The Pharma Innovation Journal 2022; 11(2): 2793-2802

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; 11(2): 2793-2802

www.thepharmajournal.com
Received: 07-11-2021
Accepted: 16-01-2022

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Impact of integrated nutrient management and fertigation on growth parameters of papaya (*Carica papaya* L.) cv. Arka Prabhath under different growing condition

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Abstract
An experiment was conducted under insect proof net and open condition to assess the impact of integrated nutrient management and fertigation levels on growth parameters of papaya cv. Arka Prabhath. The experiment was laid out in factorial randomized block design with three replications and twelve treatments. Results indicated that crop growth such as plant height, girth, number of leaves and leaf petiole length were significantly higher in treatment containing, 100 % RDF through Fertigation + Trichokavach (50g/plant) + Chitosan (20g/ plant)+ Seaweed extract (20g/plant)+ *Penicillium pinophilum* (20g/plant)+ *Pseudomonas putidda* (4 ml/litre)+ Phosphoric acid (20 ml/ lit/ plant) + Salicylic acid (300ppm) + Power plus (5 ml/ lit) and grown under insect proof net.

Keywords: Papaya, Biofertilizers, Fertigation, Biostimulants

1. Introduction
Papaya (*Carica papaya* L.) belongs to the genus Carica, of the family Caricaceae with 48 species. It is the most cultivated species and commonly called as papaw or paw paw (Australia), mamao (Brazil) and tree melon (China). It is one of the most important fruit crop cultivated in the tropical and subtropical regions of India (Krishna *et al*., 2008) [5].
Papaya grows relatively easily and quickly from seeds and can reach up to 10 or 12 ft in height. Fruits are ready to be harvested within 9 to 12 months after planting and tree can continue to produce fruits for about 2-3 years. The fruit is a good source of vitamin A and C (Manshardt, 1992) [7]. Ripe fruits are largely used as a fresh dessert, while green fruits are often used in salads and pickled or cooked as a vegetable. Papain, a proteolytic enzyme present in the latex, collected mainly from green fruits, has various uses in the beverage, food and pharmaceutical industries, *viz*., chill-proofing beer, tenderizing meat and in drug preparations for digestive ailments (Chan and Tang, 1978) [1]. It is also used in bathing hides, softening wool and as soap for washing cloth. Papaya leaves have medicinal value. Stem and bark is used for making ropes. Roots are used to cure the yaws and piles and act as a generative toxin. Because of these reason, papaya has been called as "Common man's fruit".
Papaya is valued for its economic, nutritional, industrial, pharmaceutical and medicinal values, also for local and export markets. The extensive adaptation of this plant and wide acceptance of fruit offer considerable promise as a commercial crop for local and export purposes. Due to its varied uses and development of new high yielding cultivars having medium sized fruits made its cultivation profitable for the farmers. Papaya being a short duration perennial, every growth phase is critical and any biotic and abiotic stress would immediately reflect on the flowering and fruiting of papaya. Papaya is reported to be susceptible to various maladies caused by fungi, bacteria, nematode and viruses. Among them Papaya Ring Spot Virus (PRSV) is a serious threat to papaya cultivation in India and various parts of the world. This disease is observed in almost all the states of India *viz*., Bihar (100 %), Maharashtra (3-100 %), Karnataka (60 %), Kerala (35-66 %) and West Bengal (40 %) (Yeh *et al*., 2010) [14]. The production of papaya is limited by this destructive disease which ultimately limits the large-scale exportation due to this fact, papaya lags behind banana and pineapple in the world market. These problems can be managed to some extent by selection of improved cultivars and growing under protected conditions along with use of biostimulents and biofertilizers.

The protected cultivation technology involves certain of nearly optimum environmental conditions for the sustainable growth of plants. This technology, incorporating several intensive and high-tech practices, which serve as an alternative to open field cultivation. It is most contemporary approach of producing high value crops of good quality by alternating biotic and abiotic constraints like insects, diseases, extremes of temperature, rainfall and light intensity. It facilitates the grower to obtain premium prices from their produce.

Hence the present study is aimed at growing the papaya under different growing condition and use of integrated nutrient management along with fertigation for controlling PRSV incidence.

2. Materials and methods

2.1 Experimental site

The experiment entitled "Impact of integrated nutrient management and fertigation on growth parameters of papaya (*Carica papaya* L.) Cv. Arka Prabhath under different growing condition" was undertaken during 2020-22. The research was conducted at Yelwala, Mysore, Karnataka and the experimental site was located at a latitude of N $12^0$35'90" and longitude of E $76^0$54'31" with an altitude of 770 meters above mean sea level in the Southern Dry Zone (Zone-6). The details of the materials used and methodologies adopted for the study during the investigation are described below.

2.2 Experimental design and treatments

The study was conducted under insect proof net and open field condition, the design opted was FRBD, having twelve treatments with three replications were examined in this study, T_1: 100 % RDF of NPK plant^{-1} through soil application+ Micronutrient spray. T_2: NPK is supplied through FYM, Vermicompost, Neem cake. T_3: 75 % RDF of NPK plant^{-1} through Fertigation+ Trichokavach (50g/ plant) + Seaweed extract (20g/plant)+ *Penicillium pinophilum* (20 g/ plant). T_4: 75% RDF of NPK plant^{-1} through Fertigation+ Trichokavach (50g/ plant) + Seaweed extract (20g/plant) and spray (0.2%) + *Pseudomonas putidda* (4 ml/litre) + *Penicillium pinophilum* (20g/plant). T_5: 75% RDF of NPK plant^{-1} through Fertigation+ Trichokavach (50g/ plant) + Chitosan (20g/ plant) + *Penicillium pinophilum* (20 g/ plant). T_6: 75% RDF of NPK plant^{-1} through Fertigation+ Trichokavach (50g/ plant) + Chitosan (20g/ plant) and spray (0.1%)+ *Pseudomonas putidda* (4 ml/litre)+ *Penicillium pinophilum* (20g/plant). T_7: 75% RDF of NPK plant^{-1} through Fertigation + Trichokavach (50g/ plant) + Salicylic acid (300ppm) + *Penicillium pinophilum* (20g/plant). T_8: 75% RDF of NPK plant^{-1} through Fertigation + Trichokavach (50g/ plant)+ Phosphoric acid (20 ml/ lit/ plant)+ *Penicillium pinophilum* (20 g/ plant). T_9: 75% RDF of NPK plant^{-1} through Fertigation + Trichokavach (50g/ plant)+ Power plus (5 ml/ lit) + *Penicillium pinophilum* (20 g/ plant). T_{10}: 100% RDF of NPK plant^{-1} through Fertigation + Trichokavach (50g/plant) + Chitosan (20g/ plant)+ Seaweed extract (20g/plant)+ *Penicillium pinophilum* (20g/plant)+ *Pseudomonas putidda* (4 ml/litre)+ Phosphoric acid (20 ml/ lit/ plant) + Salicylic acid (300ppm) + Power plus (5 ml/ lit). T_{11}: 75% RDF of NPK plant^{-1} through Fertigation + Trichokavach (50g/plant) + Chitosan (20g/ plant)+ Seaweed extract (20g/plant)+ *Penicillium pinophilum* (20g/plant) + *Pseudomonas putidda* (4 ml/litre)+ Phosphoric acid (20 ml/ lit/ plant) + Salicylic acid (300ppm) + Power plus (5 ml/ lit). T_{12} : 50 % RDF of NPK plant^{-1} through Fertigation + Trichokavach (50g/plant) + Chitosan (20g/ plant)+ Seaweed extract (20g/plant)+ *Penicillium pinophilum* (20g/plant) + *Pseudomonas putidda* (4 ml/litre)+ Phosphoric acid (20 ml/ lit/ plant) + Salicylic acid (300ppm) + Power plus (5 ml/ lit).

Except treatment T_1 and T_2 rest were applied with Neem cake (250g/ plant) along with VAM (5g/plant), Vermicompost (3kg/ plant) and Micronutrient spray in common.

2.3 Raising of seedlings

Arka Prabhath seeds were collected from IIHR, Bengaluru. The seeds were treated with 100 ppm of GA_3 for better germination and it was grown under insect net proof cages for 45 days with proper care to obtain virus free seedlings.

2.4 Growing condition

An insect proof net house of 50 m length, 13 m width and 3.2 m height was constructed using wooden and iron poles. All the sides were covered with insect proof net (40 mesh) for natural ventilation and protection from the pests. Whereas, the plants were grown in the ambient condition without any structure in open field condition.

2.5 Fertilizer application

The papaya crop needs heavy doses of manures and fertilizers. The recommended dose for papaya is N, P & K with 250, 250 & 500 g/plant/year. The basal dose of 90 g urea, 250 g SSP and 140g MOP along vermicompost, neem cake, Trichokawach, VAM, and *Pencilium phinophilum* were applied to the pits as per the treatment details during land preparation. Rest were supplied through 19:19:19 and MOP respectively in thirty equal split doses at bi-monthly intervals through fertigation. The soil application of seaweed extract and chitosan were applied thrice at four month interval and phosphoric acid was given at monthly interval through fertigation unit. The foliar application of chitosan, sea weed extract, salicylic acid, *Pseudomonas putidda* and power plus were applied four times at 3 months interval and micronutrients were sprayed at monthly interval.

2.6 Plant growth monitoring

Four plants were selected from each replication for recording observations in each treatment. The growth parameters were recorded at 30 days interval up to flowering. Growth attributes such as plant height, stem girth, number of leaves and petiole length were recorded.

3. Results and discussion

3.1a Plant height (cm) at 60 and 120 DAP

The interaction between growing conditions and different growth promoting substances on the plant height at 120 days after planting differed significantly. The plants treated with T_{10} and grown under insect net proof recorded significantly maximum plant height of 137.51 cm and minimum plant height of 84.80 cm was recorded in plants treated with T_2 and grown under open field (Table 1a).

Table 1a: Effect of different growth promoting substances and growing condition on plant height (cm) at 60 and 120 DAP of papaya.

Treatments (T)	Plant height (cm) at 60 DAP		Mean	Plant height (cm) at 120 DAP		Mean
	Growing condition (G)			Growing condition (G)		
	Insect proof net(G_1)	Open condition (G_2)		Insect proof net (G_1)	Open condition (G_2)	
T_1	54.50	54.33	54.41	120.83	86.45	103.64
T_2	50.67	49.22	49.94	100.00	84.80	92.40
T_3	56.00	54.30	55.15	126.67	90.00	108.33
T_4	56.33	54.45	55.39	128.17	91.00	109.58
T_5	55.31	54.00	54.65	122.83	87.45	105.14
T_6	55.97	54.50	55.23	123.50	89.75	106.62
T_7	54.85	54.32	54.58	120.83	87.00	103.91
T_8	54.48	54.09	54.28	120.67	90.00	105.33
T_9	56.00	54.00	55.00	125.50	90.25	107.87
T_{10}	58.67	54.67	56.67	137.51	95.50	116.50
T_{11}	57.17	54.17	55.67	131.97	94.75	113.35
T_{12}	51.83	52.83	52.33	107.17	85.45	96.31
Mean	55.14	53.74		122.02	89.15	
	G	T	GXT	G	T	GXT
S. Em ±	0.22	0.55	NS	0.45	1.11	1.57
CD@ 5%	0.64	1.57	NS	1.29	3.17	4.49

3.1b Plant height (cm) at 180 and 240 DAP

The interaction between growing conditions and different growth promoting substances with respect to the plant height at 180 and 240 days after planting were observed non-significant (Table 1b).

Table 1b: Effect of different growth promoting substances and growing condition on plant height (cm) at 180 and 240 DAP of papaya.

Treatments (T)	Plant height (cm) at 180 DAP		Mean	Plant height (cm) at 240 DAP		Mean
	Growing condition (G)			Growing condition (G)		
	Insect proof net (G_1)	Open condition (G_2)		Insect proof net (G_1)	Open condition (G_2)	
T_1	198.17	153.05	175.61	218.28	182.00	200.14
T_2	195.00	150.85	172.92	214.50	178.00	196.25
T_3	199.93	162.75	181.34	222.40	185.75	204.07
T_4	200.00	163.12	181.56	223.02	187.00	205.01
T_5	198.83	159.55	179.19	219.01	182.45	200.73
T_6	198.83	161.00	179.91	220.00	183.75	201.87
T_7	196.00	158.00	177.00	218.28	182.00	200.14
T_8	196.00	163.00	179.50	218.00	183.00	200.50
T_9	199.17	163.00	181.08	220.85	185.95	203.40
T_{10}	207.00	170.85	188.92	230.47	195.06	212.76
T_{11}	200.75	165.00	182.87	225.54	188.45	206.99
T_{12}	195.33	151.05	173.19	215.17	180.70	197.93
Mean	198.75	160.10		220.46	184.50	
	G	T	GXT	G	T	GXT
S.Em ±	0.77	1.88	NS	1.01	2.48	NS
CD@ 5%	2.19	5.38	NS	2.90	7.10	NS

3.1c Plant height (cm) at 300 and 360 DAP

There was no significant interaction observed between growing conditions and different growth promoting substances on the plant height at 300 and 360 days after planting (Table 1c).

Table 1c: Effect of different growth promoting substances and growing condition on plant height (cm) at 300 and 360 DAP of papaya.

Treatments (T)	Plant height (cm) at 300 DAP		Mean	Plant height (cm) at 360 DAP		Mean Open condition (G_2)
	Growing condition (G)			Growing condition (G)		
	Insect proof net (G_1)	Open condition (G_2)		Insect proof net (G_1)	Insect proof net (G_1)	
T_1	235.00	218.00	226.50	270.00	249.85	259.92
T_2	230.00	210.15	220.07	264.00	243.78	253.89
T_3	243.05	225.85	234.45	275.00	254.08	264.54
T_4	250.85	228.02	239.43	275.95	256.01	265.98
T_5	239.55	210.90	225.22	271.75	250.01	260.88
T_6	240.45	223.01	231.73	272.00	250.45	261.22
T_7	238.00	219.28	228.64	270.00	249.85	259.92
T_8	244.00	220.07	232.03	270.00	249.00	259.50
T_9	249.45	225.40	237.42	274.85	254.00	264.42
T_{10}	267.01	237.47	252.24	284.38	271.45	277.91
T_{11}	258.75	229.54	244.14	278.45	258.95	268.70
T_{12}	230.24	210.50	220.37	265.00	244.00	254.50
Mean	243.86	221.51		272.61	252.61	
	G	T	GXT	G	T	GXT
S.Em ±	0.98	2.41	NS	1.10	2.70	NS
CD@ 5%	2.81	6.89	NS	3.15	7.70	NS

3.2 Plant girth (cm)

The perusal of data on effect of different growth promoting substances and growing condition on plant girth was recorded at bimonthly intervals from 60 days after planting to 360 days after planting and the data are presented in Table 2a, 2b, 2c.

3.2a Plant girth (cm) at 60 and 120 DAP

The interaction between growing conditions and different growth promoting substances on the plant girth at 120 days after planting differed significantly. The plants treated with T_{10} and grown under insect net proof recorded significantly maximum plant girth (18.17 cm) and minimum plant girth (14.20 cm) was recorded in plants treated with T_2 and grown under open field.

Table 2a: Effect of different growth promoting substances and growing condition on plant girth (cm) at 60 and 120 DAP of papaya.

Treatments (T)	Plant girth (cm) at 60 DAP		Mean	Plant girth (cm) at 120 DAP		Mean
	Growing condition (G)			Growing condition (G)		
	Insect proof net (G_1)	Open condition (G_2)		Insect proof net (G_1)	Insect proof net (G_1)	Open condition (G_2)
T_1	6.87	6.05	6.46	15.41	15.25	15.33
T_2	6.83	6.02	6.42	15.00	14.20	14.60
T_3	6.93	6.25	6.59	16.28	15.53	15.90
T_4	6.93	6.40	6.66	16.43	15.71	16.07
T_5	6.87	6.10	6.48	15.83	15.47	15.65
T_6	6.87	6.25	6.56	16.08	15.68	15.88
T_7	6.85	6.10	6.47	15.07	15.22	15.14
T_8	6.89	6.18	6.53	16.23	15.48	15.85
T_9	6.92	6.20	6.56	16.28	15.65	15.96
T_{10}	7.33	6.75	7.04	18.17	15.96	17.06
T_{11}	7.12	6.59	6.89	17.33	15.75	16.54
T_{12}	6.85	6.03	6.44	14.67	15.09	14.88
Mean	**6.93**	6.23		16.06	15.41	
	G	T	GXT	G	T	GXT
S.Em ±	**0.02**	0.06	NS	0.08	0.19	0.28
CD@ 5%	**0.07**	0.18	NS	0.23	0.56	0.80

3.2b Plant girth (cm) at 180 and 240 DAP

The interaction between growing conditions and different growth promoting substances on the plant girth at 180 days after planting differed significantly. The plants treated with T_{10} and grown under insect net proof recorded maximum plant girth (32.50 cm) which was on par with T_{11} (31.80 cm) and minimum plant girth (25.00 cm) was recorded in plants treated with T_2 and grown under open field.

At 240 days after planting, the significant differences were observed in interaction between growing conditions and different growth promoting substances on plant girth. The plants treated with T_{10} and grown under insect net proof recorded maximum plant girth (36.25 cm) which was on par with T_{11} (35.45 cm), T_4 (35.25 cm) and T_3 (35.00 cm). The minimum plant girth (30.00 cm) was recorded in plants treated with T_2 and grown under open field.

Table 2b: Effect of different growth promoting substances and growing condition on plant girth (cm) at 180 and 240 DAP of papaya.

Treatments (T)	Plant girth (cm) at 180 DAP		Mean	Plant girth (cm) at 240 DAP		Mean
	Growing condition (G)			Growing condition (G)		
	Insect proof net (G_1)	Open condition (G_2)		Insect proof net (G_1)	Insect proof net (G_1)	Open condition(G_2)
T_1	29.00	25.85	27.42	33.75	31.20	32.47
T_2	26.00	25.00	25.50	30.75	30.00	30.37
T_3	30.00	26.45	28.22	35.00	31.45	33.22
T_4	30.45	26.90	28.67	35.25	31.85	33.55
T_5	29.40	26.25	27.82	34.00	31.25	32.62
T_6	29.55	26.40	27.97	34.00	31.40	32.70
T_7	27.45	26.00	26.72	33.25	31.20	32.22
T_8	29.85	26.25	28.05	34.45	31.38	32.91
T_9	30.00	26.45	28.22	34.80	31.65	33.22
T_{10}	32.50	27.50	30.00	36.25	32.85	34.55
T_{11}	31.80	27.00	29.40	35.45	31.90	33.67
T_{12}	26.85	25.20	26.02	31.40	30.85	31.12
Mean	29.40	26.27		33.98	31.47	
	G	T	GXT	G	T	GXT
S.Em ±	0.11	0.28	0.39	0.14	0.35	0.50
CD@ 5%	0.32	0.80	1.14	0.41	1.02	1.44

3.2c Plant girth (cm) at 300 and 360 DAP

There was no significant interaction observed between growing conditions and different growth promoting substances on the plant girth at 300 and 360 days after planting.

Table 2c: Effect of different growth promoting substances and growing condition on plant girth (cm) at 300 and 360 DAP of papaya.

Treatments (T)	Plant girth (cm) at 300 DAP		Mean	Plant girth (cm) at 360 DAP		Mean
	Growing condition (G)			Growing condition (G)		
	Insect proof net (G_1)	Open condition (G_2)		Insect proof net (G_1)	Open condition (G_2)	
T_1	43.00	41.00	42.00	46.85	45.10	45.97
T_2	41.75	40.75	41.25	45.45	44.90	45.17
T_3	44.20	41.50	42.85	49.00	45.50	47.25
T_4	45.00	41.70	43.35	49.55	46.85	48.20
T_5	43.45	41.28	42.36	48.00	46.40	47.20
T_6	43.80	41.20	42.50	48.10	46.55	47.32
T_7	43.00	41.20	42.10	46.50	45.55	46.02
T_8	44.00	41.45	42.72	48.25	45.50	46.87
T_9	44.00	41.48	42.74	49.00	46.60	47.80
T_{10}	46.25	42.00	44.12	52.00	48.25	50.12
T_{11}	45.00	41.80	43.40	50.20	47.10	48.67
T_{12}	42.00	40.83	41.41	45.90	45.06	45.48
Mean	43.78	41.34		48.23	46.10	
	G	T	GXT	G	T	GXT
S.Em ±	0.20	0.50	NS	0.21	0.51	NS
CD@ 5%	0.58	1.43	NS	0.60	1.46	NS

3.3 Number of functional leaves (Nos)

The perusal of data on effect of different growth promoting substances and growing condition on number of leaves was recorded at bimonthly intervals from 60 days after planting to 360 days after planting and the data are presented in Table 3a, 3b and 3c.

Table 3a: Effect of different growth promoting substances and growing condition on number of leaves (Nos) at 60 and 120 DAP of papaya.

Treatments (T)	Number of leaves (Nos) at 60 DAP		Mean	Number of leaves (Nos) at 120 DAP		Mean
	Growing condition (G)			Growing condition (G)		
	Insect proof net (G_1)	Open condition (G_2)		Insect proof net (G_1)	Open condition (G_2)	
T_1	14.58	13.25	13.91	20.42	19.17	19.79
T_2	14.10	12.00	13.05	18.00	16.58	17.29
T_3	14.71	13.58	14.14	23.45	20.00	21.72
T_4	14.73	14.08	14.40	23.51	20.42	21.96
T_5	14.63	13.58	14.10	21.00	21.67	21.33
T_6	14.63	14.42	14.52	21.21	21.92	21.56
T_7	14.58	12.67	13.62	22.41	22.58	22.49
T_8	14.67	12.04	13.35	22.15	23.33	22.74
T_9	14.67	12.83	13.75	22.41	23.00	22.70
T_{10}	15.33	14.83	15.08	25.24	24.33	24.78
T_{11}	15.00	14.17	14.58	23.59	23.78	23.68
T_{12}	14.29	12.33	13.31	19.25	18.58	18.91
Mean	14.66	13.31		21.88	21.28	
	G	T		G	T	GXT
S.Em ±	0.05	0.14	0.20	0.08	0.20	0.29
CD@ 5%	0.15	0.41	0.58	0.24	0.59	0.83

3.3a Number of functional leaves (Nos) at 60 and 120 DAP

The interaction between growing conditions and different growth promoting substances on the number of leaves at 60 days after planting differed significantly. The plants treated with T_{10} and grown under insect net proof recorded maximum number of leaves (15.33) which was statistically at par with T_{11} (15.00). The minimum number of leaves (12.00) was recorded in plants treated with T_2 and grown under open field. The significant differences were observed in interaction between growing conditions and different growth promoting substances on the number of leaves at 120 days after planting. The plants treated with T_{10} and grown under insect net proof recorded significantly maximum number of leaves (25.24) and minimum number of leaves (16.58) was recorded in plants treated with T_2 and grown under open field.

3.3b Number of functional leaves (Nos) at 180 and 240 DAP

The interaction observed between growing conditions and different growth promoting substances on the number of leaves at 180 and 240 days after planting differed non significantly.

Table 3b: Effect of different growth promoting substances and growing condition on number of leaves (Nos) at 180 and 240 DAP of papaya.

Treatments (T)	Number of leaves (Nos) at 180 DAP		Mean	Number of leaves (Nos) at 240 DAP		Mean
	Growing condition (G)			Growing condition (G)		
	Insect proof net (G_1)	Open condition (G_2)		Insect proof net (G_1)	Open condition (G_2)	
T_1	26.41	22.00	24.21	27.87	24.45	26.16
T_2	25.24	20.00	22.62	27.25	25.00	26.13
T_3	27.04	23.75	25.40	29.46	26.01	27.74
T_4	27.10	24.00	25.55	29.75	26.02	27.89
T_5	26.41	22.45	24.43	28.08	26.00	27.04
T_6	26.75	23.00	24.88	28.45	25.00	26.73
T_7	26.41	22.45	24.43	28.08	25.00	26.54
T_8	26.78	23.00	24.89	28.47	25.75	27.11
T_9	26.85	23.45	25.15	28.58	25.45	27.02
T_{10}	28.75	25.02	26.89	31.75	27.45	29.60
T_{11}	27.24	24.00	25.62	29.85	26.00	27.93
T_{12}	25.45	20.04	22.75	27.45	25.00	26.23
Mean	26.70	22.76		28.75	25.59	
	G	T	GXT	G	T	GXT
S.Em ±	0.11	0.28	NS	0.13	0.33	NS
CD@ 5%	0.33	0.81	NS	0.38	0.95	NS

3.3c Number of functional leaves (Nos) at 300 and 360 DAP

There was no significant interaction observed between growing conditions and different growth promoting substances on the number of leaves at 300 and 360 days after planting.

Table 3c: Effect of different growth promoting substances and growing condition on number of leaves (Nos) at 300 and 360 DAP of papaya.

Treatments (T)	Number of leaves (Nos) at 300 DAP		Mean	Number of leaves (Nos) at 360 DAP		Mean
	Growing condition (G)			Growing condition (G)		
	Insect proof net (G_1)	Open condition (G_2)		Insect proof net (G_1)	Open condition (G_2)	
T_1	35.54	27.85	31.69	35.50	34.45	34.98
T_2	35.18	27.00	31.09	35.20	34.08	34.64
T_3	37.28	28.90	33.09	37.38	36.00	36.69
T_4	37.47	29.50	33.48	37.50	36.46	36.98
T_5	36.30	28.45	32.37	36.34	35.85	36.10
T_6	36.50	28.00	32.25	36.55	35.45	36.00
T_7	36.30	28.00	32.15	36.34	35.00	35.67
T_8	36.84	28.45	32.64	36.90	35.85	36.38
T_9	36.94	29.00	32.97	36.98	36.00	36.49
T_{10}	39.79	31.00	35.39	39.82	38.25	39.04
T_{11}	37.92	29.78	33.85	37.97	36.84	37.41
T_{12}	35.22	27.08	31.15	35.25	34.24	34.75
Mean	36.77	28.58		36.81	35.71	
	G	T	GXT	G	T	GXT
S.Em ±	0.11	0.26	NS	0.17	0.41	NS
CD@ 5%	0.31	0.76	NS	0.48	1.19	NS

3.4 Leaf area (cm^2)

The perusal of data on effect of different growth promoting substances and growing condition on leaf area was recorded at bimonthly intervals from 60 days after planting to 360 days after planting and the data are presented in Table 4a, 4b and 4c.

Table 4a: Effect of different growth promoting substances and growing condition on leaf area (cm^2) at 60 and 120 DAP of papaya.

Treatments (T)	Leaf area (cm^2) at 60 DAP		Mean	Leaf area (cm^2) at 120 DAP		Mean
	Growing condition (G)			Growing condition (G)		
	Insect proof net (G_1)	Open condition (G_2)		Insect proof net (G_1)	Open condition (G_2)	
T_1	950.25	350.80	650.52	1585.12	1321.08	1453.10
T_2	785.95	300.75	543.35	1500.75	1128.63	1314.69
T_3	1000.28	420.50	710.39	1620.75	1364.05	1492.40
T_4	1110.25	435.80	773.02	1658.45	1403.78	1531.11
T_5	952.00	350.25	651.12	1590.74	1245.89	1418.31
T_6	952.25	370.58	661.41	1596.45	1308.25	1452.35
T_7	865.25	320.04	592.64	1542.69	1297.56	1420.12
T_8	954.25	360.85	657.55	1600.40	1302.54	1451.47
T_9	975.85	420.00	697.92	1600.75	1358.66	1479.70
T_{10}	1200.58	502.50	851.54	1705.86	1500.25	1603.05
T_{11}	1125.85	450.25	788.05	1699.20	1457.25	1578.22
T_{12}	852.60	320.45	586.52	1520.18	1204.78	1362.48
Mean	977.11	383.56		1601.77	1324.39	
	G	T	GXT	G	T	GXT
S.Em ±	2.56	6.29	8.89	6.15	15.08	21.32
CD@ 5%	7.33	17.96	25.40	17.58	43.07	60.91

3.4a Leaf area (cm^2) at 60 and 120 DAP

The interaction between growing conditions and different growth promoting substances on the leaf area at 60 days after planting differed significantly. The plants treated with T_{10} and grown under insect net proof recorded significantly maximum leaf area (1200.58 cm^2) and minimum leaf area (300.75 cm^2) was recorded in plants treated with T_2 and grown under open field.

The significant differences were observed in interaction between growing conditions and different growth promoting substances on the leaf area at 120 days after planting. The plants treated with T_{10} and grown under insect net proof recorded maximum leaf area (1705.86 cm^2) which was on par with T_{11} (1699.20 cm^2) and T_4 (1658.45 cm^2) whereas, the minimum leaf area (1128.63 cm^2) was recorded in plants treated with T_2 [NPK supplied through FYM, Vermicompost, Neem cake] and grown under open field.

Table 4b: Effect of different growth promoting substances and growing condition on leaf area (cm^2) at 180 and 240 DAP of papaya.

Treatments (T)	Leaf area (cm^2) at 180 DAP		Mean	Leaf area (cm^2) at 240 DAP		Mean
	Growing condition (G)			Growing condition (G)		
	Insect proof net (G_1)	Open condition (G_2)		Insect proof net (G_1)	Open condition (G_2)	
T_1	1819.68	1619.32	1719.50	1907.68	1904.43	1906.05
T_2	1758.26	1489.20	1623.73	1879.45	1796.26	1837.85
T_3	1912.04	1647.36	1779.70	2000.01	1914.68	1957.34
T_4	1926.12	1720.32	1823.22	2000.07	1946.12	1973.09
T_5	1829.78	1540.23	1685.00	1927.85	1840.75	1884.30
T_6	1845.75	1590.21	1717.98	1928.35	1869.68	1899.01
T_7	1809.50	1545.26	1677.38	1900.45	1879.78	1890.11
T_8	1904.68	1598.36	1751.52	1945.00	1895.75	1920.37
T_9	1907.43	1602.85	1755.14	1945.07	1932.04	1938.55
T_{10}	2004.25	1852.36	1928.30	2214.07	2044.25	2129.16
T_{11}	1947.00	1748.69	1847.84	2088.34	1987.00	2037.67
T_{12}	1800.75	1502.36	1651.55	1899.12	1819.50	1859.31
Mean	1872.10	1621.37		1969.62	1902.52	
	G	T	GXT	G	T	GXT
S.Em ±	7.66	18.78	NS	7.79	19.09	NS
CD@ 5%	21.89	53.63	NS	22.26	54.53	NS

3.4b Leaf area (cm^2) at 180 and 240 DAP

There was no significant interaction observed between growing conditions and different growth promoting substances on leaf area at 180 and 240 days after planting.

Table 4c: Effect of different growth promoting substances and growing condition on leaf area (cm^2) at 300 and 360 DAP of papaya.

Treatments (T)	Leaf area (cm^2) at 300 DAP		Mean	Leaf area (cm^2) at 360 DAP		Mean
	Growing condition (G)			Growing condition (G)		
	Insect proof net (G_1)	Open condition (G_2)		Insect proof net (G_1)	Open condition (G_2)	
T_1	2478.95	2275.85	2377.40	2601.45	2490.12	2545.78
T_2	2394.25	2004.08	2199.16	2500.15	2304.25	2402.20
T_3	2685.02	2308.12	2496.57	2745.89	2485.14	2615.51
T_4	2700.78	2352.89	2526.83	2784.12	2490.78	2637.45
T_5	2500.17	2102.78	2301.47	2601.75	2438.95	2520.35
T_6	2501.27	2187.14	2344.20	2601.75	2481.27	2541.51
T_7	2451.89	2190.57	2321.23	2600.12	2461.89	2531.00
T_8	2550.12	2200.45	2375.28	2685.14	2450.17	2567.65
T_9	2675.14	2281.75	2478.44	2690.78	2485.02	2587.90
T_{10}	2780.24	2464.04	2622.14	2845.69	2650.24	2747.96
T_{11}	2708.04	2390.78	2549.41	2802.07	2538.04	2670.05
T_{12}	2451.78	2109.45	2280.61	2594.65	2351.78	2473.21
Mean	2573.13	2238.99		2671.13	2468.97	
	G	T	GXT	G	T	GXT
S.Em ±	9.73	23.84	NS	12.89	31.57	NS
CD@ 5%	27.79	68.08	NS	36.81	90.17	NS

3.4c Leaf area (cm^2) at 300 and 360 DAP

There was no significant interaction observed between growing conditions and different growth promoting substances on leaf area at 300 and 360 days after planting.

3.5 Leaf petiole length (cm)

The perusal of data on effect of different growth promoting substances and growing condition on leaf petiole length was recorded at bimonthly intervals from 60 days after planting to 360 days after planting and the data are presented in Table 5a, 5b and 5c.

Table 5a: Effect of different growth promoting substances and growing condition on leaf petiole length (cm) at 60 and 120 DAP of papaya.

Treatments (T)	Leaf petiole length (cm) at 60 DAP		Mean	Leaf petiole length (cm) at 120 DAP		Mean
	Growing condition (G)			Growing condition (G)		
	Insect proof net (G_1)	Open condition (G_2)		Insect proof net (G_1)	Open condition (G_2)	
T_1	35.00	34.45	34.73	52.00	45.45	48.72
T_2	34.20	33.74	33.97	50.75	45.00	47.87
T_3	35.50	35.00	35.25	52.85	46.75	49.80
T_4	35.50	35.12	35.31	53.25	47.17	50.21
T_5	35.10	34.95	35.03	52.00	45.85	48.92
T_6	35.20	35.00	35.10	52.01	46.00	49.00
T_7	35.00	34.85	34.93	52.00	45.90	48.95
T_8	35.20	35.21	35.21	52.45	46.00	49.22
T_9	35.21	35.10	35.16	52.85	46.85	49.85
T_{10}	36.67	36.00	36.34	54.00	48.45	51.22
T_{11}	36.00	36.00	36.00	53.45	47.20	50.32
T_{12}	34.70	33.95	34.33	51.00	45.12	48.06
Mean	35.27	34.95		52.38	46.31	
	G	T	GXT	G	T	GXT
S.Em ±	0.11	0.38	NS	2.01	0.49	NS
CD@ 5%	0.30	1.09	NS	0.57	1.40	NS

Table 5b: Effect of different growth promoting substances and growing condition on leaf petiole length (cm) at 180 and 240 DAP of papaya.

Treatments (T)	Leaf petiole length (cm) at 180 DAP		Mean	Leaf petiole length (cm) at 240 DAP		Mean
	Growing condition (G)			Growing condition (G)		
	Insect proof net (G_1)	Open condition (G_2)		Insect proof net (G_1)	Open condition (G_2)	
T_1	70.24	57.09	63.67	71.00	62.00	66.50
T_2	68.00	56.45	62.23	70.01	57.00	63.51
T_3	71.45	58.45	64.95	72.00	62.20	67.10
T_4	71.95	58.68	65.32	72.55	62.85	67.70
T_5	70.45	57.85	64.15	71.75	60.45	66.10
T_6	70.48	58.40	64.44	71.80	62.00	66.90
T_7	69.85	57.00	63.43	70.90	60.00	65.45
T_8	70.75	57.40	64.08	71.85	60.60	66.23
T_9	70.95	57.85	64.40	71.90	62.00	66.95
T_{10}	73.52	58.90	66.21	75.45	66.25	70.85
T_{11}	71.95	58.20	65.08	73.45	65.40	69.43
T_{12}	68.45	57.00	62.73	70.20	59.00	64.60
Mean	70.67	57.77		71.91	61.65	
	G	T	GXT	G	T	GXT
S.Em ±	0.28	0.69	NS	0.26	0.64	NS
CD@ 5%	0.80	1.98	NS	0.75	1.84	NS

3.5a Leaf petiole length (cm) at 60, 120, 180, 240, 300 and 360 DAP

The interaction observed between growing conditions and different growth promoting substances on leaf petiole length at 60, 120, 180, 240, 300 and 360 days after planting was observed non significant.

Table 5c: Effect of different growth promoting substances and growing condition on leaf petiole length (cm) at 300 and 360 DAP of papaya.

Treatments (T)	Leaf petiole length (cm) at 300 DAP		Mean	Leaf petiole length (cm) at 360 DAP		Mean
	Growing condition (G)			Growing condition (G)		
	Insect proof net (G_1)	Open condition (G_2)		Insect proof net (G_1)	Open condition (G_2)	
T_1	79.90	69.75	74.83	83.00	70.45	76.73
T_2	76.01	67.90	71.95	80.01	70.00	75.01
T_3	80.25	71.00	75.63	84.04	71.25	77.65
T_4	80.75	71.45	76.10	84.05	72.00	78.03
T_5	79.95	70.00	74.98	83.25	70.95	77.10
T_6	80.00	70.01	75.01	83.95	71.85	77.90
T_7	79.65	70.00	74.83	81.45	71.00	76.23
T_8	80.02	70.02	75.02	84.00	71.25	77.63
T_9	80.12	70.56	75.34	84.00	71.95	77.98
T_{10}	82.05	72.08	77.07	87.64	76.00	81.82
T_{11}	81.25	71.80	76.53	84.75	74.85	79.90
T_{12}	78.52	68.00	73.26	80.24	70.02	75.13
Mean	79.87	70.21		83.37	71.66	
	G	T	GXT	G	T	GXT
S.Em ±	0.30	0.75	NS	0.27	0.67	NS
CD@ 5%	0.87	1.95	NS	0.78	1.93	NS

The congenial climate prevailed under insect proof net had a positive influence on plant growth attributes. Practically, the incidence of papaya ring spot virus (PRSV) under insect proof net was nil which might have favoured continued growth and thereby the plants under insect proof net registered more plant height, girth, number of leaves and leaf area when compared to plants grown under open field condition. Adding to that, under protected conditions there will be more competition for light which leads to partial etiolation and induce the plant to grow high with longer petiole length for intercepting light for photosynthesis. Similar observations in papaya were reported by Sauco and Pastor, (2007) [10], Ganesh (2017) [2] and Godi *et al*. (2020) [3].

The variation in the number of leaves between open condition and insect proof net might be due to the differences in the environmental conditions like, temperature, relative humidity and sunlight interpretation prevailed during growth period (Ganesh, 2017 and Kanwar, 2020) [2]. According to Martelleto *et al*. (2008) [8] compare to natural environment, protected cultivation induces the stimulatory effects on plants by providing more amount of light, which favored to increase the foliar area and leaf index by 36 per cent and 20 per cent respectively.

The application of biofertilizers and biostimulents along with recommended dose of fertilizer through fertigation produced variety of growth substances and antifungal substances, which ultimately helpful in promoting vegetative vigour of the plants. Similar finding was observed by Meena *et al*. (2014) [9] in guava. The increase in plant height and stem girth may be due to improvement of physical properties of soil, higher nutrient uptake and increased activity of microorganisms which were manifested in the form of enhanced growth and higher carbohydrates production (Yadav, *et al*., 2011) [13]. And, it could also be because of continuous supply of available nutrient from organic and inorganic sources and effect of bio active substance produced by common application of bio fertilizer and biofertilizers. The similar result was reported by Suresh, *et al*., 2010 [11] in papaya.

The enhanced growth under fertigation might be due to better turgidity of the cells, leading to cell enlargement and better cell wall development (Viers, 1972). This might have attributed to more availability of nutrient particularly nitrogen and subsequent uptake by crop. This result in higher biomass production has reflected by production of additional leaves (Kuttimani, *et al*., 2013) [6]. Similarly was reported by Yadav, *et al*., 2011 [13] in papaya. Probably, the application of biofertilizers and biostimulents along with fertigation produced variety of growth substances and antifungal substances, which ultimately helpful in promoting vegetative vigour of the plants. The result in higher biomass production has showed by production of petiole length.

Acknowledgement
Authors are thankful to all the staff members and technician for their help in conducting the experiments.

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