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Effect of Drip Fertigation on Growth and Yield of Papaya (*Carica papaya* L.) in Semi-arid Tropical Region of Maharashtra

V. V. SAGVEKAR[1]*, A. P. CHAVAN[2], V. N. SHETYE[3], K. V. MALSHE[4] and M. B. DHONDE[5]

[1]Agricultural Technical School, Lanja - 416 712, Maharashtra
[2] Dept. of Agronomy, College of Agriculture, Dr. B. S. Konkan Krishi Vidyapeeth Dapoli - 415 712, Maharashtra
[3]Agricultural Research Station, Dr. B. S. Konkan Krishi Vidyapeeth, Phondaghat Kankawali - 416 601, Maharashtra
[4] Mango Research Sub Centre, Rameshwar, Deogad - 416 806, Maharashtra
[5] Dept. of Agronomy, Mahatma Phule Krishi Vidyapeeth, Rahuri, - 413 722, Maharashtra

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The experiment was conducted for two consecutive years of 2015-16 and 2016-17 at Irrigation Water Management Farm, Mahatma Phule Krishi Vidyapeeth, Rahuri to assess the effect of drip fertigation on growth and yield of papaya (*Carica papaya* L.) cv. Red lady. The experiment was laid out in split plot design with three replications. The treatments comprised of four levels of drip irrigation *viz*., 60, 80, 100 and 120% of ET_c as main plot treatments and fertigation levels *viz*., 75, 100 and 125% of RDF as subplot treatments. Surface irrigation with soil surface application of 100% RDF was taken as control. The plant height, stem girth, number of functional leaves, and plant spread of papaya were significantly influenced by different drip irrigation levels. Significantly higher plant height (322.05 cm), stem girth (48.17 cm), number of functional leaves (38.27), E-W plant spread (294.99 cm) and N-S spread (290.56 cm) was recorded when crop was irrigated at 120% ET_c. Fertigation with 125% RDF registered significantly higher plant height (287.99 cm), stem girth (45.49 cm), number of functional leaves (35.52), E-W plant spread (284.41 cm) and N-S plant spread (280.00 cm). Drip irrigation at 125% ET_c recorded significantly higher papaya yield (222.97 t ha^{-1}) which was at par with 100% ET_c (207.96 t ha^{-1}). On the other hand, fertigation level of 125% RDF registered the maximum papaya yield (211.35 t ha^{-1}) which was 90.80% higher over control, respectively. Significant interaction effect of drip irrigation and fertigation levels on papaya yield was observed and highest yield (255.09 t ha^{-1}) was obtained with the treatment combination of drip irrigation at 100% ET_c with fertigation of 125% RDF which was at par with drip irrigation at 120% ET_c with fertigation of 125% RDF.

(***Key words:*** *Drip irrigation, Fertigation, Growth, Papaya, Yield*)

Papaya (*Carica papaya* L.) is an important commercial fruit crop of India. It is an excellent source of vitamin C and A. Excessive vegetative growth, imbalanced use of organic and inorganic fertilizers and poor agronomic practices largely attribute to low productivity of papaya in India. A review of the current literature on the use of fertigation by ICRISAT, suggests that to make agriculture sustainable and economically viable, there is need to promote fertigation on a large scale by the concerned stakeholders/ farmers (Solaimalai *et al*., 2005). Although the use of chemical fertilizer is the fastest way of counteracting the pace of nutrient depletion, its increasing cost and limited availability discourage the farmers from using these inputs in balanced proportions thereby paving way for the problems of environmental pollution. Under this context, practice of usage of chemical fertilizers through drip irrigation will result in sustainable crop yields without any detrimental effect on agro ecological balance. Irrigating the papaya through drip results in 54% saving of irrigation water and 28.84% increase in the yield over surface irrigation (Biswas *et al*., 1999).

Fertilizer is the most critical input which seriously affects the growth and yield of crop, especially in fruit crops like papaya. Nitrogen, phosphorus and potassium influence the papaya crop in many ways. Nitrogen promotes vegetative growth, flower and fruit set. High level of phosphorus throughout root zone is essential for rapid root development and good utilization of water and other nutrients by plant. Phosphorous has pronounced effect on the flowering, in combination with N and K improves peel colour, taste, hardiness

**Corresponding author:* E-mail: vvsagvekar.2011@gmail.com

and vitamin C content and hastens maturity. Potassium tends to increase fruit size, fruit quality and rectifies many disorders. It also helps in decreasing incidence of irregular shaped fruits.

Hence, with the above background the present investigation was carried out to study the effect of drip fertigation on the growth and yield of papaya cv. Red Lady.

MATERIAL AND METHODS

Field experiment was conducted for two consecutive years during 2015-16 at Irrigation Water Management Research Farm, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar (Maharashtra) situated at 19° 21´ N latitude and 74° 38´ E longitude and altitude of about 436 meters above the mean sea level (MSL) to study the effect of drip fertigation on growth and yield of papaya. The area falls under semi-arid tropical zone and receives and annual average rainfall of 520 mm.

The experiment was laid out in split plot design with three replications. Four drip irrigation levels based on crop evapo-transpiration (ET_c) *i.e.*, I_1- 60% ET_c, I_2- 80% ET_c, I_3- 100% ET_c and I_4- 120% ET_c were applied in main plot treatment, while three fertigation levels *viz*., F_1- 75% recommended dose of fertilizers (RDF, N: P_2O_5:K_2O::250:250:500 g plant^{-1}), F_2- 100% RDF and F_3- 125% RDF were scheduled in sub plot treatment. Papaya cv. Red Lady was used as the test crop. The pits of 30 x 30 x 30 cm at a distance of 1.8 m x 1.8 m were dug out about 15 days before transplanting and kept open in sunlight for 15 days. The pits were then filled with top soil along with well decomposed fine textured farm yard manure @ 10 kg per pit. Drip system was installed on broad bed furrow by connecting main and sub mainline with laterals. Irrigation was applied at every alternate day based on crop evapotranspiration (ET_c). Crop water requirement (ET_c) was calculated by multiplying reference crop evapotranspiration (ET_0) data obtained from the "*Phule Jal*" software with crop coefficient (K_c). The K_c values used were 0.9 for initial, 1.1 for middle and 0.9 for end stages of papaya crop during experimentation.

The drip system was operated at alternate day and the optimum operating pressure was 1.2 kg cm^{-2}. Before commencing irrigation treatments, the uniformity co-efficient test for the drippers was undertaken and it found to be 91%. Water soluble fertilizers were applied as per treatments through fertigation in forty five splits with the help of fertigation unit and lateral cock. Fertigation of RDF of NPK (250: 250: 500 g N, P_2O_5, K_2O plant^{-1}) was started 30 days after transplanting through injection pump as per the treatment. The fertigation was done through water soluble fertilizer (19: 19: 19 and 00: 00: 50 NPK grade). The details of fertigation schedule are presented in Table 1.

Table 1. *Details of fertigation schedule*

Crop stage	Days	No of splits	Nutrients g plant^{-1}		
			N	P	K
Transplanting to flower emergence	90	9	125 (50%)	125 (50%)	125 (25%)
Flowering to first harvest	120	17	62.5 (25%)	62.5 (25%)	125 (25%)
First harvest to end of first cropping period	150	19	62.5 (25%)	62.5 (25%)	250 (50%)
Total	360	45	250 (100%)	250 (100%)	500 (100%)

A control treatment with recommended package of practice for papaya was laid out separately. 100% RDF @ 250, 250 and 500 g plant^{-1} of N, P_2O_5 and K_2O, respectively were applied in four equal splits at 1, 3, 5 and 7 months after transplanting. Irrigation of 5 cm was applied as surface irrigation at 50 mm cumulative pan evaporation. The net depth of irrigation was calculated using the relationship given below (Michael, 2008).

Net depth of irrigation= (FC-PWP)/100 x bulk density x root zone depth x MAD)

where, FC = Field capacity of soil (% by weight)

PWP = Permanent wilting point (% by weight)

MAD = Maximum allowable depletion (%)

Bulk density = Mg m^{-3}

Root zone depth = m

The effective root zone was considered as 0.8 m and maximum allowable depletion (MAD) was considered as (50%). The quantity of irrigation water that was applied to the experimental plot was measured with a 15 cm throat size parshall flume, installed near the corner of experimental plot.

Daily evaporation recorded with the help of USWB Class I pan evaporimeter installed at meteorological observatory was used in the study. Cumulative pan evaporation (CPE) was taken as sum of the daily evaporation. The required volume of water (2268 litres $plot^{-1}$) was applied to maintain 50 mm irrigation depth. The time of water applied was measured by stop watch.

Growth parameters *viz*., stem girth, plant height, and yield attributes (number of fruits $plant^{-1}$, average fruit weight and fruit yield $plant^{-1}$) were recorded by adopting standard procedures. The papaya obtained from each harvest was weighed and yield of all pickings were accumulated and expressed in t ha^{-1}. Statistical analysis of the data was carried out according to split plot design. The experimental data were pooled and the mean data for two years are subjected to statistical scrutiny as per methods suggested by Panse and Sukhatme (1985). The 'F' test of significance was used for testing the null hypothesis and appropriate standard error of mean (S.E. mean) for each treatment effect was calculated. Where the treatment effects were significant, the critical difference (CD) at 5 % probability level was worked out for testing the significance of treatment differences.

RESULTS AND DISCUSSIONS

Growth parameters

The plant height, stem girth, number of functional leaves, E-W plant spread and N-W plant spread of papaya were significantly influenced by drip irrigation levels. Significantly higher plant height (322.05 cm), stem girth (48.17 cm) was recorded when crop was irrigated at 120% ET_c as compared to the rest of the treatments. This treatment also registered higher number of functional leaves (38), E-W plant spread (294.99 cm) and N-S spread (290.56 cm) however it was at par with 100% ET_c. Significantly lower values of growth parameters were recorded in the treatment where irrigation was applied at 60% ET_c. In the control treatment the growth parameters were the lowest (Table 2).

The increase in plant height, stem girth, number of functional leaves, E-W plant spread and N-W plant spread of papaya at drip irrigation level of 120% of ET_c may be due to retention of higher soil moisture at near field capacity levels. Adequate supply of the soil moisture in the root zone ensured better availability and absorption of the essential nutrients from soil which led to better growth of the plants. Similar results have been reported by Jeyakumar *et al*. (2010) and Tank *et al*. (2011).

The growth parameters *viz*., plant height, stem girth, number of functional leaves, E-W plant spread and N-W plant spread of papaya were influenced significantly by the different fertigation levels (Table 2). Fertigation of 125% RDF registered significantly higher plant height (287.99 cm), stem girth (45.49 cm), number of functional leaves (36), E-W plant spread (284.41 cm) and N-S plant spread (280 cm) among the fertigation treatments, however, it was at par with 100% RDF except in plant height. The lowest growth parameters were recorded in the control treatment (Table 2).

The application of 125% of RDF through fertigation of water soluble fertilisers spread over the growth period and divided in to 45 splits according to growth stages for papaya starting from 30 days after transplanting (DAT) was able to meet the nutritional requirement of crop throughout crop development. This might have resulted in higher uptake of the nutrients during growth period, which attributed to increased protein and protoplasm synthesis ultimately leading to better growth and development of the plants. The results obtained in this study are in agreement with those reported by earlier workers (Sadarunnisa *et al*., 2010; Sharma *et al*., 2005)

No significant interaction between the different drip irrigation and fertigation levels was found in respect of the growth parameters.

Yield components and yield

The data on yield components and yield of papaya are presented in Table 2. It was observed that there was significant influence of the drip irrigation levels on the

Table 2. *Effect of drip fertigation on growth and yield of papaya (Mean data for two years)*

Treatment	Plant height (cm)	Stem girth (cm)	No. of functional leaves	Plant spread (cm)		No. of fruits plant^{-1}	Weight of fruit kg plant^{-1}	Fruit yield t ha^{-1}
				E-W	N-S			
A. Drip irrigation levels (I)								
I_1 : 60% ET_c	215.89	39.11	30	253.72	250.28	37	43.10	124.17
I_2 : 80% ET_c	247.20	42.51	33	275.23	269.45	46	56.65	160.27
I_3 : 100% ET_c	286.96	45.01	36	280.45	275.56	52	73.83	207.96
I_4 : 120% ET_c	322.05	48.17	38	294.99	290.56	56	78.53	222.97
S.Em. (±)	5.91	0.91	1	6.44	6.55	1	1.92	5.97
C.D. at 5 %	20.44	3.15	4	22.27	22.67	3	5.91	18.39
B. Fertigation levels (F)								
F_1 : 75% RDF	248.34	41.76	33	264.29	259.38	42	53.80	151.86
F_2 : 100% RDF	267.75	43.85	34	279.58	275.00	48	61.35	173.32
F_3 : 125% RDF	287.99	45.49	36	284.41	280.00	53	73.94	211.35
S.Em. (±)	4.57	0.87	1	4.53	4.61	0.4	1.12	3.03
C.D. at 5 %	13.70	2.60	2	13.56	13.82	1	3.24	8.72
C. Interaction (IxF)								
I_1F_1	187.90	35.63	28	235.17	220.83	27	35.54	102.41
I_1F_2	221.83	40.43	30	260.67	258.33	40	42.55	122.45
I_1F_3	237.93	41.27	32	275.33	271.67	43	57.19	147.63
I_2F_1	232.17	42.17	32	268.00	263.33	40	47.01	131.61
I_2F_2	242.90	41.53	32	277.33	270.00	44	54.25	154.08
I_2F_3	266.52	43.83	35	280.33	275.00	53	68.68	195.10
I_3F_1	270.13	43.83	35	279.00	271.33	47	61.13	173.65
I_3F_2	286.27	46.07	37	283.00	278.33	51	70.48	195.13
I_3F_3	304.47	45.13	35	279.33	275.00	58	89.86	255.09
I_4F_1	303.13	45.40	36	285.00	280.00	53	71.50	199.74
I_4F_2	320.00	47.37	38	297.33	293.33	57	78.10	221.61
I_4F_3	343.02	51.73	41	302.63	298.33	58	85.99	247.57
S.Em. (±)	9.14	1.74	2	9.30	9.22	1	3.18	8.57
C.D. at 5 %	NS	NS	NS	NS	NS	3	9.15	24.67
Control: Surface irrigation + RDF	199.15	37.70	29	243.83	241.50	34	39.04	110.77

number of papaya fruits and weight of fruits plant^{-1}. Irrigation level of 120% ET_c significantly recorded maximum number of papaya fruits and weight of fruits (55.95 and 78.53 kg plant^{-1}, respectively) as compared to the other treatments, except in case of weight of fruit which was at par with 100% ET_c (73.83 kg plant^{-1}). This was followed by 60% ET_c, in which 37 no. of fruits and 43.10 kg plant^{-1} fruit weight were observed.

The higher irrigation regime *i.e.*, 120% ET_c maintained the soil moisture at field capacity throughout the crop growth period resulting in better nutrient uptake which enhanced all the growth attributes of the crop particularly the canopy spread of the plant and number of functional leaves. This might have resulted in maximum absorption of photosynthetically active radiation leading to higher rate of photosynthesis and dry matter accumulation through efficient translocation of photosynthates towards reproductive parts and thus more number of fruits and fruit weight plant^{-1}. The

results are in conformity with those reported by Santana *et al*. (2008) and Da Silva *et al*. (2013).

The fertigation levels also significantly influenced the number of papaya fruit and weight of fruits plant^{-1}. Significantly highest number of fruits and fruit weight (53 and 73.94 kg plant^{-1}, respectively) was recorded in the treatment consisting of fertigation @125% RDF followed by fertigation @100% RDF (48 and 61.35 kg plant^{-1}, respectively) and @75% RDF (42 and 53.80 kg plant^{-1}, respectively) (Table 2). Split application of fertilizers to papaya up to effective fruits pickings favoured better nutrient availability across the growth period leading to increased growth attributes accompanied with more absorption of photosynthetically active radiation reflected in higher photosynthetic rate. The photosynthates thus synthesised were effectively translocated towards fruit formation finally resulting in increase in fruit number and weight (Chandrakumar *et al*., 2001).

The interaction between drip irrigation levels and fertigation levels was found to have significant effect on the number of fruits and fruit yield plant^{-1}. Number of fruits plant^{-1} was significantly more under irrigation level of 120% ET_c coupled with 125% RDF (58) than rest of the treatment combinations but at par with the treatment combination I_4F_2 (irrigation level of 120% ET_c with 125% RDF fertigation) and I_3F_3 (irrigation level of 100% ET_c with 125% RDF fertigation). While in case of fruit weight plant^{-1}, it was significantly more under the treatment combination I_3F_3 (irrigation level of 100% ET_c with 125% RDF fertigation) than rest of the treatment combinations but was at par I_4F_2 (irrigation level of 120% ET_c with 125% RDF fertigation). The lowest no. of fruits (34) per plant and fruit weight (39.04 kg plant^{-1}) was recorded in the control treatment with surface irrigation with soil application of RDF.

The fruit yield of papaya was influenced significantly due to the different drip irrigation levels. From the data presented in Table 2, it is evident that significantly highest fruit yield of papaya (222.97 t ha^{-1}) was recorded in the treatment I_4- irrigation at 120% ET_c and lowest in I_1- irrigation at 60% ET_c (124.17 t ha^{-1}) but it was at par with 100% ET_c (207.96 t ha^{-1}). Drip irrigation applied at 120% ET_c, 100 % ET_c and 80 % ET_c recorded increases in fruit yield of papaya by 79.57, 67.48 and 29.07%, respectively over irrigation applied at 60% ET_c. On the other hand, the increase in yields recorded with irrigation applied at 120% ET_c, 100% ET_c and 80% ET_c was 101.28, 87.73, and 44.68%, respectively over the control (surface irrigation + RDF). The higher rate of photosynthates translocated to papaya fruits might have increased the fruit size, fruit weight and pulp weight and ultimately resulted in higher yield under the non stressed condition. Yield decrease under stress might be due to the adverse effect of moisture stress on the normal growth and development of plant (Awada *et al*., 1979; Deshmukh *et al*., 2014; Santana *et al*., 2008).

The fruit yield was influenced significantly due to the different fertigation levels and fertigation of 125% RDF recorded significantly higher fruit yield of papaya (211.35 t ha^{-1}) than fertigation of 100 RDF (173.32 t ha^{-1}) and 75% RDF (151.86 t ha^{-1}).

There was an increase in fruit yield by 39.17% and 14.13% at fertigation levels of 125% and 100% of RDF, respectively over that obtained with fertigation level of 75% of RDF. While the increase in fruit yields at fertigation levels of 125% of RDF, 100% of RDF and 75% of RDF was 90.80, 56.47 and 37.09%, respectively over control (surface irrigation with recommended practice). This might be due to uniform application of required quantity of nutrients through fertigation directly in vicinity of the root zone throughout crop growth period which increased the nutrient use efficiency. Better nutrient and water availability may have promoted the physiological process and efficient translocation of photosynthates towards reproductive organs which was reflected in higher papaya fruit yield. These results are in line with those of Jeyakumar *et al*. (2010) and Tank *et al*., (2011) who reported increases in fruit yield with fertigation of higher doses of fertilizer.

The interaction effect between drip irrigation levels and fertigation levels was found to be significant. The highest fruit yield of papaya (255.09 t ha^{-1}) was recorded in the treatment combination I_3F_3- irrigation level of 100% ET_c coupled with fertigation level of 125% RDF than rest of the treatment combinations and but it was at par with irrigation level of 120% ET_c coupled with 125% RDF (247.57 t ha^{-1}). In comparison, the lowest fruit yield of 110.77 t ha^{-1} was recorded in the control treatment with surface irrigation with soil application of RDF.

The results of the present field investigations revealed that drip irrigation at 100% ET_c on alternate day and weekly fertigation with 125% of recommended dose of fertilizer (250: 250: 500 N, P_2O_5, K_2O g $plant^{-1}$) in 45 splits (according to growth stages) registered higher growth, yield attributes and papaya fruit yield which was found to be the viable agro technique to realize the yield potential of papaya under semiarid tropical conditions of Maharashtra.

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