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Effect of Integrated Nutrient Management on Vegetative Growth, Flowering and Yield of Papaya (*Carica papaya* L.) cv. Coorg Honey Dew

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A B S T R A C T

An experiment was conducted during the year 2015-2016 and 2016-2017 at the experimental plot, College of Agriculture, Chiplima, Odisha University of Agriculture and Technology, Sambalpur, Odisha to find out the effect of integrated use nutrients (organic, inorganic and biofertilizers) on growth, flowering and yield of papaya cv. Coorg Honey Dew. The maximum plant height (218.1cm and 284.4 cm), stem girth (41.7 cm and 62.3 cm), number of functional leaves (46.9 and 51.7), petiole length (85.7 cm and 114.9 cm) were recorded at 12 and 24 months after planting in papaya plants treated with 100% RDF + PSB +AZS+AZO i.e. under the treatment T_7 which was at par with T_8 and significantly superior to untreated control (T_{10}) plants. The minimum days required for first flower appearance (148 days), fruit set (166 days) and fruit development (125 days) in papaya was obtained when the plants received with 100 % RDF + AZO+AZS+PSB (T_7) as compared to untreated control plants (T_{10}) with corresponding values (179 days, 213 days and 155 days) respectively. The cumulative fruit yield was also found highest (55.89 kg/plant) in T_7 which was closely followed by (53.91 kg/plant) under treatment T_8. The treatments T_7 and T_8 registered a yield advantage of 234.7% and 225.7% over the control (T_{10}).

Introduction

Papaya (*Carica papaya*) belonging to family Caricaceae, one of the important delicious fruit crop is commercially grown in tropical and sub tropical areas of the world (Yadava *et al.*, 1990). Successful commercial cultivation of improved high yielding varieties of papaya crop depends on critical nutrient management practices due to its continuous growth, flowering and fruiting habit. The response of any crop to added nutrients largely depends on nutrient supplying capacity of soil and crop requirement and is also highly influenced by several ecoadaphic factors and management practices owing to increased cost of fertilizers, their short supply and sustainability issues gaining importance (Hazarika and Ansaris, 2007). The use of chemical fertilizers has resulted in progressive rise in multi nutrient deficiencies, nutrient imbalances, deterioration of soil health and productivity with time. Although, the organic manure contains plant nutrients in small quantities as compared to fertilizers, they influence in building up of organic matter, good soil aggregation,

permeability of soil and related physical properties to long lasting supply of several macro and micronutrients, vital plant promoting substance substances apart from increasing the density of microbes in the soil. This helps in maintenance and possible improvement of soil fertility and health for sustaining crop productivity. The nutrition of papaya differ from other fruit crops due to its quick growth, continuous flowering and fruiting habit and heavy production as plant would exhibit sensitiveness to low supply of major and minor nutrients. Considering all these facts, the present investigation was carried out with an objective to find out the effect of combined use of organic, inorganic and biofertilizers on the growth, flowering and yield of papaya cv. Coorg Honey Dew.

Materials and Methods

The present experiment was carried out at the experimental plot, College of Agriculture, Chiplima, Odisha University of Agriculture and Technology, Sambalpur, Odisha during the year 2015-2016 and 2016-2017 respectively. The experiment was laid out in Randomized Block Design with 10 treatments replicated thrice with 6 plants as units. The recommended fertilizer dose (RDF) @ 200:200:250 g NPK per plant/year, respectively were applied in the form of urea, DAP and murate of potash. The treatments are $T_{1:}$ Recommended dose of NPK (RDF) i.e. 200:200:250 g/plant/year,$T_{2:}$ 100% RDF + PSB (25g/plant),$T_{3:}$ 100% RDF + *Azospirillum* (25g/plant),$T_{4:}$ 100% RDF + *Azotobactor* (25g/plant), $T_{5:}$ 100% RDF + PSB (25g/plant)+*Azospirillum* (25g/plant), $T_{6:}$ 100% RDF + PSB (25g/plant)+*Azotobactor* (25g/plant), $T_{7:}$ 100% RDF + PSB (25g/plant) + *Azospirillum* (25g/plant) + *Azotobactor* (25g/plant), $T_{8:}$ 75% RDF + PSB (25g/plant) + *Azospirillum* (25g/plant) +*Azotobactor* (25g/plant), $T_{9:}$ 50% RDF + PSB (25g/plant)+ *Azospirillum* (25g/plant) +*Azotobactor* (25g/plant), $T_{10:}$ without any Fertilisers /bio fertilizers (FYM will be common for all treatments (10 kg/plant) except T_{10}).The inorganic fertilizers were applied in 4 split doses i.e. at 1st,3rd,5th,7th month after planting. The pit of 45 x 45 x 45cm were dug at 1.8x1.8 m spacing and well decomposed FYM @ 10kg/treatment was applied at the time of planting. Biofertilizers are applied at the time of planting after incubation mixed with FYM @ ratio 1:8 at 30 % moisture for 7 days. The data recorded on different vegetative, flowering and yield parameters were analyzed statistically (Panse and Sukhatme, 1995).

Results and Discussion

From the data presented in the Table 1, it is obvious that the vegetative growth parameters viz. plant height (cm), stem girth (cm), number of functional leaves, leaf area, petiole length, petiole girth etc. varied significantly due to combined use of organic manures, inorganic fertilizers and biofertilizers. The plant height was found to be increased significantly in treatment T_7 (218.1cm and 284.4 cm at 12 and 24 months after planting respectively) i.e. with (100% RDF + PSB +AZS+AZO). The shortest plant was obtained in control plants i.e. T_{10} (144.4 cm & 195.7cm at 12 and 24 months after planting respectively). The tallest plant obtained in T_7 might be due to combined use of chemical fertilizers, organic manures and biofertilizers. Similar pattern was recorded with respect to stem girth (41.7 cm and 62.3 cm during 12 MAP and 24 MAP), number of functional leaves (46.9 during 12 MAP and 51.7 at 24 MAP) which were recorded maximum with the treatment $T_{7.}$ Lowest stem girth (19.7 cm and 31.2 cm) and number of functional leaves (28.8 cm and 31.6 cm) were recorded from Control plants (T_{10}) during 12 and 24 months after planting respectively. The maximum plant height and stem girth obtained in T_7 and

T_8 might be due to better utilization of nutrients within the plant as well as translocation of maximum nitrogen to the top. The average leaf area (1883 cm^2) was recorded maximum in treatment T_6 (100% RDF + PSB+AZO) closely followed by (1874 cm^2) in treatment T_7 (100% RDF + PSB +AZS+AZO) at 12 MAP. However, it was found highest in treatment T_4 (1713 cm^2) at 24 MAP. Lowest average leaf area was recorded in control plants (1618 cm^2 and 1480 cm^2) during 12 and 24 months after planting respectively. Petiole length was recorded highest (85.7 cm and 114.9 cm) in T_7 both during 12 MAP and 24 MAP respectively. Chemical fertilizers which provide nutrients in right amount and proportion at right time accelerate the growth. It is known that nitrogen is essential for cell division and cell enlargement which increased the protoplasm.

The application of biofertilizers like *Azotobacter, Azospirillum* and PSB increased the availability of nitrogen in soil and also their availability to the plant which reflected higher plant growth. Beneficial effect of applied nutrients in promoting growth was also noted by Tarai and Ghosh (2006) in sweet orange. Organic manures are known to promote microbial population and their activity in the soil that may help to decompose and mobilize the nutrients in available forms (Mustaffa *et al.*, 2002).

Similarly, application of biofertilizers along with FYM created feasible condition for enhanced activity and build up of microbes. Biofertilizers like *Azotobacter* and *Azospirillum* fixes the atmospheric nitrogen and PSB solublize the phosphorous content and help in making it available to the plant. The *Azotobacter* and *Azospirillum* in addition to N_2 fixation might secrete growth promoting substrates like gibberlic acid, indol acetic acid and cytokinins etc which influence root growth. Their proliferation and enhanced cation exchange capacity (Pattanayak *et al*., 2008) for nutrient absorption might result higher plant growth in papaya. Organic manures along with biofertilizers also improve aeration in the soil which ultimately improved the physiological activities inside the plant like plant height, plant girth, number of leaves and petiole size. The results are in close proximity with the findings of Sharma *et al.* (2003) in pomegranate, Ghosh and Tarai (2007) in papaya, Mahendra *et al*. (2009) in Ber and Tandel *et al*. (2014) in Papaya. Lowest petiole length was obtained in control plants i.e. T_{10} (70.0 cm and 93.0 cm) during 12 MAP and 24 MAP. Petiole girth was found maximum (8.80 cm) in T_6 (100 % RDF + PSB +AZS) closely followed by (8.66cm) in T_5 (100% RDF + PSB+AZS) at 12 MAP. Lowest petiole girth was recorded in control plants i.e. under treatment T_{10} (7.00 cm and 9.33 cm during 12 and 24 MAP respectively). The increased petiole length obtained under T_7 may be explained from the fact that major as well as minor elements are available at optimum proportion in the soil and assimilation of food materials within the plant.

It is evident from the data presented in the Table 2 that the minimum days required for first flower appearance (148 days), fruit set (166 days) and fruit development (125 days) in papaya was obtained when the plants received with 100 % RDF + AZO+AZS+PSB (T_7) as compared to untreated control plants (T_{10}) with corresponding values (179 days, 213 days and 155 days respectively). This result was in line with the findings of Srivastava *et al.* (2014). The earliness in flowering might be due to the production of endogenous metabolites earlier in optimum level enabling earlier flowering as reported by Singh and Varu (2013). The cumulative fruit yield varied significantly by different combinations of organic, inorganic and biofertilizers in papaya (Table 3).

Table.1 Effect of Integrated Nutrient Management on vegetative growth parameters of Papaya cv. Coorg Honey Dew

Treatment	Plant height(cm)		Stem girth (cm)		Number of functional leaves		Avg. leaf area (cm^2)		Petiole length(cm)		Petiole girth(cm)	
	12MAP	24MAP	12MAP	24MAP	12MAP	24MAP	12MAP	24MAP	12MAP	24MAP	12MAP	24MAP
$T_{1:}$ Recommended dose of NPK (RDF)	172.7	248.6	32.0	55.6	36.5	42.1	1656	1503	75.3	102.6	8.06	11.00
$T_{2:}$ 100% RDF + PSB	190.5	261.6	37.8	58.5	40.8	45.8	1787	1683	78.6	103.9	8.36	11.66
$T_{3:}$ 100% RDF + *AZS*	183.3	253.6	36.3	58.2	38.7	44.6	1698	1593	79.0	107.0	8.13	12.33
$T_{4:}$ 100% RDF + *AZO*	189.8	255.0	37.7	57.5	41.6	46.7	1740	1713	79.7	104.7	8.43	10.33
$T_{5:}$ 100% RDF + PSB +*AZS*	201.6	266.9	38.0	59.7	40.2	45.7	1799	1680	80.2	107.0	8.66	12.34
$T_{6:}$ 100% RDF + PSB+*AZO*	209.1	270.2	38.7	60.3	42.3	49.4	1883	1595	82.0	110.1	8.80	11.33
$T_{7:}$ 100% RDF + PSB +*AZS*+*AZO*	218.1	284.4	41.7	62.3	46.9	51.7	1874	1650	85.7	114.9	8.43	12.00
$T_{8:}$ 75% RDF + PSB +*AZS* +*AZO*	207.6	273.5	36.9	60.1	40.3	46.6	1813	1617	85.3	111.4	8.46	10.66
$T_{9:}$ 50% RDF+ PSB +*AZS*+*AZO*	166.3	246.5	29.0	49.6	36.0	42.4	1722	1543	81.0	108.0	8.33	10.33
$T_{10:}$ Control (No Fertilisers /biofertilizers)	144.4	195.7	19.7	31.2	28.8	31.6	1618	1480	70.0	93.0	7.00	9.33
SEm (±)	9.77	6.05	1.10	0.99	1.58	1.57	39.20	67.13	1.78	1.84	0.44	0.67
CD (P=0.05)	29.02	17.98	3.28	2.94	4.70	4.66	116.48	NS	5.29	5.48	NS	NS

RDF=(200:200:250 g/plant/year), MAP= Month After Planting

Table.2 Effect of Integrated Nutrient Management on flowering behaviour of Papaya cv. Coorg Honey Dew

Treatment	Days to first flowering	Height of first flowering (cm)	Days to first fruit set	Height of first bearing (cm)	Days for fruit development
$T_{1:}$ Recommended dose of NPK (RDF)	173	100	202	109	135
$T_{2:}$ 100% RDF + PSB	172	108	199	120	130
$T_{3:}$ 100% RDF + *AZS*	164	102	193	111	132
$T_{4:}$ 100% RDF + *AZO*	163	104	191	118	133
$T_{5:}$ 100% RDF + PSB +*AZS*	163	114	192	123	132
$T_{6:}$ 100% RDF + PSB+*AZO*	155	116	179	127	129
$T_{7:}$ 100% RDF + PSB + *AZS+AZO*	148	132	166	137	125
$T_{8:}$ 75% RDF + PSB +*AZS* +*AZO*	163	111	182	124	130
$T_{9:}$ 50% RDF+ PSB +*AZS+AZO*	167	91	196	101	141
$T_{10:}$ Control (No Fertilisers / biofertilizers)	179	72	213	84	155
SEm (±)	5.0	3.6	3.8	4.0	1.4
CD (P=0.05)	15.0	10.7	11.3	12.0	4.3

RDF=(200:200:250 g/plant/year)
MAP= Month After Planting

Table.3 Effect of Integrated Nutrient Management on Yield and yield attributing parameters of Papaya cv. Coorg Honey Dew

Treatment	Average no. of fruits/plant			Average weight of the fruits(gm)		Average fruit yield (kg/plant)			Total fruit yield (ton/ha)		
	12MAP	24MAP	Cumulative Total /plant	12MAP	24MAP	12MAP	24MAP	Cumulative Total yield / plant	12MAP	24MAP	CumulativeTotal Yield
$T_{1:}$ Recommended dose of NPK (RDF)	14.9	37.8	52.7	828	748	12.33	28.27	40.61	38.1	87.3	125.3
$T_{2:}$ 100% RDF + PSB	15.8	39.4	55.2	837	785	13.22	30.95	44.18	40.8	95.5	136.3
$T_{3:}$ 100% RDF + *AZS*	15.5	40.3	55.8	835	793	12.94	31.94	44.88	39.9	98.6	138.5
$T_{4:}$ 100% RDF + *AZO*	17.1	39.1	56.2	843	811	14.41	31.71	46.12	44.5	97.9	142.3
$T_{5:}$ 100% RDF + PSB +*AZS*	18.9	42.6	61.5	875	861	16.53	36.68	53.22	51.0	113.2	164.2
$T_{6:}$ 100% RDF + PSB+*AZO*	17.9	43.7	61.6	894	860	16.00	37.61	53.62	49.4	116.1	165.5
$T_{7:}$ 100% RDF + PSB +*AZS*+*AZO*	19.1	44.3	63.4	896	870	17.12	38.53	55.89	52.8	118.9	171.7
$T_{8:}$ 75% RDF + PSB +*AZS* +*AZO*	18.7	43.4	62.1	892	863	16.64	37.47	54.11	51.4	115.6	167.1
$T_{9:}$ 50% RDF+ PSB +*AZS*+*AZO*	13.3	33.2	46.4	792	723	10.51	23.97	34.48	32.4	74.0	106.4
$T_{10:}$ Control (No Fertilisers /biofertilizers)	10.2	22.1	32.3	602	474	6.14	10.49	16.41	19.0	32.4	51.3
SEm (±)	0.29	0.5	0.59	8.0	8.5	0.255	0.434	0.536	0.79	1.34	1.61
CD (P=0.05)	0.86	1.4	1.77	24.0	25.0	0.759	1.290	1.591	2.34	3.98	4.79

RDF=(200:200:250 g/plant/year)
MAP=Month After Planting

The number of fruits per plant were recorded highest (19.1 and 44.3 at 12 MAP and 24 MAP respectively) under treatment T_7 (100% RDF + PSB +AZS+AZO) followed by (18.7 and 43.4 at 12 MAP and 24 MAP respectively) under T_8 i.e. with application of 75 % RDF + PSB +AZS+AZO. Lowest number of fruits per plant (10.2 and 22.1 at 12 MAP and 24 MAP respectively) was noticed with control plants (T_{10}). Likewise, the fruit weight was recorded highest with treatment T_7 (896 g and 870g at 12 and 24 MAP respectively) closely followed by $T_{8.}$ (892g and 863g respectively at 12 and 24 MAP respectively). Lowest fruit weight was noticed with control plants (602 g and 474g respectively at 12 and 24 MAP). It was noticed that the number of fruits per plant was recorded lesser up to 12 MAP because of lesser fruiting period irrespective of all the treatments, whereas it was recorded higher from 13 MAP up to 24 MAP due to longer fruiting period. However, heavier fruit was obtained upto 12 MAP due to better vegetative growth of the plant as well free from attack of pest and diseases during initial period of growth. The cumulative fruit yield was recorded highest (55.89 kg/plant) under treatment T_7 which was closely followed by (54.11 kg/plant) under treatment T_8. The lowest cumulative fruit yield of 16.41 kg/plant was recorded in control plants (T_{10}). Similarly the highest fruit yield per hectare (171.7 t/ha) was found with the application of 100% RDF + PSB +AZS+AZO i.e. under treatment T_7 followed by (167.1 t/ha) in T_8 (75% RDF+PSB+AZS+AZO). The treatments T_7 and T_8 registered a yield advantage of 234.7% and 225.7% over the control (T_{10}). The significant response of biofertilizers along with organic and inorganic fertilizers had positively and significantly influenced yield and its attributes. Effectiveness of combined use of organic and inorganic fertilizers in improving the yield may be explained from the fact that organic matter helps to retain urea in the soil (Mistui *et al.* 1960) and in making the phosphate and potash available to the plants (Roychoudhuri, 1976). It is also well understood that efficiency of biofertilizers can be well exploited when used in combination with organic and inorganic fertilizers (Suther, 2009) which might have improved the yield by better availability and uptake of nutrients by plant roots and enhancing the source: sink relationship by increasing the movement of carbohydrates from the leaves to fruits. The higher dose of nutrients with three biofertilizers increased the availability of nutrients in soil and ensures optimum uptake by plants due to increase in microbial activity in soil, which enhance vegetative characteristics like plant height, stem girth, petiole length etc. that contributes assimilation of more photosynthates within the plant. This result is also in close proximity with the findings of Patil *et al*., (1995), Singh *et al* (2013), Ravisankar *et al.* (2010) and Chaudhri *et al.* (2001) in Papaya.

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