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Effect of integrated nutrient management on quality of papaya (*Carica papaya* L.) cv. Gujarat Junagadh Papaya 1

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Abstract
The present study, entitled "Effect of integrated nutrient management on quality of papaya (*Carica papaya* L.) cv. Gujarat Junagadh Papaya 1," was carried out for two consecutive years (2023-24 and 2024-25) at the Horticultural Research Farm, B. A. College of Agriculture, AAU, Anand, Gujarat. The experiment was laid out in a Randomized Block Design with ten treatments and three replications to evaluate the influence of inorganic fertilizers (RDF: 200:200:250 g NPK/plant), organic nutrient sources (FYM, vermicompost and castor cake) with Bio NPK liquid biofertilizer on quality attributes of papaya. Significant differences were observed among treatments for all recorded parameters. The treatment T_3 (75% RDF + 25% N from vermicompost + Bio NPK Liquid Biofertlizer) consistently outperformed others by increased maximum total soluble solids (TSS °Brix), reducing sugar (%), non-reducing sugar (%), total sugar (%), minimum titratable acidity (%), significantly highest β-carotene (mg/100g) and pulp thickness (cm). In contrast, the control (T_1) recorded the lowest values for quality traits, highlighting the importance of integrated nutrient application.

Keywords: Papaya, Integrated nutrient management, FYM, Vermicompost, Castor cake, Fruit quality

Introduction

Papaya (*Carica papaya L.*) is a rapidly growing, herbaceous plant belonging to the family Caricaceae, one of the 48 species known in Caricaceae. *Carica papaya* is the only species cultivated for its edible fruit. It bears chromosome no. 2n=18. Papaya, also known as papaw or pawpaw, is native to Tropical America (Hofmeyr, 1938 [6]).

It has currently expanded to numerous nations worldwide, like Australia, Hawaii, Taiwan, Puerto Rico, Peru, Florida, Texas, California, the Gold Coast, various sections of Central and South Africa, Pakistan, Bangladesh and India among the countries that cultivate it large scale.

India ranks as one of the largest producers of papaya globally, with states like Andhra Pradesh, Gujarat, Maharashtra, Karnataka and Tamil Nadu leading in cultivation. The total area under papaya cultivation in India is 149000 hectares and production is 57,44,000 MT. In Gujarat, the total area under papaya cultivation is 18,190 hectares and production is 11,07,880 MT. (Anon., 2025) [2].

Papaya is a highly valued tropical fruit, cultivated widely for its nutritional, medicinal, and commercial significance. Papaya is composed predominantly of water (approximately 88%), making it low in calories and suitable for weight management diets. It contains about 11% carbohydrates, mainly in the form of natural sugars like glucose and fructose, contributing to its characteristic sweetness (USDA, 2023) [18]. The fruit has negligible fat content and moderate amount of dietary fibre, particularly pectin, which aids digestion and supports gut health. Calories (per 100 g) 43 kcal, carbohydrates 10-11 g, protein 0.5-0.8 g and dietary fibre 1.7-2.0 g.

Papaya is especially noted for its high vitamin C content, often exceeding 60-70 mg per 100 g of fresh pulp, which is more than the daily requirement for adults. It is also a good source of provitamin A, which supports vision and immune function. Additionally, it contains vitamin E and B-complex vitamins, including thiamine, riboflavin and niacin. Beta-carotene 950 mg, folate (B_9) 37 µg (USDA, 2023 [18]; Rivera-Pastrana *et al.*, 2010 [13]). Papaya provides essential minerals such as iron, zinc and manganese, albeit in small amounts. Potassium 182-210 mg, calcium 20-25 mg and magnesium 10-15 mg.

The fruits are helpful in treating digestive issues, liver and spleen dyspepsia and piles. Candy, tutty-fruity, ready-to-serve, jam, jelly, nectars, soft drinks, ice cream flavouring, crystallized fruits and crumbled syrup are all made using ripe fruit. Papaya also contains lycopene, a red carotenoid pigment known for its antioxidant properties, which may reduce the risk of certain cancers and cardiovascular diseases (Viuda-Martos *et al*., 2012) [19]. Due to its nutritional richness, papaya supports immune health, improves digestive function, aids in wound healing and possesses anti-inflammatory and antioxidant properties. Its low glycemic index also makes it suitable for diabetic diets, while the fibre supports cholesterol reduction and colon health (Wall, 2006) [20].

Depending on the cultivar, papaya immature fruits range in colour from green to dark green before turning yellow, orange or red as they ripen. A unique component of papaya is papain, a proteolytic enzyme found mainly in unripe fruit and latex. Papain aids in protein digestion and is used medicinally in digestive enzyme supplements and wound healing.

Papain is used to pre-shrink wool, make dental paste and cosmetics, soften meat, clear beer and gumming silk and rayon. Papain is renowned for its industrial and medical applications, much like the animal enzyme pepsin. Papain is used to cure ulcers and other conditions it is supposed to make skin imperfections disappear.

In papaya farming, integrated nutrient management (INM) balances soil health and crop nutrition by combining chemical fertilizers, organic manures, biofertilizers and crop wastes. For growth, roots and fruit quality, chemical fertilizers provide potassium, phosphorus and nitrogen. Compost and FYM are examples of organic manures that enhance soil aeration, moisture retention and microbial activity. Nutrient uptake is improved by biofertilizers like *Azospirillum* and phosphate-solubilizing bacteria. Mulching and crop residues improve soil organic matter, prevent erosion and preserve moisture, which helps improve the fruit quality. Combining these techniques ensures increased soil fertility and long-term productivity (Ghosh & Das, 2017) [5].

Considering this background, the present investigation titled "Effect of integrated nutrient management on quality of papaya (*Carica papaya* L.) cv. Gujarat Junagadh Papaya 1" was undertaken to evaluate how different combinations of organic, inorganic, and biofertilizer inputs influence the physicochemical quality attributes of papaya fruits. The findings of this study will contribute to developing location-specific INM modules that can enhance papaya quality, improve soil health, reduce chemical fertilizer dependency and promote sustainable fruit production systems.

Materials and Methods

The current experiment entitled "Effect of integrated nutrient management on growth, yield and quality of papaya (*Carica papaya* L.) cv. Gujarat Junagadh Papaya 1", was conducted during July to May in 2023-24 and 2024-25 for two consecutive years. The research study was executed at the Horticultural Research Farm, B. A. College of Agriculture, Anand Agricultural University, Anand, Gujarat, India. The crop was planted at a spacing of 1.8 × 1.8 m following a Randomized Block Design (RBD). Each plot measured 7.2 × 5.4 m, with a total of 3 replications and 10 treatments. Twelve plants were maintained per treatment, making a total of 720 plants in the entire experiment, with two plants accommodated per hill.

The experiment consisted of ten treatments: T_1 included the recommended dose of fertilizers (RDF) at 200:200:250 g NPK per plant along with 10 kg FYM as the control. T_2 comprised 75% RDF supplemented with 25% nitrogen from FYM along with Bio NPK liquid biofertilizer, while T_3 included 75% RDF with 25% nitrogen from vermicompost and Bio NPK liquid biofertilizer. T_4 consisted of 75% RDF with 25% nitrogen from castor cake + Bio NPK liquid biofertilizer. T_5 involved 50% RDF and 50% nitrogen from FYM along with Bio NPK liquid biofertilizer, whereas T_6 included 50% RDF with 50% nitrogen from vermicompost and Bio NPK liquid biofertilizer. T_7 consisted of 50% RDF with 50% nitrogen from castor cake Bio NPK liquid biofertilizer. T_8 included 25% RDF and 75% nitrogen from FYM along with Bio NPK liquid biofertilizer, while T_9 consisted of 25% RDF with 75% nitrogen from vermicompost and Bio NPK liquid biofertilizer. Finally, T_{10} included 25% RDF with 75% nitrogen from castor cake along with Bio NPK Liquid Biofertilizer.

The observations recorded in the study in quality parameters included Total soluble solids (^{0}Brix), Reducing sugar (%), Non-reducing sugar (%), Total sugar (%), Titratable Acidity (%), β-Carotene (mg/100g) and Pulp thickness (cm) at the time of 5th picking.

Results and discussion

Total soluble solids (^{0}Brix)

Total soluble solids (°Brix) exhibited a notable response to integrated nutrient management for both experimental years. The highest TSS values (10.03, 10.24 and 10.13°Brix, respectively) were consistently recorded under treatment T_3 [75% RDF + 25% N from Vermicompost + Bio NPK Liquid Biofertilizer] as shown (Table 1) during 2023-24, 2024-25 and the pooled analysis. Whereas, the minimum TSS (8.20, 8.13 and 8.17°Brix) in the years 2023-24, 2024-25 and pooled analysis, respectively, was recorded with the control treatment T_1 [RDF (200:200:250 NPK g/plant) + 10 kg FYM].

The significantly higher TSS is due to the combined effect of chemical fertilizers, vermicompost, and biofertilizers, which together improve nutrient availability, root activity and sugar formation in papaya fruits. Similar findings were also reported by Singh *et al.* (2008) [14], Amrish *et al.* (2014) [1] in papaya, Dwivedi (2013) [4] in guava and Baviskar *et al.* (2011) [3] in sapota.

Reducing sugar and Non-reducing sugar (%)

During the two experimental years, reducing sugar content showed a significant impact of integrated nutrient management practices. In the years 2023-24, 2024-25 and the pooled analysis, the highest reducing sugar (7.72, 7.84 and 7.78%, respectively) and non-reducing sugar content (1.45, 1.44 and 1.44%, respectively) were consistently observed under treatment T_3 [75% RDF + 25% N from Vermicompost + Bio NPK Liquid Biofertilizer] was shown (Table 1). Whereas, the treatment T_1 [RDF (200:200:250 NPK g/plant) + 10 kg FYM] had the lowest reducing sugar level (6.23, 6.58 and 6.41%, respectively) and non-reducing sugar (0.95, 0.98 and 0.96%, respectively) across the corresponding years and pooled data.

Vermicompost supports beneficial soil microbes and boosts enzyme activity, while biofertilizers help fix nitrogen and release phosphorus, both of which are essential for producing and moving sugars into the fruit. Similar results were also reported by Amrish *et al.* (2014) [1] in papaya, Kumawat *et al.* (2018) [8] in guava, Ravikiran *et al.* (2018) [12] in mango and Raghavan *et al.* (2018) [11] worked on litchi.

Total sugar (%)

The integrated nutrient management treatments had a substantial impact on the total sugar content of papaya fruits during both study years. The highest total sugar content (9.17, 9.28 and 9.22%) was consistently observed with treatment T_3 [75% RDF + 25% N from Vermicompost + Bio NPK Liquid Biofertilizer] as shown (Table 2) in 2023-24, 2024-25, and the pooled analysis. While T_1 [RDF (200:200:250 NPK g/plant) + 10 kg FYM] consistently had the lowest total sugar content (7.18, 7.56 and 7.37%) during 2023-24, 2024-25 and pooled result, respectively.

Fruit sugar content may be influenced by the application of bio-NPK liquid biofertilizer comprising *Azotobacter*, *Azospirillum* and organic manures with a balanced manner of inorganic fertilizers. This consortium may have a regulatory role in the absorption and translocation of carbohydrates and various metabolites. One possible explanation for the improvement in total sugar content is the increased microbial biomass in the rhizosphere, which continuously supplements the plant. Jhade *et al.* (2020) [7] in papaya, Dwivedi (2013) [4] in guava and Ravikiran *et al.* (2018) [12] in mango revealed findings that are partially similar to the current research.

Titratable Acidity (%)

Among the different nutrient management treatments, T_3 [75% RDF + 25% N from Vermicompost + Bio NPK Liquid Biofertilizer] recorded the significantly minimum titratable acidity (0.096, 0.093 and 0.095%) during the years 2023-24, 2024-25 and pooled study, respectively. On the contrary, the maximum titratable acidity (0.172, 0.176 and 0.174%) was recorded with the control treatment T_1 [RDF (200:200:250 NPK g/plant) + 10 kg FYM] during 2023-24, 2024-25 and pooled analysis, respectively.

This suggests that the nutrient combination effectively supported the conversion of organic acids into sugars during the fruit ripening process. Balance fertilizer with vermicompost and biofertilizers enhances microbial populations in the soil, leading to improved nutrient absorption and more efficient metabolic activity. As a result, the fruits developed with lower acidity and better flavour. Similar observations were noted by Amrish *et al.* (2014) [1], Jhade *et al.* (2020) [7] in papaya, Raghavan *et al.* (2018) [11] worked on litchi and Sutariya *et al.* (2018) [17] in phalsa.

β-Carotene (mg/100g)

In both study years, integrated nutrient management interventions had a substantial impact on the amount of β-carotene (mg/100 g) in papaya fruits. Treatment T_3 [75% RDF + 25% N from Vermicompost + Bio NPK Liquid Biofertilizer] consistently produced higher results (0.897, 0.862 and 0.880 mg/100 g) in 2023-24, 2024-25 and the pooled analysis, respectively. On the contrary, the lower β-carotene content (0.584, 0.631 and 0.607 mg/100 g) was recorded with the control treatment T_1 [RDF (200:200:250 NPK g/plant) + 10 kg FYM] during 2023-24, 2024-25 and pooled analysis, respectively.

The highest β-carotene content is due to better nutrient synergy and microbial activity that enhance carotenoid synthesis during fruit ripening. Organic source like vermicompost with a proper amount improve soil health, promoting antioxidant accumulation like β-carotene. Similar findings were reported by Srividhya and Jeyakumar (2017) [16] found that favourable ripening conditions increased β-carotene in papaya, Patel *et al.* (2023) [10] and Mehta (2021) [9] reported similar improvements in mango under integrated nutrient management.

Pulp thickness (cm)

Among the different nutrient management treatments, T_3 [75% RDF + 25% N from Vermicompost + Bio NPK Liquid Biofertilizer] recorded the significantly highest pulp thickness (2.95, 2.96 and 2.96 cm) during the years 2023-24, 2024-25 and pooled analysis, respectively. The minimum pulp thickness was observed in T_1 [RDF (200:200:250 NPK g/plant) + 10 kg FYM] *i.e.* control recording (2.14, 2.17 and 2.16 cm) during the years 2023-24, 2024-25 and pooled mean, respectively.

This result might be due to the synergistic effect of organic and biofertilizer inputs enhances nutrient availability, microbial activity and physiological processes like cell expansion and sugar accumulation. Vermicompost improves soil structure and microbial biomass, while biofertilizers facilitate nutrient solubilization and uptake, especially nitrogen and phosphorus, key elements for fruit development. This integrated approach promotes better fruit texture and pulp formation. Analogous observations were also recorded by Singh *et al.* (2010) [15], Jhade *et al.* (2020) [7] in papaya and Mehta (2021) [9] in mango.

Table 1: Effect of integrated nutrient management on quality parameters of papaya

Treatment No.	Treatment Details	TSS (^{0}Brix)			Reducing sugar (%)			Non-reducing sugar (%)		
		2023-24	2024-25	Pooled	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled
T_1	RDF (200:200:250 NPK g/plant) + 10 kg FYM (Control)	8.20	8.13	8.17	6.23	6.58	6.41	0.95	0.98	0.96
T_2	75% RDF + 25% N from FYM + Bio NPK Liquid Biofertilizer	9.63	9.54	9.59	7.31	7.28	7.29	1.36	1.33	1.35
T_3	75% RDF + 25% N from Vermicompost + Bio NPK Liquid Biofertilizer	10.03	10.24	10.13	7.72	7.84	7.78	1.45	1.44	1.44
T_4	75% RDF + 25% N from Castor cake + Bio NPK Liquid Biofertilizer	9.43	9.36	9.40	7.29	7.26	7.28	1.28	1.30	1.29
T_5	50% RDF + 50% N from FYM + Bio NPK Liquid Biofertilizer	9.85	9.70	9.77	7.34	7.32	7.33	1.39	1.35	1.37

T_6	50% RDF + 50% N from Vermicompost + Bio NPK Liquid Biofertilizer	9.80	9.84	9.82	7.36	7.34	7.35	1.41	1.41	1.41
T_7	50% RDF + 50% N from Castor cake + Bio NPK Liquid Biofertilizer	9.30	9.25	9.28	7.28	7.25	7.27	1.27	1.24	1.26
T_8	25% RDF + 75% N from FYM + Bio NPK Liquid Biofertilizer	8.97	8.67	8.82	7.18	7.22	7.20	1.20	1.31	1.25
T_9	25% RDF + 75% N from Vermicompost + Bio NPK Liquid Biofertilizer	9.16	9.16	9.16	7.27	7.24	7.26	1.22	1.23	1.23
T_{10}	25% RDF + 75% N from Castor cake + Bio NPK Liquid Biofertilizer	8.64	8.15	8.39	7.16	7.19	7.18	1.17	1.19	1.18
T	S. Em. ±	0.33	0.33	0.21	0.21	0.19	0.13	0.04	0.04	0.02
	C. D. (P=0.05)	0.99	0.98	0.61	0.63	0.56	0.45	0.12	0.12	0.08
Year	S. Em. ±	-	-	0.10	-	-	0.64	-	-	0.01
	C. D. (P=0.05)	-	-	NS	-	-	NS	-	-	NS
YxT	S. Em. ±	-	-	0.33	-	-	0.20	-	-	0.04
	C. D. (P=0.05)	-	-	NS	-	-	NS	-	-	NS
C.V. %		6.21	6.20	6.21	5.13	4.51	4.83	5.60	5.69	5.64

Table 2: Effect of integrated nutrient management on quality parameters of papaya

Treatment No.	Treatment Details	Total sugar (%)			Titratable acidity (%)			β-carotene (mg/100g)		
		2023-24	2024-25	Pooled	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled
T_1	RDF (200:200:250 NPK g/plant) + 10 kg FYM (Control)	7.18	7.56	7.37	0.172	0.176	0.174	0.584	0.631	0.607
T_2	75% RDF + 25% N from FYM + Bio NPK Liquid Biofertilizer	8.67	8.61	8.64	0.146	0.144	0.145	0.791	0.803	0.797
T_3	75% RDF + 25% N from Vermicompost + Bio NPK Liquid Biofertilizer	9.17	9.28	9.22	0.096	0.093	0.095	0.897	0.862	0.880
T_4	75% RDF + 25% N from Castor cake + Bio NPK Liquid Biofertilizer	8.57	8.56	8.57	0.155	0.151	0.153	0.749	0.769	0.759
T_5	50% RDF + 50% N from FYM + Bio NPK Liquid Biofertilizer	8.73	8.67	8.70	0.138	0.126	0.132	0.833	0.811	0.822
T_6	50% RDF + 50% N from Vermicompost + Bio NPK Liquid Biofertilizer	8.77	8.75	8.76	0.115	0.109	0.112	0.861	0.827	0.844
T_7	50% RDF + 50% N from Castor cake + Bio NPK Liquid Biofertilizer	8.55	8.49	8.52	0.157	0.154	0.155	0.814	0.754	0.784
T_8	25% RDF + 75% N from FYM + Bio NPK Liquid Biofertilizer	8.38	8.53	8.45	0.164	0.170	0.167	0.777	0.794	0.785
T_9	25% RDF + 75% N from Vermicompost + Bio NPK Liquid Biofertilizer	8.50	8.47	8.48	0.160	0.155	0.157	0.720	0.727	0.723
T_{10}	25% RDF + 75% N from Castor cake + Bio NPK Liquid Biofertilizer	8.33	8.38	8.36	0.170	0.172	0.171	0.711	0.735	0.723
T	S. Em. ±	0.19	0.24	0.14	0.004	0.005	0.003	0.018	0.019	0.012
	C. D. (P=0.05)	0.57	0.72	0.48	0.010	0.015	0.008	0.053	0.054	0.036
Year	S. Em. ±	-	-	0.06	-	-	0.001	-	-	0.005
	C. D. (P=0.05)	-	-	NS	-	-	NS	-	-	NS
YxT	S. Em. ±	-	-	0.21	-	-	0.004	-	-	0.018
	C. D. (P=0.05)	-	-	NS	-	-	NS	-	-	NS
C.V. %		3.89	4.90	4.43	4.21	6.02	5.18	4.03	4.07	4.05

Table 3: Effect of integrated nutrient management on quality parameter of papaya

Treatment No.	Treatment Details	Pulp thickness (cm)		
		2023-24	2024-25	Pooled
T_1	RDF (200:200:250 NPK g/plant) + 10 kg FYM (Control)	2.14	2.17	2.16
T_2	75% RDF + 25% N from FYM + Bio NPK Liquid Biofertilizer	2.62	2.68	2.65
T_3	75% RDF + 25% N from Vermicompost + Bio NPK Liquid Biofertilizer	2.95	2.96	2.96
T_4	75% RDF + 25% N from Castor cake + Bio NPK Liquid Biofertilizer	2.51	2.46	2.49
T_5	50% RDF + 50% N from FYM + Bio NPK Liquid Biofertilizer	2.70	2.73	2.72
T_6	50% RDF + 50% N from Vermicompost + Bio NPK Liquid Biofertilizer	2.86	2.91	2.89
T_7	50% RDF + 50% N from Castor cake + Bio NPK Liquid Biofertilizer	2.44	2.39	2.42
T_8	25% RDF + 75% N from FYM + Bio NPK Liquid Biofertilizer	2.25	2.21	2.23
T_9	25% RDF + 75% N from Vermicompost + Bio NPK Liquid Biofertilizer	2.35	2.32	2.34
T_{10}	25% RDF + 75% N from Castor cake + Bio NPK Liquid Biofertilizer	2.20	2.19	2.20
T	S. Em. ±	0.17	0.18	0.11
	C. D. (P=0.05)	0.51	0.54	0.32
Year	S. Em. ±	-	-	0.05
	C. D. (P=0.05)	-	-	NS
YxT	S. Em. ±	-	-	0.18
	C. D. (P=0.05)	-	-	NS
C.V. %		11.95	12.65	12.30

Conclusion

The present investigation clearly demonstrated that integrated nutrient management significantly enhanced the quality attributes of papaya cv. Gujarat Junagadh Papaya-1 over the two consecutive years of study. Among all treatments, T_3 (75% RDF + 25% N from vermicompost + Bio NPK liquid biofertilizer) consistently outperformed the others by improving fruit biochemical parameters such as TSS, reducing and non-reducing sugars, total sugars, β-carotene content and pulp thickness, while simultaneously reducing titratable acidity. The superior performance of T_3 can be attributed to improved nutrient availability, enhanced microbial activity and better physiological functioning within the plant-soil system. The combined use of vermicompost and biofertilizers with reduced chemical fertilizers proved effective in promoting balanced nutrition and better fruit quality. In contrast, the control treatment (T_1) recorded the lowest values across most quality parameters, indicating the limitations of relying solely on inorganic fertilizers. Overall, the results suggest that integrating organic sources and biofertilizers with chemical fertilizers not only improves fruit quality but also enhances soil health and nutrient use efficiency. Therefore, T_3 emerges as the most suitable nutrient management practice for achieving superior quality and sustainable production of papaya cv. GJP-1 under the agro-climatic conditions of Gujarat.

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