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Precision Farming in Papaya for the Enhancement of Fruit Yield and Quality

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ABSTRACT: The aim of the present study was to enhance the yield and quality of papaya through precision farming practices *viz*., raised bed cultivation, drip irrigation, fertigation, micro nutrient foliar spray, use of polyethylene mulches etc. The results of the study on precision farming practices in TNAU CO 8 papaya revealed that the highest fruit yield (73.45 kg/plant and 190.94t/ha) and quality was recorded in the treatment combination, T3 (Raised bed cultivation + Drip irrigation (80% ER) + Fertigation (75% RDF) + micronutrient spray $ZnSO_4$ 0.5% + boric acid (0.2%) at alternate months) indicating the efficient use of water and nutrients under the raised bed cultivation. The treatment (T1) with polyethylene mulching along with other practices as in T3 proved to be an inefficient technology for papaya as it caused the occurrence of root rot disease (*Phytophthora* spp.) due to the continuous water soaking in the collar region of the stem. Leaf nutrient status, though varied significantly among treatments, it did not follow a definite trend among the treatments.

Keywords: *Carica papaya*, L, precision farming, raised bed, drip fertigation, micro nutrients, yield and quality.

INTRODUCTION

Papaya (*Carica papaya* L.) belongs to the family Caricaceae and is a highly nutritive crop, rich in vitamins and minerals, especially vitamin A (2020 IU) and ascorbic acid (40-60mg/100g), including dietary fiber (Premchand *et al*., 2021). It has attained the status of a commercially and industrially important tropical fruit crop in India over the past decade. India is the largest producer and consumer of papaya covering an area of 1.44 lakh ha, producing 57.80 MT/ ha (NHB, second Advance Estimates, 2019-2020), and has vast export potential. India, though ranks first in area and production of papaya, still lot of challenges which curtail the production which needs to be addressed (Auxcilia *et al.,* 2020). Several factors such as irrigation, nutrition, variety, spacing, climatic conditions, etc. are responsible for better fruit production in papaya. Presently, growers face a wide array of problems that hinder the growth and production of papaya. The apparent and the most frequent constraints are found to be related to irrigation and nutrient availability during the critical physiological phases interconnected with different growth periods.

Papaya responds well to irrigation and adequate irrigation helps in better flower production, fruit set, fruit development, and continuous fruit production. Irrigation with 50 to 75 mm water every 3-4 weeks and irrigating the plants at 1.3 times the evapotranspiration has been recommended for papaya earlier under the flood irrigation systems. Later, Padmakumari and Sivanappan (1989) reported that this recommendation under drip irrigation produced a higher yield as compared to flood irrigation. A significant yield reduction can occur with water shortage at certain critical growth stages leading to reduced plant height, trunk diameter, and the number of leaves per tree, and also retarded growth and development of papaya fruits (Masri *et al.,* 1990).

The nutrient requirement of papaya differs from other crops as flower, fruit formation, and fruit development is a continuous and simultaneous phenomenon that is a unique nature of this crop. The source-sink capacity is also very high for this crop, which warrants efficient fertilizer application including foliar nutrition too. Studies conducted by Sadarunnisa *et al.* (2010) indicated that 75% N and K_2O when applied through drip recorded a yield of 100.42 kg/plant which was on par with the yield of plants supplied with 100% RDF (102.60 kg/plant) in papaya var. Red Lady. Similarly, Jeyakumar *et al.* (2010) studies revealed that the application of 100% recommended dose of N and K_2O (50 g N and 50 g K_2O) through drip irrigation resulted in flowering at the shortest height (96.32 cm) in CO 7 papaya. An increase in fruit weight, fruit length, fruit volume, circumference and latex yield, TSS, and total sugars were observed in papaya cv. CO 5 with the foliar spray of zinc sulfate (0.5%) along with boron (0.1 %) (Kavitha and Kumar 2001). Application of a bio-stimulant, humic acid along with foliar spray of micronutrients @ $ZnSO_4$ (0.5%) + $FeSO_4$ (0.5%) + $MgSO_4$ (0.5%) + $CuSO_4$ (0.5%) + Boric acid (0.1%) at 3rd, 5th and 7th MAP + biofertilizers increased the fruit yield (72.96 kg plant) in TNAU CO 8 papaya, (Deepika, 2014). Hence, papaya can be considered a highly responsive crop to the application of micronutrients.

Mulching through plastic film has been proved long back as an efficient technology for the conservation of soil moisture, weed control, etc. The black polythene film mulching is ideal for eliminating weeds, warming up soil for cooler seasons, and retaining soil's moisture while the clear plastic film works best for warming up the soil and encouraging faster plant growth early in the growing season and is not effective in eliminating weed growth. Mulching may improve soil biological activity since organic matter and microorganisms establish a favorable carbon balance in the soil for the maintenance of productivity. The decomposition of organic residues under plastic mulch adds organic acids to the soil resulting in low soil pH, which may increase the bioavailability of micronutrients such as Mn, Zn, Cu, and Fe. This was also evident from the increased Fe and Zn content in soil under plastic mulch as reported by Tisdale *et al*. (1990).

In papaya, several hi-tech practices such as irrigation at 75% of the Evaporation Replenishment (ER), 75% of RDF through fertigation, foliar application of micronutrients such as boron and zinc, and plastic mulching by various workers are standardized for improving crop productivity, the combined effect of these practices as a holistic package for improving productivity and its cost-effectiveness needs thorough study to establish a package of precision practices. Hence, the present study on "Precision farming in papaya for the enhancement of fruit yield and quality" was undertaken.

MATERIALS AND METHODS

The experiment was conducted on 2014 to 15 at the College Orchard, Department of Fruit Crops, Horticultural College & Research Institute, Tamil Nadu Agricultural University, Coimbatore-3. The trial was laid out in Randomized Complete Block Design (RCBD) with four replications. The treatments comprised of the following components.

a) Raised Bed cultivation
b) Drip irrigation (80% ER at all stages)
c) Fertigation (75% recommended dose of fertilizers (RDF))
d) Mulching with 100 micron UV stabilized black polyethylene
e) Micronutrient spray {($ZnSO_4$ (0.5%) + Boric acid (0.2%)} at alternate months starting from second month.

The treatment combinations are as follows

T1: a+b+c+d+e
T2: a+b+c+d
T3: a+b+c+e
T4: a + b+ e (100 % recommended dose of fertilizers – Pocket application of fertilizers)
T5: Control (Soil application of a recommended dose of fertilizers, basin irrigation, and no mulching)

The weather data (Maximum & Minimum temperature, Rainfall, Evaporation, Sunshine hours, and Relative humidity) during the crop growing period were recorded daily to calculate the daily water requirement of the crop for 80% ER (Bhattacharyya and Rao 1985). The water requirement was calculated using the formula given below

(CPE × Kp × Kc × Area ×Wp) – RF, where
CPE: Cumulative Pan Evaporation
RF: Effective Rainfall (mm)
Kp: Pan coefficient (0.75 – 0.8)
Kc: Crop coefficient (0.75 = initial; 1.10 = Grand growth; 1.00; latter growth)
Area: Spacing of the crop (1.8 x 1.8 m)
Wp: Wetting percent (0.4 = wider spacing crop; 0.8 = closer spacing crop)

The observations on growth, yield, and quality of papaya were recorded to study the integrated effect of fertigation and polythene mulching in TNAU CO 8 papaya.

RESULTS AND DISCUSSION

Among the treatments, plant biometric traits *viz.,* plant height at time of harvest was the lowest (156.76cm) for the treatment combination of Raised Bed cultivation+ Drip irrigation (80% ER at all stages) + Fertigation (75% RDF) + Mulching with 100 micron UV stabilized black polyethylene and treatment combination of Raised Bed cultivation + Drip irrigation (80% ER at all stages) + Micronutrient spray {($ZnSO_4$ (0.5%) + Boric acid (0.2%)} recorded 166.00 cm. However, an increase in plant height is not a desirable character for a papaya which reduces the economic life span of the crop. Medium-statured types, bearing fruits at a lower height on the trunk have greater significance in papaya (Singh, 1990). First bearing height is an important parameter, as it reflects on the overall yielding pattern, besides deciding the economic life span of the papaya tree. In the present study, the lowest bearing height (91.38 cm) was observed in Raised Bed cultivation + Drip irrigation (80% ER at all stages) + Fertigation (75%

RDF) +Mulching with 100 micron UV stabilized black polyethylene + Micronutrient spray {(ZnSO + (0.5%) + Boric acid (0.2%)} followed by treatment combination of Raised bed cultivation + Drip irrigation (80% ER) + Fertigation (75% RDF) + micronutrient spray $ZnSO_4$ 0.5% + boric acid (0.2%) at alternate months (95.71cm). Stem girth in papaya is the indication of vigour that was highest in Raised bed cultivation + Drip irrigation (80% ER) + Fertigation (75% RDF) + micronutrient spray $ZnSO_4$ 0.5% + boric acid (0.2%) (36.50 cm). Continuous application of nutrients through fertigation, irrigation, and micronutrients as a foliar spray once in two months might have ensured efficient allocation of nutrients and assimilation for the radial growth of the tree, during which, there is a gradual change in the orientation of phloem ray cells and sieve tubes for improving the bark thickness (Bhalerao *et al.,* 2014; Bisht *et al.,* 2010).

As far as papaya is concerned, the leaf production and leaf area are important phenomena especially at the time of fruiting, since every leaf is acting as a source of assimilation for all the developing fruits. Petiole girth rather than petiole length is more indicative of the healthiness of the plant (Shekhar *et al.,* 2010; Singh *et al.,* 2010). On the other hand, longer petioles are more advantageous than the shorter ones because the fruits in the central axis could be better exposed to sunlight, necessary for fruit growth and quality (Reddy *et al.,* 1986). In the present study also these vigor indicators for enhancing the papaya production were observed in terms of more number of leaves (33.03), greater leaf area (2198.75 cm^2), longer petiole length (75.27 cm), and better petiole girth (8.28 cm) with the application of Raised bed cultivation + Drip irrigation (80% ER) + Fertigation (75% RDF) + micronutrient spray $ZnSO_4$ 0.5% + boric acid (0.2%).

The same treatment combinations also significantly enhanced the fruit yield (73.45 kg/plant and 190.94t/ha) and quality in terms of fruit circumference (54.48 cm), cavity index (48.63), pulp thickness (3.08 cm), and Total Soluble Solids (15.80 brix) with the highest Benefit-Cost Ratio(BCR) of 2.93. On the other hand, the lowest yield (33.64 kg/plant and 87.46 t/ha) with a BCR of 1.54 was recorded in the control where soil application of a recommended dose of fertilizers along with basin irrigation was practiced. The growth and yield enhancement in fertigated plants compared to flood irrigation might be due to a constant and continuous supply of water and nutrients in the soluble form at the root zone ensuring better availability of nutrients as validated by Mahalakshmi *et al*. (2001); Kavino *et al.* (2004) in a banana crop. Various studies in papaya authenticated that higher fruit length, diameter, circumference, weight, and volume in drip fertigated plants might be due to the production of more photosynthates from larger leaf areas resulting in better transfer of photosynthates to the sink. Moreover, the present investigation gave an insight into the correlation between the TSS with the frequency of irrigation (Ghanta *et al.,* 1995; Jeyakumar *et al*., 2001; Modi *et al.,* 2012; Manjunatha *et al.,* 2014). It was observed that there was a general reduction in TSS when irrigation is given at frequent intervals as corroborated by Hegde and Srinivas (1990) in bananas. The treatment T1, wherein the precision practices are similar to T3, but for the addition of plastic mulching recorded the second-best yield ((59.20 kg/plant and 153.92t/ha). The mortality of plants was noticed in the mulching treatment with the incidence of root rot disease (*Phytophthora* spp.) that escalated due to the continuous soaking of water at the root zone.

Soil nutrient analysis for the treatment of T3 revealed that the organic carbon content (0.31%), available N (179 kg/ha), available K (684 kg/ha), available Cu (4.78 ppm), available Mn (5.05 ppm) and available B (0.92 ppm) were higher as compared to other treatments. The second best treatment, T1 with black polythene mulch along with other practices registered the higher values for available Zn (3.74 ppm) and available Fe (4.98 ppm) contents in the soil. The decomposition of organic residues under plastic mulch adds organic acids to the soil resulting in low soil pH, which might have increased the bioavailability of micronutrients (Purohit, 1977; Mustaffa, 1988). This was also evident from the increased Fe and Zn content in soil under plastic mulch as reported by Tisdale *et al*. (1990) which implies that the plastic mulch not only eliminates weeds, warm up the soil for cooler seasons and retain soil's moisture but also conserves the soil nutrients. Fruit yield was the highest (73.45 kg/plant and 190.94t/ha) in the input combination of Raised bed cultivation + Drip irrigation (80% ER) + Fertigation (75% RDF) + micronutrient spray $ZnSO_4$ 0.5% + boric acid (0.2%) at alternate months. The above treatment combination also enhanced the fruit biometric and quality parameters *viz*., fruit length (41.23cm), fruit circumference (54.48 cm), cavity index (48.63), pulp thickness (3.08 cm), and TSS (15.87°brix) compared to other treatments. The lowest yield (33.64 kg/plant and 87.46 t/ha) was observed in control where the flood irrigation and soil application of fertilizers were practiced. Soil nutrient analysis was improved and the highest organic carbon content (0.31%), available N (179 kg/ha), K (684 kg/ha), Cu (4.78 ppm), Mn (5.05 ppm), and B (0.92 ppm) was observed. The economic efficiency in terms of benefit cost ratio was higher (2.93) for the input combination of Raised bed cultivation + Drip irrigation (80% ER) + Fertigation (75% RDF) + micro nutrient spray $ZnSO_4$ 0.5% + boric acid (0.2%) as it improved the fruit yield and quality. On the other hand, plastic mulching treatment combinations were not found suitable for papaya, as it resulted in incidence of root rot disease (*Phytophthora* spp.) and mortality of the bearing plants, due to prolonged moist condition in the root zone. Leaf nutrient status varied significantly among treatments and did not show a definite pattern which implies further advanced research on this aspect.

Leaf and soil nutrient status. Leaf nutrient status, though varied significantly among treatments, it did not follow a definite trend concerning the treatments. However, T1, the second-best treatment recorded the highest leaf Fe (199.10 ppm), leaf Zn (20.61 ppm), and leaf cu (6.70 ppm), while the highest leaf calcium content (6.40%) was recorded in control (T5) where the basin irrigation was followed.

The study on precision farming practices in TNAU CO 8papaya revealed that the fruit production was more enhancing the fruit yield (73.45 kg/plant and 190.94t/ha) and quality in the treatment combination, T3 (Raised bed cultivation + Drip irrigation (80% ER) + Fertigation (75% RDF) + micronutrient spray $ZnSO_4$ 0.5% + boric acid (0.2%) at alternate months) indicating the efficient use of water and nutrients under the raised bed cultivation. On the other hand, polyethylene mulching proves to be an inefficient technology for papaya as it caused the occurrence of root rot disease (*Phytophthora* spp.) due to the continuous water soaking in the collar region of the stem.

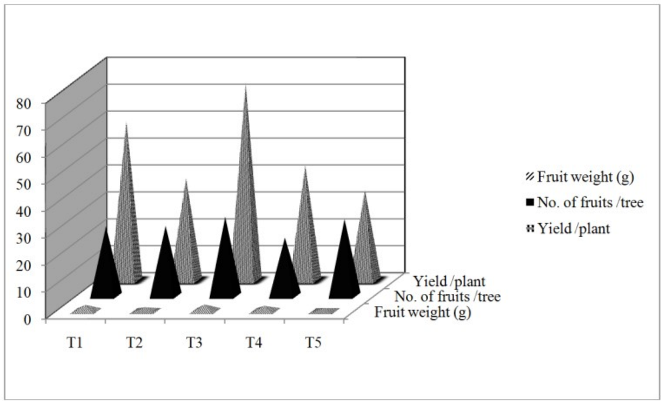

Fig. 1. Effect of precision practices on fruit yield of TNAU CO 8 Papaya.

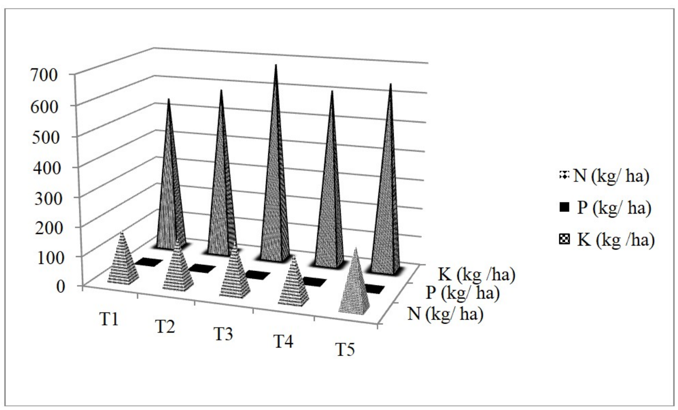

Fig. 2. Effect of precision practices on soil available N, P_2O_5 and K_2O contents.

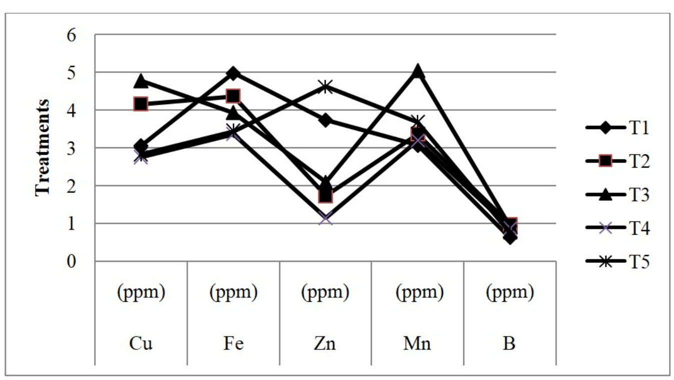

Fig. 3. Effect of precision practices on soil available micro nutrients.

Table 1: Effect of precision farming practices on plant biometric characters of TNAU CO 8 Papaya.

Treatments	Plant height (cm)	Stem girth (cm)	Days to flowering	First bearing height (cm)	No. of leaves	Leaf area (cm^2)	Petiole length (cm)	Petiole girth (cm)
T1	171.81	34.49	120.00	91.38	32.46	1972.18	72.61	8.13
T2	156.76	33.80	126.00	95.66	29.59	2198.75	67.83	7.79
T3	170.85	36.50	122.00	95.71	33.03	2166.07	75.27	8.28
T4	170.88	31.31	114.75	117.14	30.58	2028.71	68.19	7.82
T5	166.00	33.34	140.25	98.65	30.26	2076.85	68.78	7.78
CV%	**2.95**	**2.95**	**0.40**	**3.01**	**1.84**	**1.91**	**2.91**	**2.55**
SED	**3.48**	**0.70**	**0.35**	**1.73**	**0.32**	**22.90**	**1.15**	**0.11**
CD (0.05)	**7.42**	**1.50**	**0.76**	**3.77**	**0.70**	**49.90**	**2.51**	**0.24**

Table 2: Effect of precision practices on yield and fruit characters of TNAU CO 8 Papaya.

Treatments	Fruit weight (g)	No. of fruits /tree	Yield /plant (first crop 14 months)	Yield (t/ha)	Fruit length (cm)	Fruit circum ference (cm)	Cavity Index	Pulp thickne ss (cm)	TSS (°Brix)	BCR
T1	2.29	25.85	59.20	153.92	37.77	52.31	53.14	2.24	14.85	2.26
T2	1.46	26.01	37.98	98.75	33.19	47.74	60.72	1.96	14.45	1.51
T3	2.50	29.38	73.44	190.94	41.23	54.48	48.63	3.08	15.87	2.93
T4	1.97	21.65	42.64	110.86	35.65	45.98	56.10	2.30	13.89	1.71
T5	1.18	28.51	33.64	87.46	31.04	43.24	50.58	1.98	12.83	1.54
CV%	1.56	2.96	2.11	-	0.57	0.49	0.46	0.94	0.40	-
SED	0.02	0.55	2.82	-	0.14	0.16	0.17	0.01	0.04	

*TSS- Total Soluble Solids, BCR- Benefit Cost Ratio

Table 3: Effect of precision practices on leaf nutrient contents.

Treatments	Leaf N (%)	Leaf P_2O_5 (%)	Leaf K_2O (%)	Leaf Ca (%)	Leaf Mn (ppm)	Leaf Fe (ppm)	Leaf Zn (ppm)	Leaf Cu (ppm)
T1	0.310	0.89	2.55	2.80	3.50	199.10	20.61	6.70
T2	0.310	0.86	3.43	2.56	7.00	145.30	10.77	4.00
T3	0.390	0.57	2.50	2.56	3.90	130.90	9.39	3.80
T4	0.390	0.59	5.51	2.00	2.30	107.20	12.34	4.50
T5	0.310	0.86	3.21	6.40	3.00	182.80	12.84	4.70
CV%	2.29	2.51	1.50	2.91	1.37	1.40	2.38	1.00
SEd	0.01	0.01	0.03	0.06	0.03	1.51	0.22	0.03
CD (0.05)	0.03	0.03	0.08	0.14	0.08	3.30	0.48	0.07

Nitrogen, P_2O_5- Phosphorous, K_2O- Potassium, Ca- Calcium, Mn- Manganese, Fe- Iron, Zn- Zinc, Cu- Copper

Table 4: Effect of precision practices on soil nutrient status.

Treatments	Organic carbon (%)	pH	EC (dS m^{-1})	Available N (kg/ ha)	Available P_2O_5 (kg/ ha)	Available K_2O (kg /ha)	Available Zn (ppm)	Available Cu (ppm)	Available Fe (ppm)	Available Mn (ppm)	Available B (ppm)
T1	0.23	8.7	0.61	176	6.7	541	3.74	3.06	4.98	3.07	0.63
T2	0.25	8.69	0.75	168	6.3	585	1.73	4.17	4.37	3.37	0.98
T3	0.31	8.54	0.73	179	6.4	684	2.09	4.78	3.94	5.05	0.92
T4	0.29	8.78	0.32	157	6.2	607	1.14	2.75	3.36	3.19	0.88
T5	0.27	8.43	0.82	207	6.3	643	4.63	2.83	3.45	3.69	0.76
CV%	2.54	1.17	2.06	2.09	1.24	1.40	2.43	2.11	2.53	2.24	2.48
Sed	0.004	0.07	0.01	2.63	0.05	6.06	0.04	0.05	0.07	0.05	0.01
CD 5%	0.011	0.15	0.02	5.73	0.12	13.21	0.10	0.11	0.15	0.12	0.03
Initial soil sample	0.45	7.98	0.13	196 .00	10.00	590	0.90	9.17	0.23	3.83	0.75

*EC- Electrical conductivity, N- Nitrogen, P_2O_5- Phosphorous, K_2O- Potassium, Zn- Zinc, Cu- Copper, Fe- Iron, Mn- Manganese, B- Boron

CONCLUSION

Precision farming practices in TNAU CO 8papaya revealed that Raised bed cultivation + Drip irrigation (80% ER) + Fertigation (75% RDF) + micronutrient spray $ZnSO_4$ 0.5% + boric acid (0.2%) at alternate months (T3) enhanced the fruit yield (73.45 kg/plant and 190.94t/ha) and quality indicating the efficient use of water and nutrients by the plants. The treatment with polyethylene mulching along with other precision farming techniques as in T3, though recorded higher yield next to T3, not appropriate technique for papaya as it resulted in occurrence of root rot disease (*Phytophthora* spp.) due to the continuous water soaking in the collar region of the stem.

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