The benefit cost ratio was calculated by dividing net return to total cost of cultivation.

Total soluble solids (TSS) of the fruit pulps was determined by Zeiss Hand Juice Brix Refractometer, values corrected to 20°C and expressed as °Brix. Acidity (as citric acid) was determined by using standard N/10 NaOH solution in the presence of phenolphthalein as an indicator, AOAC (1984). Total sugar in the pulp was determined by the Anthrone reagent method AOAC, (1984). The ascorbic acid (vitamin C) content of the pulp was estimated by titration method with 2, 6-dichlorophenol-indonenol dye solution (AOAC, 1984). The pulp thickness was measured from cavity surface to outer surface of fruit by scale and expressed in centimeter. The over all quality (pulp colour, cavity size, seed content, skin colour, size and shape of papaya fruits) and consumer preference of fruits was done by a panel of five semi-trained judges using 10 point hedonic scale (Amerine et al 1965). Chlorophyll content of leaves was estimated by the method of Arnon (1949) at 6 and 24 month after transplanting. Incidence or occurrence of leaf curl and ring spot virus as well as sun scald and frost injury symptoms were recorded visually on leaves and fruits, respectively and expressed in percentage in relation to the total sample by the panel of five members at 6, 12 and 18 months after transplanting.

All data were subjected to analysis of variance (ANOVA) to determine significant differences followed by Tukey's test for comparisons of means at significance level of $P \leq 0.05$.

Results and Discussion

Vegetative growth parameters

It appears from the figure-1 that the maximum seedling survivality was recorded at 20 DAT (89.30%) closely followed by at 30 DAT (81.45%) in T_9 treatment (1st week of September + 2.5m x 1.6m), which was significantly superior to other treatment combinations but at par with T_8 treatment (1st September + 2m x 2m). The maximum survival per cent of seedling in T_9 treatment might be due to more favorable environmental condition (Temp. 32°C and RH 70%) in the month of September for seedling transplanting and re-establishment of the seedling than other. The results of present investigation were also supported by Bhardwaj et al (2013) in papaya. Data presented in Table 1, 2 and 3 the vegetative parameters i.e., plant height (77.83 cm), leaf area (2.40 m^2) and number of leaves (12.22) was recorded maximum in treatment T_4 (Ist week of July + 3m x3 m), whereas stem girth (8.99 cm) was in T_1 (Ist week of March + 3m x3 m) at 3 months after transplanting. At the end of crop season *i.e.*, at 24th month after transplanting maximum plant height (289.61 cm), stem diameter (50.76cm), leaf area (3.84 m^2) and number of leaves (42.45) were recorded in treatment T_1 (Ist week of March + 3m x3 m). Whereas, respective vegetative parameters were recorded minimum in T_8 treatment (Ist week of September + 2m x 2m).

The seedling transplanted in Ist week of March favour higher vegetative growth than later dates of transplanting of papaya seedling due to better establishment of seedlings prior to onset of monsoon and that plants use maximum rain water and soluble nutrients for initial growth and development. The warmer and intermediate temperature with wider diurnal fluctuation in environment gave congenial conditions for good mean growth rate in papaya plant, accumulation of reserves in more quantity and fairly large sweet fruit (Allan et al 1987). Similarly better plant growth due to higher temperature (36°C/28°C) in the present study confirms the observations of Singh and Singh (1998) in papaya.

Vigorous vegetative growth (plant height, stem girth, number of leaves and leaf area) and root volume in wider line spacing (3m x 3m) planting, might be due to reduction in crop competition for nutrients, water, light and spacing than the closer space planting (T_2 & T_3), eventually enhanced photosynthesis and contributed to produce higher dry matter. This was also enunciated by Chattopadhayay *et al* (1985), Reynolds and Robinson (1985), Chaudhuri and Baruah (2010) in banana and Bhardwaj et al (2013) in papaya, lending ample support to the present study.

Yield and yield attributes

The yield among different months was strongly influenced by transplanting dates and crop geometry. Transplanting of seedling in month of March with 2.5m x 1.6 m crop geometry was more productive over the other months of transplanting and crop geometry. However, highest number of fruits plant^{-1} (82.46), fruit weight (1.98 kg), fruit yield plant^{-1} (163.28 kg) was recorded in treatment T_1 (Ist week of March + 3m x 3m), whereas the minimum number of fruit plant^{-1} (50.78), lowest fruit weight (1.15 kg) and fruit yield plant^{-1} (58.39 kg) was recorded in T_8 treatment (Ist week of September + 2m x 2m). Reduction in number of fruits, fruit weight and fruit yield plant^{-1} with increasing plant density may be due to excessive interception of light by the enhanced canopy and higher crop competition for nutrients and water under high density planting. When the plant population was low, more leaf surface was exposed to sunlight and indirectly greater amount of assimilates accumulated in the various organs of the plant leading to increased number of fruits plant^{-1}, fruit weight and fruit yield plant^{-1}. Interestingly, computation the marketable yield from fruit weight, the present study showed a tremendous increase in yield per unit area with increasing plant population (T_3 and T_2). Similar results were also reported by Bhardwaj et al (2013) in papaya.

Minimum days required in flower initiation (154.40 days) and least days taken from fruit set to harvest (112.12 days), maximum fruit set (57.70 %), fruit retention (75.50%), fruit yield ha^{-1} (2372.47 q in 24 month of cropping duration), net return (Rs.10.689 lakh) and benefit: cost ratio (4.54:1) was observed in T_3 treatment (Ist week of March + 2.5m x 1.6m) which was significantly different from all other treatments. Maximum number of flowers plant^{-1} (285.33 in 24 month of cropping duration) was reported in T_7 treatment. Minimum days required in flower initiation and least days taken from fruit setting to harvesting in T_3 treatment might be due to more total leaf surfaces exposed to light due to wider spacing between rows, which increased the metabolism of the plant causing early physiological maturity and flowering. The enhanced yield components might be due to the fact that wider space availability between the rows and closer space between plants is favourable for more sun light penetrates within the crop canopy leading to increased photosynthesis area (total leaf area), thus higher photosynthetic rate and accumulation of more assimilates which in turn increased the sink size and finally increased yield and quality of fruits. Higher yield attributes of papaya under wider row space planting due to better availability of resources was also noted by Bhardwaj et al (2013) in papaya. Mehta et al (2012) they were reported that the proper crop geometry significantly increases yield, quality of seed, profitability and productivity of dill. The present study gets ample support from the work of Singh and Singh (1998), Kudada and Prasad (1999) in papaya.

Seedling transplanting dates also play a significant role on quality and yield of fruit in papaya. The seedling transplanted in the month of March the fruiting cycle of papaya was started in the month of August - September (154 DAT), which was coincide with suitable climatic condition (Temp. 28-32°C with 50-60% RH) for maximum flowering, fruit setting, fruit retention and development of fruit and harvesting of fruits in month of March-April before on-set of sever hot season, these conditions congenial for enhancing yield and quality of fruits. Bhardwaj et al (2013) also observed that the transplanting of papaya seedling in the month of March significantly increase number of flower, fruits, fruit set per cent and yield due to coincide with favorable climatic condition for first flowering and fruiting. Similar results were also in conformity with the finding of Muthukrishnan and Irulappan (1990), Singh and Singh (1998) in papaya plants.

Quality parameters

The maximum leaf chlorophyll content (3.38 um $100g^{-1}$ leaf) was observed in T_1 treatment, which was at par with T_4 (3.36 um $100g^{-1}$ leaf) and minimum in treatment T_8. Higher chlorophyll content in wider space planting might be due to high light penetration at lower leafy portion of the plants and availability of nutrient and water also higher than other crop geometry. Similar result was also reported by Bhardwaj et al (2013) in papaya and Bhardwaj and Agrawal (2014) in fennel.

It was interesting to know that the seedling transplanting dates and crop geometry exhibited a significant effect on the fruit quality parameter viz., TSS, acidity, total sugar, ascorbic acid, pulp thickness and overall quality score of fruits (pulp colour, cavity size, seed content, skin colour, size and shape of papaya fruits) (Table 5). In the present investigation, the plant raised under high density (2500 plant ha^{-1}) with wider line spacing exhibited superior fruit quality and extended harvesting period. The sweetness of papaya, mainly assessed by TSS (total soluble solids) content and maximum TSS (11.80°Brix) was reported in T_3 treatment which was statistically similar to T_1 (11.78°Brix) and T_2 (11.75°Brix), and rest of the treatments was significantly different and lowest TSS (11.17°Brix) was in T_8. Lower acidity in papaya fruit increase public choice and market value of the fruits. The minimum acidity (1.30%) was observed in T_3 treatment, which was *at par* with T_1 (1.32%) and T_2 (1.31%), and rest of the treatments was significantly different and highest acidity (1.45%) was in T_9 treatment. Maximum total sugar (7.97%), highest ascorbic acid (58.35 mg $100g^{-1}$ of fruit pulp), pulp thickness (3.20 cm) and maximum overall fruit quality score (8.36) was also observed in T_3 treatment. This probably due to the fact that papaya planted in wider line space and closer plant space (2.5m x 1.6m), there is no significant change in plant population per hectare and high light penetration at lower leafy portion of the plants due to wider line spacing which is positive for increased rate of photosynthesis and accumulate more dry matter in fruits which ultimately resulted in higher quality of the fruits. Higher acidity in higher plant population (2m x 2m) may be due to shade effect where sugar conversion from organic acid is hampered due to lack of sufficient light. Moreover, lower

Table 1. Effect of transplanting dates and crop geometry on plant height of papaya cv. Red Lady

Treatments	Plant height (cm)							
	3 MAT	6 MAT	9 MAT	12 MAT	15 MAT	18 MAT	21 MAT	24 MAT
T_1	61.90	153.05	201.68	236.84	267.10	271.92	284.87	289.61
T_2	54.12	129.30	173.68	212.88	240.50	245.87	251.77	254.56
T_3	49.47	125.28	166.68	201.92	223.45	228.82	235.87	239.96
T_4	77.83	162.65	191.62	212.01	220.28	234.34	241.99	246.58
T_5	69.87	145.90	175.62	197.02	204.33	219.34	235.09	237.83
T_6	62.91	136.64	168.62	191.00	200.33	214.34	226.29	229.44
T_7	71.17	143.04	170.38	185.52	190.37	201.25	207.69	209.20
T_8	61.30	128.00	157.38	175.50	178.37	182.25	188.29	185.78
T_9	56.25	122.25	152.38	165.47	167.57	179.55	184.30	191.58
S. Em ±	6.43	1.859	4.011	5.862	6.102	5.054	5.433	6.513
CD at 5%	2.17	5.579	12.033	17.586	18.308	15.162	16.299	19.540

*All data in table are pooled of 2011-12 & 2013-14. MAT= months after transplanting

Table 2. Effect of transplanting dates and crop geometry on stem girth of papaya cv. Red Lady

Treatments	Stem girth (cm)							
	3 MAT	6 MAT	9 MAT	12 MAT	15 MAT	18 MAT	21 MAT	24 MAT
T_1	8.99	18.80	27.40	34.70	40.16	44.60	48.20	50.76
T_2	7.18	15.47	22.45	28.37	32.32	35.27	37.22	38.50
T_3	7.92	17.13	25.01	31.89	36.77	40.65	42.20	43.56
T_4	8.09	16.07	23.05	29.03	33.01	36.11	37.88	43.15
T_5	6.41	14.32	21.25	27.18	31.11	33.95	35.88	37.30
T_6	6.70	15.07	22.45	29.25	33.63	37.01	39.05	39.97
T_7	7.24	15.53	22.83	29.07	33.83	37.00	39.28	39.87
T_8	5.57	12.95	19.36	24.77	28.18	30.98	32.38	33.23
T_9	5.59	13.35	20.08	25.83	29.56	32.68	34.43	35.48
S. Em±	0.250	0.636	0.636	0.636	0.938	1.450	1.450	1.450
CD at 5%	0.751	1.908	1.908	1.908	2.814	4.352	4.352	4.352

Table 3. Effect of transplanting dates and crop geometry on leaf area and total number of leaves per plant of papaya cv. Red Lady

Treatments	Leaf area (m^2)			Number of total leaves, months after transplanting							
	3 MAT	12 MAT	24 MAT	3 MAT	6 MAT	9 MAT	12 MAT	15 MAT	18 MAT	21 MAT	24 MAT
T_1	1.80	6.25	3.84	9.30	17.55	25.17	31.55	36.55	39.55	41.55	42.45
T_2	1.57	5.17	3.00	8.20	15.25	21.30	26.65	29.45	31.45	34.95	34.25
T_3	1.62	5.73	3.20	8.25	16.30	23.55	29.45	33.45	36.35	38.45	39.45
T_4	2.40	6.14	3.50	12.22	19.47	29.00	33.00	34.10	36.10	27.00	38.05
T_5	2.10	4.48	3.04	10.26	15.56	21.30	24.10	26.10	28.30	29.50	30.50
T_6	2.20	5.13	3.43	11.31	17.51	24.10	28.00	30.90	33.10	34.00	34.10
T_7	2.01	5.08	3.23	10.10	16.10	21.47	25.27	28.87	30.17	33.47	35.37
T_8	1.84	4.03	2.61	9.25	13.60	17.47	20.07	22.37	24.47	25.57	25.87
T_9	1.63	4.52	2.71	8.50	13.10	19.47	22.47	24.97	26.37	27.17	28.67
SEm±	0.092	0.159	0.102	0.487	0.487	1.162	1.162	1.162	1.162	1.162	1.162
CD at 5%	0.278	0.478	0.307	1.463	1.463	3.487	3.487	3.487	3.487	3.487	3.487

* All data in table are pooled of 2011-12 & 2013-14. MAT= months after transplanting

Table 4. Effect of transplanting dates and crop geometry on yield attributes and economics of papaya cv. Red Lady

Treatments	Days taken to first flower initiation	Number of flowers plant^{-1}	Fruit set (%)	Fruit retention (%)	Number of fruit plant^{-1}	Days taken fruit set to harvest	Fruit weight (kg)	Fruit yield plant^{-1} (kg)	Fruit yield ha^{-1} (q)	Net return (Rs.in lakh)	B:C ratio
T_1	165.65	263.70	45.25	69.11	82.46	126.32	1.98	163.28	1814.05	7.617	3.24
T_2	157.50	173.65	51.33	71.40	63.64	120.27	1.28	81.46	2036.55	8.841	3.76
T_3	154.40	155.60	57.70	75.50	67.78	112.12	1.40	94.90	2372.47	10.689	4.54
T_4	169.14	278.79	42.17	66.87	78.61	132.39	1.91	150.14	1668.03	7.007	2.88
T_5	166.19	179.14	47.84	69.17	59.27	123.34	1.25	74.09	1852.25	8.021	3.31
T_6	163.39	159.39	53.79	72.92	62.51	125.39	1.32	82.52	2062.89	9.179	3.80
T_7	169.38	285.33	37.73	64.73	69.69	131.58	1.75	121.96	1355.03	5.093	2.39
T_8	165.33	193.38	42.53	61.73	50.78	123.38	1.15	58.39	1459.80	5.669	2.64
T_9	161.08	175.13	48.83	65.73	56.22	125.38	1.28	71.96	1798.90	7.534	3.43
S Em±	1.603	6.259	1.570	1.570	1.952	1.472	0.044	3.932	45.137	0.111	0.066
CD at 5%	4.809	18.778	4.712	4.712	5.857	4.418	0.134	11.796	135.413	0.335	0.200

Table 5. Effect of transplanting dates on quality of papaya cv. Red Lady.

Treatments	TSS of fruit pulp (°B)	Acidity (%)	Total sugar (%)	Ascorbic acid (mg/100g pulp)	Pulp thickness (cm)	Overall organoleptic score (out of 10 marks)	Leaf chlorophyll content (mg/g leaf)	
							6 MAT	24 MAT
T_1	11.78	1.31	7.92	57.20	3.10	7.82	3.43	3.38
T_2	11.75	1.32	7.78	58.15	3.15	7.46	3.38	3.32
T_3	11.80	1.30	7.97	58.35	3.20	8.36	3.39	3.34
T_4	11.50	1.40	7.90	56.52	2.70	7.30	3.41	3.36
T_5	11.45	1.43	7.75	57.05	2.75	6.90	3.37	3.30
T_6	11.52	1.42	7.82	57.94	2.80	7.95	3.38	3.33
T_7	11.26	1.43	7.84	55.08	2.45	7.15	3.40	3.35
T_8	11.17	1.45	7.72	55.63	2.53	6.75	3.32	3.29
T_9	11.21	1.44	7.75	56.81	2.58	7.50	3.36	3.31
SEm ±	0.576	0.016	0.078	1.570	0.008	0.162	0.008	0.008
CD at 5%	0.172	0.048	0.235	4.712	0.026	0.486	0.026	0.026

* All data in table are pooled of 2011-12 & 2013-14. MAT= months after transplanting

total sugar in late transplanted (September) and 2m x 2m crop geometry plants may be due to less conversion of sugar from starch. The present study support from the work of Reddy (1991), Chaudhuri and Baruah (2010) in Banana.

Occurrence of abiotic stresses

Occurrence of papaya leaf curl and ring spot virus was observed throughout the investigation period. Least in viral infection was observed with transplanting in first week of March with 2.5 m x 1.6 m crop geometry (Fig.2 and Fig.3) The minimum incidence of leaf curl virus (27.52 %) and papaya ringspot virus (26.30 %) was observed in T_3 treatment (Ist week of March + 2.5m x 1.6m), whereas maximum incidence of leaf curl virus (42.57%) and papaya ring spot virus (30.45%) at 18 month after transplanting was reported in T_8 treatment (Ist week of September + 2m x 2m). The papaya leaf curl virus was transmitted by white fly and its infestation is higher in weed infested field. Change in crop geometry (wider line spacing and closer plant spacing) for weed management by tractor operated machine, which was significantly reduces weed infestation as well as white fly population in initial stage of the plants. However, March transplanting was found to be safer in respect to virus infestation because at that time the weed and vector population was very low due to high temperature and low relative humidity upto month of July. Mora-Aguilera et al (1996) reported the usefulness of transplanting dates in controlling papaya ringspot virus in Maxico. Occurrence of virus infestation influenced by different planting months was also reported by Singh and Singh (1998), Ray et al (1999), Kudada and Prasad (1999) in papaya. Similarly Bhardwaj and Agrawal (2014) was also observed that minimum infestation of disease in fennel, when crop was planted in higher line spacing and low plant spacing method then other crop geometry.

The minimum sun scald and frost injury (32.25%) was observed in T_2 treatment whereas highest incidence (89.10%) was reported in T_8 treatment (Fig. 4). The possible explanation of minimum incidence of abiotic stress (sun scald and frost) in the later transplanting dates (First week of July) and close planting (2m x 2m) due to favorable environmental condition and high density planting reduce effect of sun scald and frost by shading effect on each other. Similar results are also reported by Bhardwaj et al (2013) in papaya crop.

Conclusion

The papaya seedling transplanted in first week of March in 3m x 3m crop geometry gave better vegetative growth rates and development compared to other treatments. On the same date of transplanting with 2.5m x1.6 m (2500 plants ha^{-1}) crop geometry recorded maximum fruit set, retention, yield ha^{-1} and better quality attributes of fruits and highest net return and benefit: cost ratio along with minimum days to first flower initiation and fruit set to harvest. In addition to this, this transplanting date (Ist week of March) and crop geometry (2.5 x 1.6 m) also reduce the severity of leaf curl and papaya ring spot virus including comparatively less incidence of sun scald and frost injury. Thus, March transplanting with 2.5 m x 1.6 m crop geometry treatment combination (T_3) is much suitable for higher yield with better fruit quality under agro-climatic conditions of South- West Rajasthan.

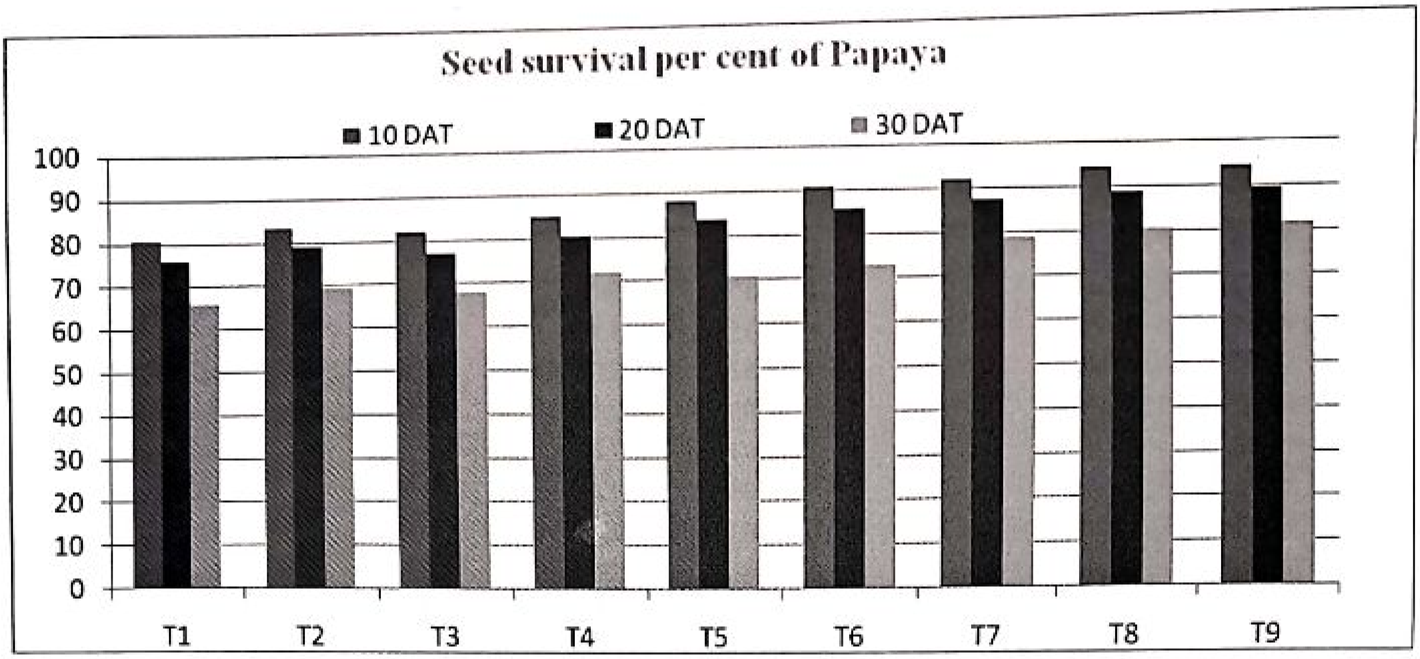


Figure 1. Effect of transplanting dates and crop geometry on field survival of seedlings of papaya.

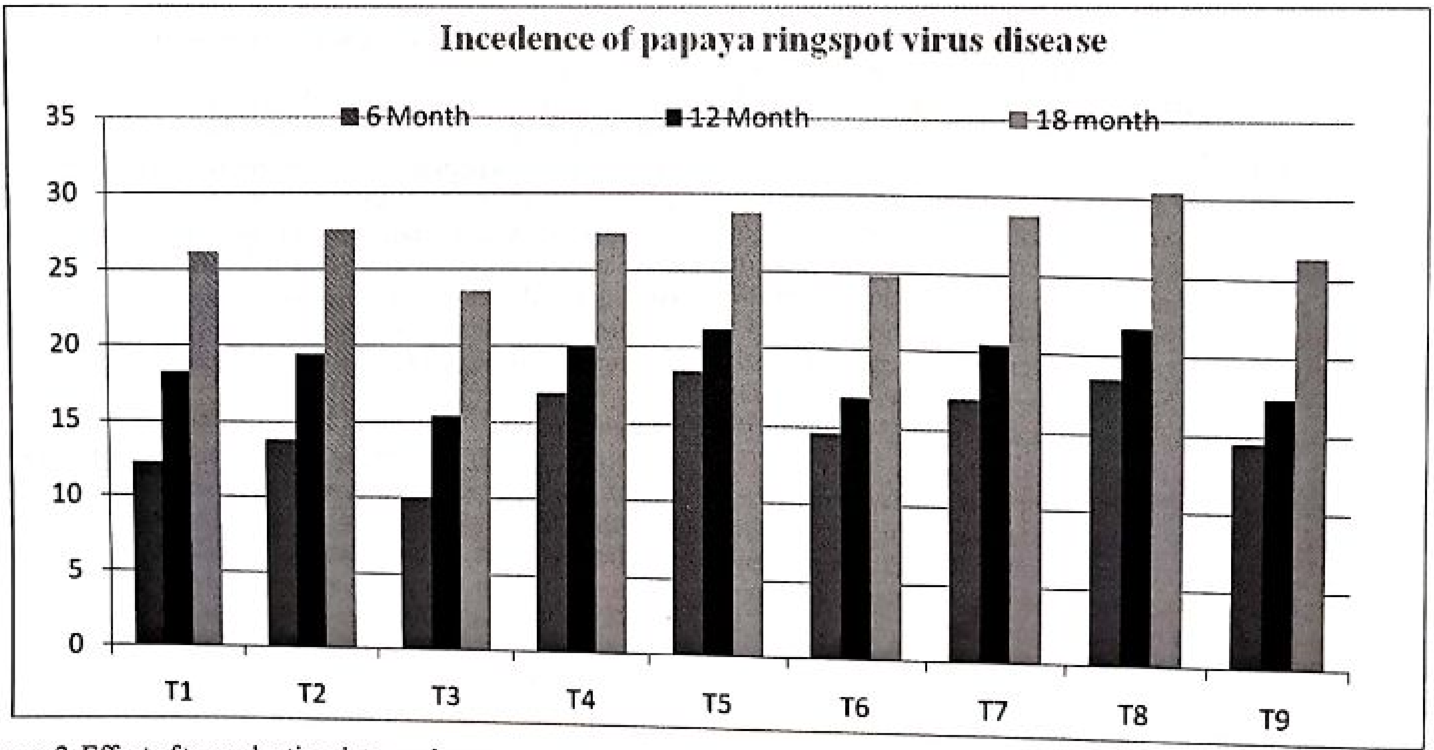


Figure 2. Effect of transplanting dates and crop geometry on incidence of papaya ring spot virus in papaya.

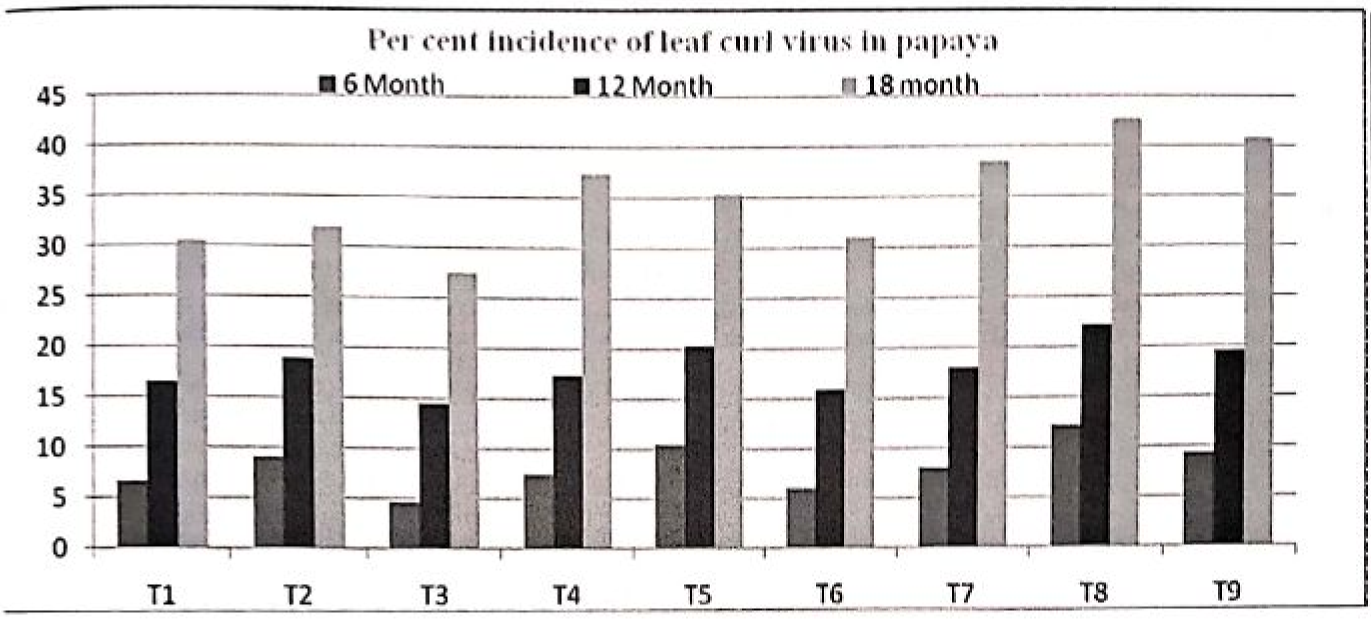
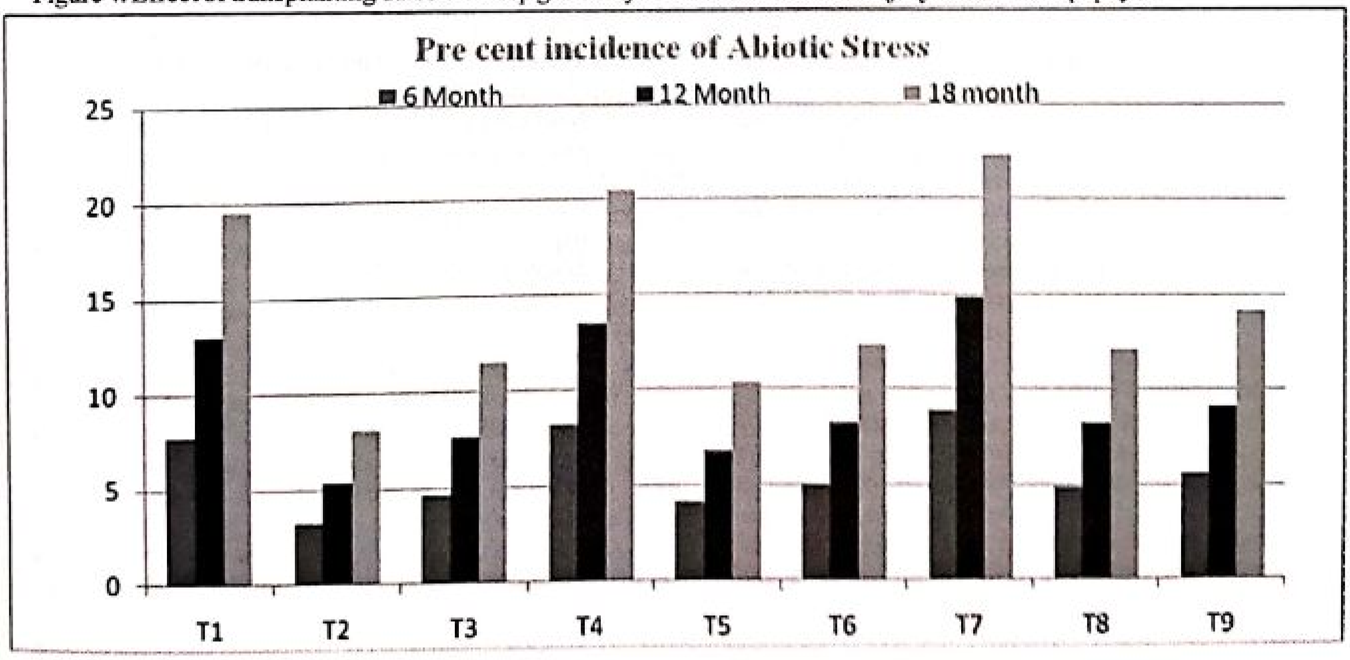


Figure 3. Effect of transplanting dates and crop geometry on incidence of leaf curl in papaya.

Figure 4. Effect of transplanting dates and crop geometry on sun scald and frost injury incidence in papaya.



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