Int.J.Curr.Microbiol.App.Sci (2020) *9*(10): 3811-3822

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Volume 9 Number 10 (2020)**
Journal homepage: http://www.ijcmas.com

Original Research Article https://doi.org/10.20546/ijcmas.2020.910.438

Influence of INM on Vegetative Growth, Fruiting, Yield and Soil Physical Characters in Papaya (*Carica papaya* L.)

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Keywords

Papaya, Integrated Nutrient Management, Growth, Fruiting, Yield and Soil physical characters

Article Info

Accepted:
25 September 2020
Available Online:
10 October 2020

A B S T R A C T

An experiment was carried out in the Department of Horticulture, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur (U.P.), India, during 2015-16 and 2016-17 to study the influence of integrated nutrient management on vegetative growth, fruiting, yield and soil physical characters in papaya (*Carica papaya* L.). For this plant of Sapna cultivar was planted on 20th March during both years of experimentation at a spacing of 2.0 x 2.0 m. There were eighteen treatments comprising *Azotobacter*, PSB and vermicompost with graded dose of RDF including one control, replicated thrice in randomized block design. All treatments were applied at the time of planting in the field. The data of both the years of experiment were analyzed which clearly shows that maximum plant spread from North to South direction and from East to West direction, maximum number of leaves and font area, biomass per plant, number of flowers, number of fruits set and yield per plant with minimum fruiting height and fruit developmental period were recorded with the application of RDF 75% + *Azotobacter* 100 g + PSB 100 g + vermicompost 2 kg/plant, which was significantly higher than the control, whereas the minimum plant spread from North to South direction and from East to West direction, minimum number of leaves and font area, biomass per plant, number of flowers, number of fruits set and yield per plant with maximum fruiting height and fruit developmental period were recorded under unfertilized plants during both years of experimentation. As various soil physical characters are concerned maximum available potassium, organic carbon per cent, available nitrogen, available phosphorus with minimum soil pH and soil electrical conductivity were recorded in the field fertilized with RDF 75%+ *Azotobacter* 100 g + PSB 100 g + vermicompost 2 kg/plant, whereas the minimum available potassium, available nitrogen, available phosphorus, minimum organic carbon per cent with maximum soil pH and electrical conductivity were recorded in field kept under control, where non amount of fertilizers were applied during both years of present investigation.

Introduction

Papaya (*Carica papaya* L.), a member of family Caricaceae, is a fast growing, 1 to 5 meter in height, perennial plant, which is basically a tropical fruit plant and commercially grown in tropical and sub-tropical areas. The optimum temperature for papaya is reported to be 21° to 33° C. In India, it is being cultivated in an area of 1.38 Lakh ha with a total production of 5.99 Lakh MT and average productivity is 43.27 MT per hectare (Anonymous (2018). Papaya is a cheap and rich source of vitamins and minerals in the daily diet of millions of people. The latex obtained from raw papaya fruit is used for the preparation of an enzyme papain, which helps in the digestion of proteins, because of its proteolytic enzymatic activity. In addition to these unripe fruits are also used as vegetables, whereas the ripe fruits are very delicious in taste, which are used as dessert fruit. Its higher nutritive value, huge industrial importance, high remunerative price and fruiting throughout the year, put the papaya fruits to an important place in fruit industry and make this an important fruit for the growers, consumers, traders, exporter and processors.

An INM (Integrated Nutrient Management) is one of the most effective alternatives which involve combined use of chemical fertilizers, organic manures and bio-fertilizers for the maintenance of long-term soil fertility and productivity along with sustainable crop production. Organic manures mostly enhance the nutrient availability in order to improve the soil structure, texture, tilth and better environment for root development and aeration. Bio-fertilizers like *Azotobacter* and Phosphate Solubilising Bacteria (PSB) results an increased availability of nitrogen and phosphorus nutrients in the soil. Contrary to various chemical fertilizers, organic manures and bio-fertilizers are available indigenously at lower cost which also improve soil health and enhanced crop yield per unit of applied nutrient and there by save energy, keeping in all above facts in view, the present investigation was carried out to standardized most suitable combination of *Azotobacter*, PSB and vermicompost with a dose of chemical fertilizers in an integrated way to get increased vegetative growth, fruiting and higher yield of papaya (*Carica papaya* L.) fruits with improved soil physical characters.

Materials and Methods

The present investigation was carried out in the garden, Department of Horticulture, C.S. Azad University of Agriculture & Technology Kanpur during two subsequent years *i.e.*, 2015-16 and 2016-17. The experiments were laid out in Randomized Block Design with eighteen treatments *viz.*, T_0 (No amount of fertilizers), T_1 (recommended dose of fertilizers (RDF)-200:200:300 g/plant),T_2 (RDF 75%+ *Azotobacter* 50 g + PSB 50 g/plant), T_3 (RDF 75%+ *Azotobacter* 50 g + PSB 50 g+ vermicompost 1 kg/plant), T_4 (RDF 75%+ *Azotobacter* 50 g + PSB 50 g+ vermicompost 1.5 kg/plant), T_5 (RDF 75%+ *Azotobacter* 50 g + PSB 50 g + vermicompost 2 kg/plant), T_6 (RDF 75%+ *Azotobacter* 100 g+ PSB 100 g/plant), T_7 (RDF 75%+ *Azotobacter* 100 g + PSB 100 g + vermicompost 1 kg/plant), T_8 (RDF 75%+ *Azotobacter* 100 g + PSB 100 g + vermicompost 1.5 kg/plant), T_9 (RDF 75%+ *Azotobacter* 100 g + PSB 100 g + vermicompost 2 kg/plant), T_{10} (RDF 50%+ *Azotobacter* 50 g + PSB 50 g/plant), T_{11} (RDF 50%+ *Azotobacter* 50 g + PSB 50 g + vermicompost 1 kg/plant), T_{12} (RDF 50%+ *Azotobacter* 50 g + PSB 50 g + vermicompost 1.5 kg/plant), T_{13} (RDF 50%+ *Azotobacter* 50 g + PSB 50 g + vermicompost 2 kg/plant), T_{14} (RDF 50%+ *Azotobacter* 100 g + PSB 100 g/plant), T_{15} (RDF 50%+ *Azotobacter* 100 g + PSB 100 g + vermicompost 1 kg/plant), T_{16} (RDF 50%+ *Azotobacter* 100 g + PSB 100 g + vermicompost 1.5 kg/plant), T_{17} (RDF 50%+ *Azotobacter* 100 g + PSB 100 g + vermicompost 2 kg/plant). Planting was done at a distance of 2m × 2m on 20th March during both years of experimentation *i.e.*, 2015-16 and 2016-17, using 'Sapna' cultivar. Two plants are used as a unit.

Observations on plants spread from North to South and East to West direction were measured by measuring tape along with measuring pole in centimeter, whereas number of leaves per plant was counted started from the time of transplanting and to the harvesting of last fruit. Font of leaves was measured by using leaf area meter and biomass production of plant was recorded by weighing the whole plant, including shoot and leaves expressed in kilograms (kg). Data on number of flowers and fruits set per plant were recorded by counting at ten days interval during entire fruiting season. Height at which first fruit appeared was recorded from the base of the plant to denote the fruiting height, whereas the period between fruit set and fruit maturity was calculated as fruits developmental period. At the time of harvesting, fruit were weighted to calculate yield per plant. As soil physical characters are concerned, soil pH was analyzed with the help of digital pH meter, Electrical conductivity by digital conductivity meter as advocated by Jackson, (1973). Organic carbon (%) by rapid titration method as describe by Walkley and Black (1934), available nitrogen by alkaline potassium permanganate method as suggested by Subbiah and Asija (1956), available phosphorus (kg ha^{-1}) by Olsen's method as described by *Olsen et al.,* (1954) and available potassium (kg ha^{-1}) by flame photometer with the use of saturation extract of soil as describe by Jackson (1973).

Results and Discussion

Plant spread (North to South and East to West direction)

Plant spread in all direction was significantly more over control when *Azotobacter*, PSB and vermicompost were used in combinations with different doses of RDF during both years of experimentation (Table 1). Maximum plant spread from North to South direction (191.08 and 189.15 cm, respectively) and from East to West direction (182.22 and 173.86 cm, respectively) were recorded with the application of RDF 75% + *Azotobacter* 100 g + PSB 100 g + vermicompost 2 kg/plant, which was significantly higher than the control, whereas the minimum plant spread from North to South direction (140.85 and 139.26 cm, respectively) and from East to West direction (129.15 and 126.89 cm, respectively) was recorded under unfertilized plants during both years of experimentation. The marked increase in plant spread in all direction with the use of bio-fertilizers and vermicompost along with graded dose of NPK may be due to the fact that absorbed nutrients combined with carbohydrates in leaves could lead to the formation of amino acids, nucleic acid, proteins, chlorophyll, alkaloid and amides. These complex compounds are responsible for building up of new tissues and are associated in a number of metabolic steps in fruit crops. Bio-fertilizers and vermicompost are also known to enrich the soil by biological N-fixation and improving the availability of different nutrients to plants, which results more vegetative growth in all directions. These results are in conformity with the findings of Kirankumar *et al.,* (2017) in guava, Gautam *et al.,* (2012) in Mango and Srivastava *et al.,* (2014) in papaya.

Fruiting height

Data presented in Table 1 clearly shows that during both years of experimentation fruiting height of plants were significantly decreased over control when *Azotobacter*, PSB and vermicompost were used in combinations with different doses of RDF. Plants having minimum fruiting height (36.24 and 35.92 cm, respectively) were recorded when they were fertilized with RDF 75% + *Azotobacter* 100 g + PSB 100 g + vermicompost 2 kg/plant (T_9) and this was significantly higher than rest all other treatments except T_8, T_1, T_{15}, T_{16}, T_{17}, T_6 and T_7. On the contrary, maximum fruiting height (46.12 and 45.96 cm, respectively) was recorded in untreated control plants during both years of experimentation. The results with respect to fruiting height is also in conformity with the findings of Srivastava (2008), who reported that 100% NPK + FYM + *Azotobacter* + PSB showed significant differences as compared with the control (100% NPK + FYM) for measured fruiting height in papaya.

Number of leaves and font area

During both years of investigation, the number of leaves and font area were significantly increased over control when *Azotobacter*, PSB and vermicompost were used in combinations with different doses of RDF (Table-1). Plants fertilized with RDF 75% + *Azotobacter* 100 g + PSB 100 g + vermicompost 2 kg/plant produced significantly maximum number of leaves (35.54 and 36.52, respectively) and maximum font area (33.19 and 33.20 cm), whereas the minimum number of leaves (26.00 and 25.65, respectively) and font area (21.51 and 20.75 cm, respectively) were recorded under untreated control plants during both years of experimentation. This increase in leaves number and font area during entire experimental period might be due to the continuous supply of available nutrient from organic and inorganic form and effect of bio-active substance produced by the application of bio-fertilizers.

Organic manures (vermicompost) along with bio-fertilizers also improve the aeration in the soil which ultimately improved the physiological activities inside the plant like plant height, stem girth, number of leaves and font area. The present results are in accordance to the findings of Srinu *et al.*, (2017), Srivastava *et al.*, (2014) in papaya, Gupta and Tripathi (2012), Tripathi *et al.*, (2015b) in strawberry cv. Chandler and Tripathi *et al.*, (2013) in Isabgol.

Biomass production (green weight)

During both years of experimentation biomass production (green weight) was significantly more over control when *Azotobacter*, PSB and vermicompost were used in combinations with different doses of RDF (Table 1). When the plants were fertilized with RDF 75% + *Azotobacter* 100 g + PSB 100 g + vermicompost 2 kg/plant produced maximum biomass (29.00 and 28.34 kg, respectively) per plant followed by RDF 75%+ *Azotobacter* 100 g + PSB 100 g + vermicompost 1.5 kg/plant fertilized plants which produces 28.00 and 27.37kg, respectively biomass per plant on green weight. On the contrary, minimum biomass (12.00 and 11.65 kg, respectively) per plant on green weight was produced under untreated control plants in which non amount of fertilizers were applied during both years of experimentation.

Plants treated with *Azotobacter*, PSB and vermicompost showed significantly higher shoot biomass accumulation over control and untreated ones might be due to the induction of growth hormones, which stimulated cell division, cell elongation, activate the photosynthesis process. Further application of organic manure, there was also significant increase in shoot biomass content over control.

These results are corroborated with the findings of Sukhada *et al.*, (1995) who reported that papaya plants inoculated with *G. mosseae* exhibited an increased dry matter (26.6%) under sterile conditions. The present results are in accordance to the findings of Kirankumar *et al.*, (2017) in guava and Mamta *et al.*, (2017) in papaya.

Table.1 Influence of Integrated Nutrient Management on growth parameters of papaya (*Carica papaya* L.)

Treatments	Plant spread (North-South) (cm)		Plant spread (East-West) (cm)		Number of leaves per plant		Font of leaf (cm)		Biomass production of plant (green weight in kg)	
	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
T_0	140.85	139.26	129.15	126.89	26.00	25.65	21.51	20.75	12.00	11.65
T_1	184.20	180.12	166.06	158.50	33.33	31.45	31.30	31.34	27.00	26.39
T_2	153.84	151.28	142.88	136.44	28.76	27.87	27.16	26.99	18.46	18.08
T_3	159.01	157.08	145.56	138.98	26.57	27.24	28.79	28.96	19.67	19.25
T_4	162.65	163.42	146.68	140.05	33.24	31.67	30.18	30.20	20.00	19.58
T_5	170.86	169.95	163.11	155.68	34.24	32.62	30.93	30.82	22.00	21.52
T_6	175.86	171.29	149.28	142.53	29.97	29.86	31.00	31.05	20.00	19.58
T_7	180.23	175.58	156.05	148.97	30.91	30.76	31.80	31.78	17.33	16.98
T_8	187.64	184.64	176.07	168.02	33.44	33.49	32.89	32.85	28.00	27.37
T_9	191.08	189.15	182.22	173.86	35.54	36.52	33.19	33.20	29.00	28.34
T_{10}	152.61	150.20	150.52	143.71	28.33	27.45	23.65	26.60	17.45	17.09
T_{11}	159.25	155.45	157.73	150.56	27.79	26.50	24.49	24.45	22.00	21.52
T_{12}	163.09	160.91	154.06	147.07	31.33	30.86	25.84	25.86	19.00	18.60
T_{13}	165.27	164.32	152.64	145.72	30.33	31.81	26.66	26.38	23.00	22.50
T_{14}	174.21	171.84	147.07	140.42	27.24	28.97	27.39	27.38	15.67	15.36
T_{15}	178.40	177.24	151.90	145.02	29.33	27.96	29.22	29.24	18.00	17.63
T_{16}	181.51	180.10	161.23	153.89	32.33	30.81	29.81	29.83	21.00	20.55
T_{17}	185.07	184.80	177.50	169.37	33.15	32.98	30.10	30.14	26.00	27.44
SEm ±	9.29	9.01	8.11	8.75	1.76	2.00	2.07	2.28	1.95	1.98
$CD_{5\%}$ level	28.17	27.34	24.59	26.55	5.34	6.08	6.29	6.92	5.91	5.99
CV	9.44	9.28	8.99	10.16	9.95	11.47	12.52	13.74	16.23	16.62

Treatments notations: T_0 (No amount of fertilizers), T_1 (recommended dose of fertilizers (RDF)-200:200:300 g/plant),T_2 (RDF 75%+ *Azotobacter* 50 g + PSB 50 g/plant), T_3 (RDF 75%+ *Azotobacter* 50 g + PSB 50 g+ vermicompost 1 kg/plant), T_4 (RDF 75%+ *Azotobacter* 50 g + PSB 50 g+ vermicompost 1.5 kg/plant), T_5 (RDF 75%+ *Azotobacter* 50 g + PSB 50 g + vermicompost 2 kg/plant), T_6 (RDF 75%+ *Azotobacter* 100 g+ PSB 100 g/plant), T_7 (RDF 75%+ *Azotobacter* 100 g + PSB 100 g + vermicompost 1 kg/plant), T_8 (RDF 75%+ *Azotobacter* 100 g + PSB 100 g + vermicompost 1.5 kg/plant), T_9 (RDF 75%+ *Azotobacter* 100 g + PSB 100 g + vermicompost 2 kg/plant), T_{10} (RDF 50%+ *Azotobacter* 50 g + PSB 50 g/plant), T_{11} (RDF 50%+ *Azotobacter* 50 g + PSB 50 g + vermicompost 1 kg/plant), T_{12} (RDF 50%+ *Azotobacter* 50 g + PSB 50 g + vermicompost 1.5 kg/plant), T_{13} (RDF 50%+ *Azotobacter* 50 g + PSB 50 g + vermicompost 2 kg/plant), T_{14} (RDF 50%+ *Azotobacter* 100 g + PSB 100 g/plant), T_{15} (RDF 50%+ *Azotobacter* 100 g + PSB 100 g + vermicompost 1 kg/plant), T_{16} (RDF 50%+ *Azotobacter* 100 g + PSB 100 g + vermicompost 1.5 kg/plant), T_{17} (RDF 50%+ *Azotobacter* 100 g + PSB 100 g + vermicompost 2 kg/plant)

Table2 Influence of Integrated Nutrient Management on fruiting and yield parameters of papaya (*Carica papaya* L.)

Treatments	Fruit developmental period (Days)		Number of flowers per plant		Number of fruits set per plant		Fruit yield (kg/tree)	
	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
T_0	**164.00**	**163.26**	**73.86**	**72.24**	**24.00**	**22.80**	**22.34**	**23.49**
T_1	**144.23**	**142.20**	**103.85**	**103.28**	**40.00**	**38.00**	**58.80**	**52.98**
T_2	**159.37**	**158.33**	**77.00**	**75.15**	**28.00**	**27.56**	**29.38**	**26.47**
T_3	**152.19**	**151.34**	**84.76**	**80.25**	**30.00**	**28.50**	**35.70**	**36.17**
T_4	**160.00**	**158.08**	**89.00**	**84.55**	**32.00**	**30.40**	**39.81**	**35.87**
T_5	**155.67**	**154.68**	**97.25**	**94.05**	**36.00**	**34.20**	**49.18**	**44.31**
T_6	**159.93**	**155.86**	**85.10**	**83.95**	**28.50**	**27.70**	**31.20**	**28.11**
T_7	**159.33**	**154.96**	**91.00**	**89.45**	**31.00**	**29.45**	**38.22**	**34.44**
T_8	**141.32**	**141.65**	**104.20**	**104.75**	**41.50**	**39.43**	**62.94**	**56.71**
T_9	**140.25**	**141.37**	**104.69**	**104.80**	**43.00**	**40.85**	**67.08**	**60.44**
T_{10}	**155.34**	**151.67**	**79.00**	**75.05**	**25.18**	**24.97**	**26.93**	**26.26**
T_{11}	**154.35**	**153.42**	**81.30**	**80.15**	**29.00**	**27.55**	**32.66**	**31.83**
T_{12}	**152.67**	**153.32**	**82.00**	**83.08**	**27.00**	**25.65**	**35.07**	**33.60**
T_{13}	**155.00**	**144.35**	**84.22**	**82.50**	**28.00**	**26.60**	**35.17**	**32.69**
T_{14}	**149.28**	**147.93**	**81.10**	**82.05**	**27.00**	**25.65**	**28.51**	**25.69**
T_{15}	**147.59**	**146.20**	**88.00**	**87.60**	**33.00**	**31.35**	**35.54**	**32.03**
T_{16}	**162.47**	**157.19**	**94.00**	**89.30**	**36.00**	**34.20**	**46.80**	**42.17**
T_{17}	**163.24**	**160.23**	**98.00**	**93.10**	**38.00**	**36.10**	**53.58**	**48.28**
SEm ±	**4.50**	**4.53**	**4.08**	**3.18**	**2.29**	**1.81**	**2.33**	**1.94**
$CD_{5\%}$ level	**13.67**	**13.74**	**12.37**	**9.66**	**6.95**	**5.50**	**7.06**	**5.87**
CV	**5.06**	**5.16**	**7.95**	**6.35**	**12.37**	**10.26**	**9.96**	**8.99**

Treatments notations: T_0 (No amount of fertilizers), T_1 (recommended dose of fertilizers (RDF)-200:200:300 g/plant),T_2 (RDF 75%+ *Azotobacter* 50 g + PSB 50 g/plant), T_3 (RDF 75%+ *Azotobacter* 50 g + PSB 50 g+ vermicompost 1 kg/plant), T_4 (RDF 75%+ *Azotobacter* 50 g + PSB 50 g+ vermicompost 1.5 kg/plant), T_5 (RDF 75%+ *Azotobacter* 50 g + PSB 50 g + vermicompost 2 kg/plant), T_6 (RDF 75%+ *Azotobacter* 100 g+ PSB 100 g/plant), T_7 (RDF 75%+ *Azotobacter* 100 g + PSB 100 g + vermicompost 1 kg/plant), T_8 (RDF 75%+ *Azotobacter* 100 g + PSB 100 g + vermicompost 1.5 kg/plant), T_9 (RDF 75%+ *Azotobacter* 100 g + PSB 100 g + vermicompost 2 kg/plant), T_{10} (RDF 50%+ *Azotobacter* 50 g + PSB 50 g/plant), T_{11} (RDF 50%+ *Azotobacter* 50 g + PSB 50 g + vermicompost 1 kg/plant), T_{12} (RDF 50%+ *Azotobacter* 50 g + PSB 50 g + vermicompost 1.5 kg/plant), T_{13} (RDF 50%+ *Azotobacter* 50 g + PSB 50 g + vermicompost 2 kg/plant), T_{14} (RDF 50%+ *Azotobacter* 100 g + PSB 100 g/plant), T_{15} (RDF 50%+ *Azotobacter* 100 g + PSB 100 g + vermicompost 1 kg/plant), T_{16} (RDF 50%+ *Azotobacter* 100 g + PSB 100 g + vermicompost 1.5 kg/plant), T_{17} (RDF 50%+ *Azotobacter* 100 g + PSB 100 g + vermicompost 2 kg/plant)

Table.3 Influence of Integrated Nutrient Management on soil physical characters in papaya (*Carica papaya* L.) field

Treatments	Soil pH		Electrical conductivity (dSm^{-1})		Organic carbon (%)		Available nitrogen (kg ha^{-1})		Available Phosphorus (kg ha^{-1})		Available potassium (kg ha^{-1})	
	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
T_0	7.65	7.70	0.43	0.44	0.33	0.34	251.26	252.34	20.35	21.95	260.17	261.24
T_1	7.42	7.42	0.40	0.42	0.36	0.37	265.15	271.24	22.48	23.60	260.14	266.62
T_2	7.40	7.38	0.39	0.38	0.38	0.39	265.14	264.19	23.73	24.30	265.80	266.29
T_3	7.44	7.40	0.41	0.40	0.40	0.41	267.07	266.13	24.07	25.77	266.73	267.22
T_4	7.46	7.41	0.42	0.41	0.41	0.42	268.84	268.91	24.94	26.08	267.50	269.00
T_5	7.54	7.39	0.38	0.37	0.43	0.44	269.96	270.28	25.74	26.68	271.83	272.35
T_6	7.44	7.39	0.40	0.39	0.39	0.40	265.48	268.53	23.48	24.65	266.14	267.63
T_7	7.40	7.35	0.39	0.38	0.41	0.42	268.81	268.91	25.81	25.20	268.47	270.98
T_8	7.37	7.32	0.36	0.35	0.42	0.43	270.14	270.65	27.14	26.95	269.82	271.31
T_9	7.10	7.26	0.33	0.32	0.44	0.45	271.15	300.85	27.89	27.80	270.14	272.65
T_{10}	7.43	7.35	0.39	0.38	0.37	0.38	264.92	262.97	23.14	24.12	265.58	266.07
T_{11}	7.45	7.39	0.40	0.39	0.39	0.40	266.48	265.56	24.48	25.14	266.14	266.84
T_{12}	7.44	7.37	0.38	0.39	0.40	0.41	268.01	267.41	24.40	25.81	267.00	268.50
T_{13}	7.42	7.37	0.38	0.37	0.42	0.43	268.04	269.12	25.04	26.34	268.70	270.20
T_{14}	7.45	7.40	0.41	0.40	0.38	0.39	261.61	267.88	22.81	24.38	268.87	266.97
T_{15}	7.41	7.36	0.37	0.36	0.39	0.40	266.34	269.40	24.34	24.73	268.00	270.18
T_{16}	7.40	7.35	0.36	0.35	0.41	0.42	268.15	268.22	26.34	26.45	268.80	270.49
T_{17}	7.42	7.37	0.38	0.39	0.42	0.43	268.78	270.57	27.48	27.10	269.15	270.74
SEm ±	0.06	0.06	0.02	0.01	0.01	0.02	1.57	4.61	1.12	1.04	9.91	11.24
$CD_{5\%}$ level	0.20	0.17	0.05	0.04	0.04	0.05	4.77	13.99	3.39	3.15	NS	NS
CV	1.51	1.33	7.44	5.34	5.77	6.93	1.02	2.97	7.84	7.09	6.43	7.25

Treatments notations: T_0 (No amount of fertilizers), T_1 (recommended dose of fertilizers (RDF)-200:200:300 g/plant),T_2 (RDF 75%+ *Azotobacter* 50 g + PSB 50 g/plant), T_3 (RDF 75%+ *Azotobacter* 50 g + PSB 50 g+ vermicompost 1 kg/plant), T_4 (RDF 75%+ *Azotobacter* 50 g + PSB 50 g+ vermicompost 1.5 kg/plant), T_5 (RDF 75%+ *Azotobacter* 50 g + PSB 50 g + vermicompost 2 kg/plant), T_6 (RDF 75%+ *Azotobacter* 100 g+ PSB 100 g/plant), T_7 (RDF 75%+ *Azotobacter* 100 g + PSB 100 g + vermicompost 1 kg/plant), T_8 (RDF 75%+ *Azotobacter* 100 g + PSB 100 g + vermicompost 1.5 kg/plant), T_9 (RDF 75%+ *Azotobacter* 100 g + PSB 100 g + vermicompost 2 kg/plant), T_{10} (RDF 50%+ *Azotobacter* 50 g + PSB 50 g/plant), T_{11} (RDF 50%+ *Azotobacter* 50 g + PSB 50 g + vermicompost 1 kg/plant), T_{12} (RDF 50%+ *Azotobacter* 50 g + PSB 50 g + vermicompost 1.5 kg/plant), T_{13} (RDF 50%+ *Azotobacter* 50 g + PSB 50 g + vermicompost 2 kg/plant), T_{14} (RDF 50%+ *Azotobacter* 100 g + PSB 100 g/plant), T_{15} (RDF 50%+ *Azotobacter* 100 g + PSB 100 g + vermicompost 1 kg/plant), T_{16} (RDF 50%+ *Azotobacter* 100 g + PSB 100 g + vermicompost 1.5 kg/plant), T_{17} (RDF 50%+ *Azotobacter* 100 g + PSB 100 g + vermicompost 2 kg/plant)

Fruit developmental period

Fruit developmental period were significantly reduced over control when *Azotobacter*, PSB and vermicompost were used in different combinations with graded doses of RDF during both years of experimentation (Table 2). Significantly minimum fruit developmental period (140.25 and 141.37 days, respectively) was recorded when the plants were treated with RDF 75% + *Azotobacter* 100 g + PSB 100 g + vermicompost 2 kg/plant, whereas the maximum fruit developmental period (164.00 and 163.26 days, respectively) was recorded in plants kept as untreated control. Application of graded dose of chemical fertilizers in association with organic manure and bio-fertilizers, may results in enhanced activity of biological nitrogen fixation and higher net assimilation rate on account of better growth leading to the production of endogenous metabolites. These results are in conformity with the findings of Srinu *et al.*, (2017), Srivastava *et al.*, (2014) in papaya.

Number of flowers and fruits set per plant

Data presented in Table 2, it is clearly reveals that during both years of experimentation number of flowers and fruits set per plant were significantly more over control when *Azotobacter*, PSB and vermicompost were used in combinations with different doses of RDF. Higher number of flowers (104.69 and 104.80, respectively) with maximum number of fruits set (43.00 and 40.85, respectively) per plant was recorded in plants which were fertilized with RDF 75%+ *Azotobacter* 100 g + PSB 100 g + vermicompost 2 kg/plant, whereas the minimum number of flowers (73.86 and 72.24, respectively) and fruits set (24.00 and 22.80, respectively) were recorded in plants which were kept under control without application of non-amount of fertilizers during both years of experimentation. This increase in number of flowers and fruits set in this treatment might be due to the fact that the application *Azotobacter* and PSB along with vermicompost and NPK fertilizers as a balanced dose accelerated the development of inflorescence, leaf number in autumn which results in increased levels of nutrients in assimilating area of crop due to which the rate of dry matter production was enhanced, which is positively correlated with the number of flowers and fruits in the following spring. Proper supply of nutrients and induction of growth hormones stimulated cell division, cell elongation, which results an increase in number of flowers and fruits. Similar findings have been reported by Srinu *et al.*, (2017) in papaya, Gupta and Tripathi (2012) in strawberry cv. Chandler, Tripathi *et al.*, (2015a) in aonla and Katiyar *et al.*, (2012) in ber.

Fruit yield

Data presented in Table 1 clearly shows that significantly maximum fruit yield was recorded when plants were fertilized with *Azotobacter*, PSB and vermicompost in combinations with different doses of RDF during both years of experimentation. The maximum yield per plant (67.08 and 60.44 kg, respectively) was recorded in plants fertilized with the combination of RDF 75% + *Azotobacter* 100 g + PSB 100 g + vermicompost 2 kg/plant (T_9) and this yield was significantly higher as compared to all other treatments. Plants kept under control produced the minimum yield of fruits (22.34 and 23.49 kg, respectively) during both years of experimentation. This increase in yield parameters during both years of experimentation with the use of vermicompost, *Azotobacter* and PSB in combination with graded dose of NPK might be due to an increased number of fruits set, higher nitrogen fixation in soil, increase in the availability of phosphorus with increased uptake of various other trace elements and translocation of photosynthates from leaves to developing fruits. Use of vermicompost results in increased microflora, which produce useful products in the soil, which ultimately helps in the biodegradation of various agricultural residues present in the soil. Relatively higher amount of carbohydrates could have promoted the growth rate and increased fruit weight. These findings are in line with the findings of Tripathi (2017), Nayyer *et al.,* (2014) in banana, Tripathi *et al.,* (2014), Tripathi *et al.,* (2016) in strawberry, Kumar *et al.,* (2015) in Guava, Srivastava *et al.,* (2014), Srinu *et al.,* (2017) and Kanwar *et al.,* (2020) in papaya.

Soil physical characters

During both years of present investigation available potassium (kg ha^{-1}) content in the soil have non-significant effect when *Azotobacter,* PSB and vermicompost were used in combinations with different doses of RDF during their production process (Table 3). However, maximum available potassium (270.14 and 272.65 kg ha^{-1}, respectively) content was recorded in the field fertilized with RDF 75%+ *Azotobacter* 100 g + PSB 100 g + vermicompost 2 kg/plant, whereas the minimum available potassium (260.17 and 261.24 kg ha^{-1}, respectively) content was recorded in field kept under control during both years of experimentation. The reason for increased available K under inorganic and bio-fertilizer application may be due to the results of additional K supply, the solubilization action of certain organic acids produced during decomposition process and its greater capacity of hold K in available form in the soil and also due to the interaction of organic matters with clay and direct addition of potassium to the available pool of soil. Results are in conformity with the findings of Srivastava (2008), Yadav (2005) in guava.

Further investigation of orchard soil during both years of experimentation results that soil pH, soil electrical conductivity, organic carbon per cent, available nitrogen and phosphorus contents in the soil were significantly influenced/increased over control, when *Azotobacter*, PSB and vermicompost were used in combinations with different doses of RDF during their production process (Table 3). During entire period of investigation minimum soil pH (7.10 and 7.26, respectively), soil electrical conductivity (0.33 and 0.32 dSm^{-1}, respectively), maximum organic carbon per cent (0.44 and 0.45 %, respectively), maximum available nitrogen (271.15 and 300.85 kg ha^{-1}, respectively) and maximum available phosphorus (27.89 and 27.80 kg ha^{-1}, respectively) contents were recorded in the field fertilized with RDF 75% + *Azotobacter*100 g + PSB 100 g + vermicompost 2 kg/plant, whereas the field having maximum soil pH (7.65 and 7.70, respectively), maximum electrical conductivity (0.43 and 0.44 dSm^{-1}, respectively), minimum organic carbon per cent (0.33 and 0.34 %, respectively), minimum available nitrogen (251.26 and 252.34 kg ha^{-1}, respectively) and available phosphorus (20.35 and 21.95 kg ha^{-1}, respectively) content were under control, where non amount of fertilizers were applied during both years of experimentation.

The significant reduction in pH and EC with the application of *Azotobacter*, PSB and vermicompost in combinations with different doses of inorganic fertilizers might be due to the fact that during decomposition of these manures and production of acidity with bio-fertilizers might have resulted in decline in soil pH. The significant improvement in organic carbon content of soil with the application of *Azotobacter,* PSB and vermicompost in combinations with different graded doses of inorganic fertilizers may be due to the facts that *Azotobacter*, PSB and vermicompost results in death and decay of microorganism in the soil. Results for soil pH, EC and organic carbon content are in close conformity with the findings of Babu *et al.*, (2008) and Tiwari *et al.*, (1999) in banana, Geo Jose *et al.*, (2008).

The higher availability of nitrogen and phosphorus in the soil with the application of bio-fertilizers (*Azotobacter* and PSB) and vermicompost with inorganic fertilizers might be due to the reason that the *Azotobacter* not only fixes atmospheric nitrogen but also produces some organic acids, which stimulate the availability of other nutrients in the soil. PSB also induces some organic acids which help in solubilisation of unavailable phosphorus in soil. These results are in conformity with the findings of Gaurishankar *et al.*, (2002), Krishnakumar *et al.*, (*2005*), Chang *et al.*, *(*2007), Reddy *et al.*, *(*2010) in papaya.

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How to cite this article:

Amar Singh and Tripathi, V. K. 2020. Influence of INM on Vegetative Growth, Fruiting, Yield and Soil Physical Characters in Papaya (*Carica papaya* L.). *Int.J.Curr.Microbiol.App.Sci.* 9(10): 3811-3822. doi: https://doi.org/10.20546/ijcmas.2020.910.438