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Srinu B
College of Horticulture, SKLTHU, Rajendranagar, Hyderabad, Telangana, India

Manohar Rao A
College of Agriculture, PJTSAU, Rajendranagar, Hyderabad, Telangana, India

Veenajoshi K
College of Horticulture, SKLTHU, Rajendranagar, Hyderabad, Telangana, India

Harish Kumar Sharma
College of Agriculture, PJTSAU, Rajendranagar, Hyderabad, Telangana, India

Corresponding Author:
Srinu B
College of Horticulture, SKLTHU, Rajendranagar, Hyderabad, Telangana, India

Influence of INM on growth, yield and quality of papaya (*Carica papaya* L.) cv. red lady

Srinu B, Manohar Rao A, Veenajoshi K and Harish Kumar Sharma

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Abstract
A field study was carried out at the College of Agriculture, Department of Horticulture, Rajendranagar, Hyderabad, during 2014-15 and 2015-16 to evaluate integrated nutrient management (INM) options in papaya (Carica papaya L.) cv. Red Lady. Ten nutrient treatments involving the recommended dose of fertilizers (RDF), organic manures (FYM, vermicompost, neem cake) and biofertilizers (Azotobacter and phosphate-solubilizing bacteria, PSB) were tested in a randomized block design with three replications. Across seasons, the combined application of 75% RDF + 10 kg vermicompost + 100 g Azotobacter + 100 g PSB per plant consistently recorded superior vegetative growth, earlier flowering and maturity, higher fruit yield (31.72 kg plant^{-1}), and improved quality attributes (TSS 10.62 °Brix; total sugars 10.91%; ascorbic acid 23.63 mg 100 g^{-1} pulp), along with reduced postharvest losses. The results demonstrate that partial substitution of chemical fertilizers with vermicompost and biofertilizers can enhance productivity and fruit quality of papaya under the study conditions.

Keywords: Integrated nutrient management, Papaya, *Carica papaya* L., Red Lady, Fruit quality, Yield attributes, Bio-fertilizers, Vermicompost, Economics

Introduction
Papaya (*Carica papaya* L.), also known as papaw, is a fast growing, short-lived, perennial herbaceous fruit crop that is typically single stemmed. It belongs to the family Caricaceae and has gained considerable importance among fruit crops in recent years due to its ease of cultivation, early bearing, quick economic returns, and adaptability to a wide range of soil and climatic conditions. Consequently, papaya is widely cultivated across tropical and subtropical regions of the world.
Papaya is considered a unique and complex fruit crop from botanical, genetic, cytogenetic, and horticultural perspectives. It is indigenous to southern Mexico and Costa Rica and was later introduced into India through Malacca. In India, papaya is extensively cultivated for both fresh fruit consumption and Papain extraction. The crop occupies an area of approximately 1.48 lakh ha, with a production of about 5.86 million tones.

Materials and Methods
The experiment was conducted at the Department of Horticulture, College of Agriculture, PJTSAU, Rajendranagar, Hyderabad, for two consecutive seasons (2014-15 and 2015-16). The trial was laid out in a randomized block design (RBD) with ten treatments and three replications.
The treatments details as follows: T_1- Recommended Dose of Fertilizers (RDF: 200 g N, 200 g P_2O_5, and 250 g K_2O per plant); T_2 -RDF + 20 kg FYM per plant; T_3 - RDF + 10 kg Vermicompost per plant; T_4 - RDF + 5 kg Neem cake per plant; T_5 - RDF + 20 kg FYM + 100 g *Azotobacter* + 100 g PSB per plant; T_6 - RDF + 10 kg Vermicompost + 100 g *Azotobacter* + 100 g PSB per plant; T_7 -RDF + 5 kg Neem cake + 100 g *Azotobacter* + 100 g PSB per plant; T_8 - 75% RDF + 20 kg FYM + 100 g *Azotobacter* + 100 g PSB per plant; T_9 - 75% RDF + 10 kg Vermicompost + 100 g *Azotobacter* + 100 g PSB per plant; and T_{10} - 75% RDF + 5 kg Neem cake + 100 g *Azotobacter* + 100 g PSB per plant.
Seedlings were planted at an inter and intra row spacing of 2.5 m × 2.5 m spacing. Growth and yield attributes were recorded at regular intervals, including fruit number per plant, fruit length,

average fruit weight, pulp thickness and yield per plant. Quality parameters such as total soluble solids (°Brix), sugars, titratable acidity and ascorbic acid content were analysed using standard procedures. The data were statistically analysed following the methods described by Panse and Sukhatme (1985).

Results and Discussion

Effect of Integrated Nutrient Management on Growth Parameters

Integrated nutrient management practices significantly influenced the vegetative growth parameters of papaya, as evident from the data presented in Tables 1. Among the treatments, the best overall performance was observed under T_9 (75% RDF + 10 kg vermicompost + Azotobacter + PSB), which recorded the highest plant height (212.85 cm), maximum trunk girth (52.48 cm) and longest petiole (52.93 cm). These values were distinctly higher than those obtained with RDF alone.

Table 1: Influence of different integrated nutrient management on plant height, Trunk girth and Petiole length parameters

Treatments	Plant height (cm)	Trunk girth (cm)	Petiole length (cm)
RDF (200 N: 200 P_2O_5: 250 K_2O g/plant)	178.18	41.08	45.03
RDF + 20 kg FYM plant^{-1}	190.25	46.38	45.00
RDF + 10 kg Vermicompost plant^{-1}	187.37	45.75	42.21
RDF + 5 kg Neem cake plant^{-1}	188.68	47.55	39.75
RDF + 20 kg FYM plant^{-1} + 100 g *Azotobacter* + 100 g PSB plant^{-1}	187.24	47.03	43.06
RDF + 10 kg VC + 100 g *Azotobacter* + 100 g PSB plant^{-1}	192.46	48.51	44.34
RDF + 5 kg NC + 100 g *Azotobacter* + 100 g PSB plant^{-1}	182.06	48.15	46.41
75% RDF + 20 kg FYM plant^{-1} + 100 g *Azotobacter* + 100 g PSB plant^{-1}	199.97	50.75	50.34
75% RDF + 10 kg VC + 100 g *Azotobacter* + 100 g PSB plant^{-1}	212.85	52.48	52.93
75% RDF + 5 kg NC + 100 g *Azotobacter* + 100 g PSB plant^{-1}	190.39	49.05	44.43
S.Em. ±	2.81	0.65	1.34
C.D at 5%	8.23	1.91	3.94

The superior growth under integrated nutrition can be explained by better nutrient availability and an active soil biological environment. Vermicompost contributes to improved soil physical condition and nutrient retention, while biofertilizers help mobilize and solubilize nutrients, enhancing uptake efficiency. Similar positive responses of papaya to combined organic, inorganic and microbial inputs have been reported by Aneesa Rani and Sathiamoorthy (1997) [1] and Shivakumar (2010) [11], with comparable trends documented in banana and other horticultural crops (Jayabaskaran *et al*., 2001; Bhavidoddi Rahulkumar, 2003) [5, 2].

Influence on Number of Leaves, Flowering, and Fruit Maturity

Treatments differed significantly for leaf production and crop phenology. The integrated treatment comprising 75% RDF + 10 kg vermicompost with Azotobacter and PSB produced the highest leaf number (46.85 leaves per plant) and also promoted earlier flowering (139.64 days) and earlier fruit maturity (200.82 days) compared with the other treatments.

Earlier flowering and maturity under INM likely resulted from a more balanced nutrient supply and improved plant physiological efficiency. Greater microbial activity and better nutrient acquisition can hasten metabolic processes and support a quicker shift from vegetative growth to reproductive development. The present observations agree with earlier reports in papaya (Singh *et al*., 2010; Singh and Varu, 2013) [10, 13] and with findings that highlight the contribution of biofertilizers to nutrient uptake and phenology (Suresh *et al*., 2010) [15].

Effect on Fruit Physiological Traits and Yield

Integrated nutrient treatments significantly influenced fruit characters and yield (Table 2). The highest fruit weight (1929.12 g), pulp thickness (2.34 cm), fruit length (26.34 cm), fruits per plant (32.22) and yield (31.72 kg per plant) were obtained with 75% RDF + 10 kg vermicompost + Azotobacter + PSB.

Table 2: Influence of Integrated Nutrient Management Practices on Fruit Physiological Traits

Treatments	Fruit weight (g)	Pulp thickness (cm)	Fruit length (cm)	Number of fruits per plant	Fruit yield (kg plant^{-1})
RDF (200 N: 200 P_2O_5: 250 K_2O g/plant)	1682.34	1.67	23.83	22.06	20.66
RDF + 20 kg FYM plant^{-1}	1743.00	1.91	19.47	23.11	22.45
RDF + 10 kg Vermicompost plant^{-1}	1632.08	1.86	22.66	24.09	23.68
RDF + 5 kg Neem cake plant^{-1}	1473.85	1.70	19.20	27.08	24.67
RDF + 20 kg FYM plant^{-1} + 100 g *Azotobacter* + 100 g PSB plant^{-1}	1577.45	1.63	24.45	26.76	25.77
RDF + 10 kg VC + 100 g *Azotobacter* + 100 g PSB plant^{-1}	1731.94	1.54	21.86	28.48	26.74
RDF + 5 kg NC + 100 g *Azotobacter* + 100 g PSB plant^{-1}	1795.00	1.38	21.07	28.69	27.76
75% RDF + 20 kg FYM plant^{-1} + 100 g *Azotobacter* + 100 g PSB plant^{-1}	1861.85	2.22	23.25	28.02	29.81
75% RDF + 10 kg VC + 100 g *Azotobacter* + 100 g PSB plant^{-1}	1929.12	2.34	26.34	32.22	31.72
75% RDF + 5 kg NC + 100 g *Azotobacter* + 100 g PSB plant^{-1}	1750.16	1.68	21.24	28.81	29.79
S.Em. ±	37.09	0.07	0.23	0.29	0.10
C.D at 5%	108.78	0.21	0.69	0.84	0.28

The improvement in fruit size and yield under INM can be attributed to steady nutrient availability, better root activity and more effective assimilation and translocation of photosynthates. Organic inputs supply nutrients gradually, and biofertilizers enhance nutrient use efficiency, together supporting better fruit development. Comparable increases in papaya yield and fruit characters under integrated nutrient management were reported by Chaudhri *et al*. (2001) [3], Ravishankar *et al*. (2010) [9] and Tandel *et al*. (2014) [17].

Effect on Fruit Quality Parameters

Quality attributes were significantly affected by nutrient management (Tables 3). The integrated treatment of 75% RDF + 10 kg vermicompost with biofertilizers resulted in lower physiological loss in weight (9.71%), higher firmness (8.36 kg cm^{-2}), reduced spoilage (45.43%) and higher TSS (10.62 °Brix), indicating better fruit quality and keeping behaviour.

The same nutrient combination also produced higher total sugars (10.91%) and ascorbic acid (23.63 mg per 100 g pulp) with comparatively lower titratable acidity. Such improvements are often associated with better carbohydrate synthesis, balanced mineral nutrition and favourable enzymatic activity under integrated nutrient supply. The findings align with reports in papaya by Srivastava (2008) [14] and Yadav *et al*. (2011) [19] and with similar quality improvements reported under organic/integrated nutrition in other crops (El-Naby, 2000; Sha and Karuppaiah, 2010) [10].

Overall Performance of Integrated Nutrient Management

The overall results clearly show that replacing a portion of chemical fertilizers with organic manure and biofertilizers improved growth, yield and fruit quality in papaya. The treatment 75% RDF + 10 kg vermicompost + Azotobacter + PSB was consistently superior for most parameters, underscoring the usefulness of INM for sustainable and profitable papaya production. These observations are consistent with earlier studies that reported benefits of integrated nutrient strategies in horticultural crops (Patel, 2008; Srivastava, 2008; Singh *et al*., 2010) [8, 12, 14].

Table 3: Influence of Integrated Nutrient Management Practices on Fruit quality Traits

Treatments	PLW (%)	Firmness (kg cm^{-2})	Spoilage (%)	TSS (°Brix)	Reducing sugars (%)
RDF (200 N: 200 P_2O_5: 250 K_2O g/plant)	18.29	5.88	64.43	6.95	7.68
RDF + 20 kg FYM $plant^{-1}$	15.15	7.23	47.58	7.44	8.19
RDF + 10 kg Vermicompost $plant^{-1}$	15.89	6.99	52.89	7.42	8.83
RDF + 5 kg Neem cake $plant^{-1}$	15.79	7.39	49.18	7.89	8.24
RDF + 20 kg FYM $plant^{-1}$ + 100 g *Azotobacter* + 100 g PSB $plant^{-1}$	15.66	7.68	49.32	8.11	8.41
RDF + 10 kg VC + 100 g *Azotobacter* + 100 g PSB $plant^{-1}$	15.06	7.09	52.90	7.99	8.46
RDF + 5 kg NC + 100 g *Azotobacter* + 100 g PSB $plant^{-1}$	15.17	7.52	46.00	8.46	8.54
75% RDF + 20 kg FYM $plant^{-1}$ + 100 g *Azotobacter* + 100 g PSB $plant^{-1}$	11.00	7.31	48.40	8.45	9.01
75% RDF + 10 kg VC + 100 g *Azotobacter* + 100 g PSB $plant^{-1}$	9.71	8.36	45.43	10.62	8.97
75% RDF + 5 kg NC + 100 g *Azotobacter* + 100 g PSB $plant^{-1}$	13.73	6.35	51.37	7.65	8.23
S.Em. ±	0.54	0.04	1.70	0.12	0.04
C.D at 5%	1.59	0.13	4.97	0.36	0.13

Table 4: Influence of Integrated Nutrient Management Practices on Fruit quality Traits

Treatments	Ascorbic acid (mg/100 g pulp)	Titratable acidity (%)	Total sugars (%)
RDF (200 N: 200 P_2O_5: 250 K_2O g/plant)	20.49	0.19	8.68
RDF + 20 kg FYM $plant^{-1}$	20.68	0.18	9.53
RDF + 10 kg Vermicompost $plant^{-1}$	22.01	0.18	9.89
RDF + 5 kg Neem cake $plant^{-1}$	22.51	0.16	10.20
RDF + 20 kg FYM $plant^{-1}$ + 100 g *Azotobacter* + 100 g PSB $plant^{-1}$	21.50	0.20	9.63
RDF + 10 kg VC + 100 g *Azotobacter* + 100 g PSB $plant^{-1}$	22.22	0.18	10.36
RDF + 5 kg NC + 100 g *Azotobacter* + 100 g PSB $plant^{-1}$	22.70	0.18	10.37
75% RDF + 20 kg FYM $plant^{-1}$ + 100 g *Azotobacter* + 100 g PSB $plant^{-1}$	23.03	0.14	10.66
75% RDF + 10 kg VC + 100 g *Azotobacter* + 100 g PSB $plant^{-1}$	23.63	0.13	10.91
75% RDF + 5 kg NC + 100 g *Azotobacter* + 100 g PSB $plant^{-1}$	20.69	0.17	10.50
S.Em. ±	0.21	0.01	0.08
C.D at 5%	0.63	NS	0.24

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