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Optimising Bio-intensive Organic Nutrient Management for Growth, Yield and Fruit Quality in Mango (*Mangifera indica* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. Author GD conducted the study and wrote the first draft of the manuscript. Authors BPR and SAK designed the study, wrote the protocol, guided the study and done statistical analysis. Author BND managed the analysis and provided technical advices during the study. Author BD managed the literature searches. All authors read and approved the final manuscript.

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Abstract

Aim: To evaluate six nutrient-management practices in two mango orchards in relation to vegetative development, flowering, fruiting, yield and fruit quality of Alphonso and Totapuri mango.
Study design: Six nutrient-management treatments were evaluated in two cultivar-specific orchard blocks, with four replications per treatment in each block.

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Place and Duration of Study: The study was conducted from July 2025 to May 2026 in Bengaluru, Karnataka, India. The Alphonso trees were located in the mango block of the Regional Horticultural Research and Extension Centre, and the Totapuri trees were located in the Fruit Science Farm of the College of Horticulture.
Methodology: The treatments comprised the recommended fertiliser practice (N1), seaweed extract (N2), humic acid (N3), microbial consortia (N4), vermicompost tea (N5) and jeevamrutha (N6). Growth, flowering, fruiting, fruit yield as well as biochemical and postharvest quality traits were measured. Treatment means were evaluated using analysis of variance and critical differences at the 5% level.
Results: Jeevamrutha (N6) recorded the highest treatment means across the two orchards for final tree height (4.01 m), tree volume (67.92 m^3), panicles per tree (89.24), fruit retention (23.47%), mature fruits per panicle (1.76), fruit weight (470.60 g) and yield (73.01 kg $tree^{-1}$; approximately 20.28 t ha^{-1}). N6 also recorded the highest treatment means for total soluble solids (19.59 °Brix) and total sugars (17.71%), and the lowest mean titratable acidity (0.11%). The largest yield among the orchard–cultivar combinations was observed in Totapuri under N6 (78.34 kg $tree^{-1}$; 21.76 t ha^{-1}).
Conclusion: Under the conditions of the two orchards during the single study season, five foliar applications of 5% jeevamrutha produced the strongest overall treatment response for several growth, reproductive, yield and quality variables. The results support further assessment of jeevamrutha-based management across orchards and seasons.

Keywords: Alphonso; Totapuri; jeevamrutha; vermicompost tea; mango yield; fruit quality.

1. Introduction

Mango (*Mangifera indica* L.) is an economically important tropical fruit crop whose productivity and commercial value reflect orchard conditions, cultivar characteristics and nutrient availability. In perennial fruit systems, nutrient management supports canopy development, reproductive performance and the replenishment of nutrients removed in harvests. Practices combining organic amendments and microbial inputs are therefore relevant to long-term nutrient cycling and soil biological activity (Palm *et al.*, 1997; Vessey, 2003).

Mango orchard research has demonstrated responses to different nutrient sources and biological inputs. Jiao *et al.* (2024) reported changes in mango yield, fruit quality and soil microbial communities following organic and slow-release fertiliser applications. Meena *et al.* (2025) observed improvements in soil biochemical properties, canopy development and fruit attributes in Amrapali mango under compost-based treatments, including combinations with microbial consortia. Kumar *et al.* (2025) examined the integration of organic, mineral and microbial nutrient inputs in Langra mango. In Mallika mango, Rathod *et al.* (2024) assessed biofertilisers and foliar bioinoculants, including seaweed extract and jeevamrut. Kuldeep *et al.* (2026) further described responses of Amrapali mango floral health to plant growth-promoting rhizobacteria applied with micronutrients and a growth regulator.

Organic nutrient inputs can supply mineralisable nutrients and influence microbial activity and nutrient transformations in soil. Mango studies have evaluated the integrated use of organic manures and biofertilisers in relation to flowering, fruit set, yield and quality (Patil *et al.*, 2005; Singh *et al.*, 2015; Yadav *et al.*, 2011). Ram *et al.* (2019) also documented yield and fruit-quality responses to organic amendments. However, solid organic amendments, soluble biostimulants, microbial consortia and fermented liquid preparations differ in nutrient concentration, microbial composition and application pathway. Direct comparisons of these inputs under orchard conditions can help clarify their associations with reproductive performance, harvested fruit yield and fruit characteristics.

The studies discussed above do not establish the relative responses of Alphonso and Totapuri mango to these six nutrient-management practices under the respective orchard conditions.

The present investigation compared six nutrient-management practices in Alphonso and Totapuri mango orchards in Bengaluru, Karnataka, focusing on final vegetative measurements, flowering and fruiting, harvested yield, and fruit biochemical and postharvest attributes.

2. Materials and Methods

2.1 Experimental Site and Climate

The experiment was conducted from July 2025 to May 2026 in the Eastern Dry Zone of Karnataka, India. The experimental trees were 7–8 years old. Alphonso trees occupied the mango block of the Regional Horticultural Research and Extension Centre, while Totapuri trees occupied the Fruit Science Farm of the College of Horticulture, Bengaluru. Both orchard sites were described as having red sandy loam soil. During the study period, mean maximum and minimum temperatures ranged from 26.6 to 35.2 °C and from 15.3 to 22.2 °C, respectively; recorded rainfall totalled 727.1 mm.

2.2 Experimental Design and Treatments

The study involved two cultivar-specific orchard blocks (V1, Alphonso; V2, Totapuri) and six nutrient-management treatments (N1–N6). Four replications were used for each cultivar–treatment combination, giving 24 study trees per cultivar and 48 trees overall. Treatment effects were assessed across the two orchard contexts, while cultivar–treatment combinations were described separately because the cultivars occupied distinct orchard locations. The treatments were as follows:

N1: Recommended fertiliser practice comprising farmyard manure (FYM) at 25 kg tree^{-1}, N:P:K at 584:144:544 g tree^{-1} and Arka Mango Special at 0.5% at the prescribed crop stages.
N2: Two soil drenches of 0.4% seaweed extract, at panicle emergence and flowering.
N3: Two soil drenches of 1% humic acid, during the monsoon and at panicle emergence.
N4: Microbial consortia at 5 kg acre^{-1} applied twice, during the monsoon and at panicle emergence.
N5: Five foliar sprays of 5% vermicompost tea, during the monsoon and at flowering, pea, marble and lemon fruit stages.
N6: Five foliar sprays of 5% jeevamrutha, including two pre-flowering sprays at 7–15-day intervals and one spray each at pea, marble and lemon fruit stages.

2.3 Preparation of Jeevamrutha

Jeevamrutha was prepared from 10 kg of local cow dung, 10 L of cow urine, 2 kg of jaggery, 2 kg of pulse flour and a handful of garden soil, and water was added to obtain a final volume of 200 L. The mixture was kept in the shade under a wet gunny covering, stirred three times daily and incubated before application (Palekar, 2006).

2.4 Preparation of Vermicompost Tea

Vermicompost tea was prepared by combining one volume of vermicompost with four volumes of non-chlorinated, aerated water. The preparation was stirred, brewed for 24 h and filtered before foliar application (Edwards *et al.*, 2006).

2.5 Observations on Growth, Flowering, Fruiting, Yield and Fruit Quality

At the final observation, tree height, stem girth, canopy spread along east–west and north–south axes, and canopy volume were recorded; a spheroid-based method was used to estimate canopy volume. Reproductive observations comprised days to inflorescence emergence, days to 50% and 100% flowering, number of panicles per tree, and panicle length and width. Twenty healthy panicles per tree, five in each cardinal direction, were tagged to follow fruit development. Lemon-sized and mature fruits per panicle, fruit retention and fruit drop were recorded.

At harvest, the number of fruits per tree was recorded. Fruit length and diameter were measured with a vernier caliper, mean fruit weight with a precision balance and fruit volume by water displacement. Yield per tree was estimated from the harvested fruit number and fruit weight. Per-hectare yield was calculated using a conversion density of approximately 277.78 trees ha^{-1}, with yield (t ha^{-1}) equal to yield (kg tree^{-1}) multiplied by 277.78/1,000.

Fruit total soluble solids (TSS) were measured using a hand refractometer and expressed as °Brix. Total sugars were estimated by the method of Sadasivam and Manickam (1996). Titratable acidity was determined by titration with 0.1 N NaOH and expressed as citric acid equivalent (AOAC, 1980). Fruit firmness was measured with a texture analyser, while shelf life was recorded as the number of days for which fruits remained marketable under the study storage conditions.

2.6 Statistical Analysis

Analysis of variance was undertaken according to the factorial randomised complete block framework described by Panse and Sukhatme (1967), considering cultivar block (V), nutrient-management treatment (N) and their interaction. The F-test was used for treatment effects, with standard errors of the mean (SEm) and critical differences (CD) calculated at the 5% level where effects were significant. The nutrient-management means were interpreted as averages across the two study orchards. Differences between V1 and V2 represent cultivar–orchard comparisons rather than independent genetic cultivar contrasts.

3. Results and Discussion

3.1 Vegetative Growth and Canopy Development

Final vegetative and canopy measurements varied among the six nutrient-management treatments (Table 1). Jeevamrutha (N6) produced the greatest across-orchard mean tree height (4.01 m), stem girth (242.50 cm), tree volume (67.92 m^3), east–west and north–south canopy spreads (6.12 and 5.85 m) and canopy area (28.16 m^2). Under the recommended fertiliser practice (N1), the corresponding means were 3.18 m, 165.00 cm, 25.27 m^3, 3.84 m, 3.88 m and 11.67 m^2. Vermicompost tea (N5) recorded the second-highest mean tree height (3.60 m) and tree volume (49.84 m^3). Across the two cultivar-specific orchards, Totapuri trees had greater final tree height (3.80 versus 3.02 m) and canopy volume (48.17 versus 33.25 m^3). The largest observed tree volume among cultivar–treatment combinations occurred in V2N6 (72.79 m^3).

The greater canopy dimensions observed under N6 are consistent with a favourable response to repeated liquid organic applications during active growth and fruit development. Microbial communities and metabolites have been characterised in jeevamrutha preparations (Duraivadivel *et al.*, 2022; Sudheer *et al.*, 2025), while Vaishnav *et al.* (2025) reported improvements in mango vegetative traits under organic manure treatments. Vermicompost-derived materials can provide soluble organic compounds and influence crop nutrition (Sinha *et al.*, 2010). These observations offer a plausible agronomic context for the treatment patterns in Table 1, particularly the larger final canopies under N5 and N6.

Table 1. Vegetative growth and canopy attributes of Alphonso and Totapuri mango under six nutrient-management treatments

Treatment	Tree height (m)	Stem girth (cm)	Tree volume (m^3)	Canopy spread E–W (m)	Canopy spread N–S (m)	Canopy area (m^2)
Factor 1: Variety (V)						
V_1	3.02	175.42	33.25	4.51	4.38	15.91
V_2	3.80	192.50	48.17	5.04	4.85	19.61
S.Em ±	**0.06**	**4.94**	**0.80**	**0.06**	**0.08**	**0.40**
C.D. @ 5%	**0.17**	**14.20**	**2.31**	**0.16**	**0.23**	**1.14**
Factor 2: Nutrient-management treatment (N)						
N_1	3.18	165.00	25.27	3.84	3.88	11.67
N_2	3.21	170.00	30.16	4.08	4.29	13.74
N_3	3.20	171.25	43.12	5.30	4.79	19.95
N_4	3.24	155.00	27.94	4.05	3.98	12.66
N_5	3.60	200.00	49.84	5.26	4.91	20.38
N_6	4.01	242.50	67.92	6.12	5.85	28.16
S.Em ±	**0.10**	**8.55**	**1.39**	**0.10**	**0.14**	**0.69**
C.D. @ 5%	**0.29**	**25.33**	**3.96**	**0.28**	**0.40**	**1.95**
Variety × nutrient-management interaction (V × N)						
V_1N_1	2.87	155.00	19.77	3.43	3.80	10.23
V_1N_2	2.77	175.00	22.34	3.63	4.23	12.01
V_1N_3	2.94	180.00	35.95	5.28	4.38	18.11
V_1N_4	2.71	162.50	20.06	3.64	3.88	11.08
V_1N_5	3.21	185.00	38.31	5.05	4.50	17.87
V_1N_6	3.60	195.00	63.06	6.05	5.50	26.15
V_2N_1	3.50	175.00	30.78	4.25	3.95	13.12
V_2N_2	3.65	165.00	37.99	4.53	4.35	15.47
V_2N_3	3.46	162.50	50.28	5.33	5.20	21.79
V_2N_4	3.76	147.50	35.82	4.45	4.08	14.24
V_2N_5	4.00	215.00	61.38	5.48	5.33	22.89
V_2N_6	4.43	290.00	72.79	6.19	6.20	30.16
S.Em ±	**0.14**	**12.09**	**1.968**	**0.14**	**0.199**	**0.970**
C.D. @ 5%	**NS**	**36.79**	**5.662**	**0.40**	**NS**	**NS**

Note. V1 = Alphonso orchard; V2 = Totapuri orchard; E–W = east–west; N–S = north–south; SEm = standard error of the mean; CD = critical difference at 5%; NS = non-significant. Cultivar and cultivar × treatment means describe observations from separate orchard blocks

Table 2. Flowering and panicle characteristics of Alphonso and Totapuri mango under six nutrient-management treatments

Treatment	Days to inflorescence emergence	Days to 50% flowering	Days to 100% flowering	Panicles $tree^{-1}$	Panicle length (cm)	Panicle width (cm)
Factor 1: Variety (V)						
V_1	21.46	11.17	34.08	83.83	28.31	4.51
V_2	24.50	13.69	39.42	65.74	32.31	6.84
S.Em ±	**0.80**	**0.24**	**0.61**	**0.75**	**0.83**	**0.15**
C.D. @ 5%	**2.29**	**0.68**	**1.74**	**2.16**	**2.40**	**0.42**
Factor 2: Nutrient-management treatment (N)						
N_1	26.25	14.20	39.38	59.36	24.49	4.57
N_2	23.50	12.70	36.50	72.57	29.38	5.14
N_3	22.50	12.45	35.75	77.59	31.19	5.67
N_4	24.50	12.83	38.25	67.76	27.13	4.53
N_5	22.00	11.95	35.50	82.19	34.06	6.25
N_6	19.13	10.45	35.13	89.24	35.60	7.90
S.Em ±	**1.38**	**0.41**	**1.05**	**1.30**	**1.45**	**0.25**
C.D. @ 5%	**3.92**	**1.17**	**2.99**	**3.69**	**4.11**	**0.72**
Variety × nutrient-management interaction (V × N)						
V_1N_1	24.75	13.00	36.50	67.37	22.23	3.20
V_1N_2	22.00	11.50	34.00	81.42	27.77	3.85
V_1N_3	21.00	10.00	33.50	86.75	29.01	4.56
V_1N_4	23.00	12.25	35.00	78.00	24.82	3.62
V_1N_5	20.50	11.25	32.50	91.40	32.69	4.91
V_1N_6	17.50	9.00	33.00	98.05	33.34	6.92
V_2N_1	27.75	15.40	42.25	51.35	26.75	5.94
V_2N_2	25.00	13.90	39.00	63.72	30.99	6.42
V_2N_3	24.00	14.90	38.00	68.43	33.38	6.78
V_2N_4	26.00	13.40	41.50	57.51	29.44	5.45
V_2N_5	23.50	12.65	38.50	72.97	35.43	7.59
V_2N_6	20.75	11.90	37.25	80.44	37.86	8.88
S.Em ±	**1.95**	**0.58**	**1.48**	**1.836**	**2.044**	**0.36**
C.D. @ 5%	**NS**	**1.67**	**4.45**	**NS**	**NS**	**NS**

Note. V1 = Alphonso orchard; V2 = Totapuri orchard; SEm = standard error of the mean; CD = critical difference at 5%; NS = non-significant. Cultivar and cultivar × treatment means refer to separate orchard blocks

3.2 Flowering and Fruiting Behaviour

Flowering and panicle measurements varied among treatments in both orchards (Table 2). The Totapuri orchard had longer mean intervals to inflorescence emergence (24.50 versus 21.46 days), 50% flowering (13.69 versus 11.17 days) and 100% flowering (39.42 versus 34.08 days), while the Alphonso orchard recorded more panicles per tree (83.83 versus 65.74). Totapuri panicles were longer and wider on average (32.31 and 6.84 cm versus 28.31 and 4.51 cm). Among nutrient treatments, N6 recorded the shortest means for inflorescence emergence (19.13 days), 50% flowering (10.45 days) and 100% flowering (35.13 days), and the greatest number of panicles per tree (89.24), panicle length (35.60 cm) and panicle width (7.90 cm). The corresponding N1 means were 26.25, 14.20 and 39.38 days, 59.36 panicles per tree, and 24.49 and 4.57 cm.

Mango floral initiation and panicle development are influenced by shoot maturity and environmental conditions (Davenport, 2007). The greater panicle production under N6 accompanied its larger observed canopy size, which could have supported the developing inflorescences. Jeevamrutha contains diverse microorganisms and organic constituents (Duraivadivel *et al.*, 2022), while vermicompost-based extracts contain soluble substances of agronomic interest (Sinha *et al.*, 2010). Increases in beneficial microorganisms and crop yield under jeevamrutha were also reported by Boraiah *et al.* (2017) in capsicum. Table 2 shows that the N6 treatment combined greater panicle production with earlier flowering observations in the studied orchards.

3.3 Fruit Physical Attributes and Yield

Fruit retention, fruit physical characteristics and productivity varied across treatments (Table 3). Alphonso trees had more recorded fruits per tree (214.07) than Totapuri trees (106.49), whereas Totapuri fruits were heavier (506.90 versus 227.40 g); mean yield was 54.76 kg tree^{-1} in the Totapuri orchard and 49.07 kg tree^{-1} in the Alphonso orchard. Among the nutrient-management treatments, N6 produced the greatest mean mature fruits per panicle (1.76), fruit retention (23.47%), fruit length (20.44 cm), fruit weight (470.60 g), fruit diameter (11.63 cm), fruit volume (288.22 mL) and yield (73.01 kg tree^{-1}; approximately 20.28 t ha^{-1}). N1 recorded 0.60 mature fruits per panicle, 17.84% retention, 304.04 g mean fruit weight and 37.54 kg tree^{-1} yield. N5 recorded the highest numerical mean number of fruits per tree (176.40), close to N6 (173.31).

Table 3. Fruit retention, fruit physical characteristics and yield of Alphonso and Totapuri mango under six nutrient-management treatments

Treatment	Mature fruits panicle^{-1}	Fruit retention (%)	Fruit length (cm)	Fruit weight (g)	Fruit diameter (cm)	Fruit volume (mL)	Fruits tree^{-1}	Yield (kg tree^{-1})	Yield (t ha^{-1})
Factor 1: Variety (V)									
V_1	1.25	22.03	13.83	227.40	7.58	124.90	214.07	49.07	13.63
V_2	1.00	19.44	19.16	506.90	11.11	332.49	106.49	54.76	15.21
S.Em ±	**0.06**	**0.70**	**0.37**	**6.02**	**0.19**	**5.48**	**2.03**	**0.57**	**0.16**
C.D. @ 5%	**0.16**	**2.00**	**1.07**	**17.32**	**0.55**	**15.76**	**5.83**	**1.63**	**0.45**
Factor 2: Nutrient-management treatment (N)									
N_1	0.60	17.84	12.75	304.04	7.84	173.79	143.33	37.54	10.43
N_2	0.95	20.25	15.38	344.29	8.81	228.94	156.30	46.92	13.03
N_3	1.15	21.17	17.00	366.30	9.72	242.99	162.82	51.54	14.32
N_4	0.82	19.58	14.73	314.43	7.63	191.69	149.48	40.88	11.36
N_5	1.47	22.09	18.68	403.26	10.46	246.52	176.40	61.58	17.11
N_6	1.76	23.47	20.44	470.60	11.63	288.22	173.31	73.01	20.28
S.Em ±	**0.10**	**1.21**	**0.65**	**10.43**	**0.33**	**9.49**	**3.51**	**0.98**	**0.27**
C.D. @ 5%	**0.27**	**3.43**	**1.84**	**29.66**	**0.95**	**27.00**	**9.98**	**2.79**	**0.77**
Variety × nutrient-management interaction (V × N)									
V_1N_1	0.69	19.43	9.14	187.07	6.57	93.77	194.83	36.45	10.13
V_1N_2	1.01	20.97	12.16	216.20	7.06	121.45	210.07	45.39	12.61
V_1N_3	1.29	22.45	13.13	218.75	7.76	126.25	218.00	47.77	13.27
V_1N_4	0.87	20.38	11.54	195.81	6.08	105.91	201.00	39.34	10.93
V_1N_5	1.67	23.72	17.22	244.29	8.51	135.31	236.50	57.77	16.05
V_1N_6	1.97	25.23	19.81	302.29	9.50	166.69	224.00	67.67	18.80
V_2N_1	0.51	16.24	16.36	421.01	9.11	253.81	91.82	38.64	10.73
V_2N_2	0.89	19.54	18.60	472.37	10.57	336.44	102.54	48.44	13.46
V_2N_3	1.01	19.90	20.88	513.85	11.67	359.73	107.65	55.32	15.37
V_2N_4	0.78	18.78	17.92	433.05	9.18	277.46	97.97	42.43	11.79
V_2N_5	1.28	20.45	20.15	562.22	12.40	357.73	116.31	65.39	18.17
V_2N_6	1.55	21.71	21.08	638.92	13.76	409.75	122.63	78.34	21.76
S.Em ±	**0.136**	**1.704**	**0.92**	**14.74**	**0.47**	**13.42**	**4.960**	**1.387**	**0.385**
C.D. @ 5%	**NS**	**NS**	**2.63**	**42.42**	**NS**	**38.61**	**NS**	**3.992**	**1.108**

Note. V1 = Alphonso orchard; V2 = Totapuri orchard; per-hectare yields use approximately 277.78 trees ha^{-1}; SEm = standard error of the mean; CD = critical difference at 5%; NS = non-significant. Cultivar and cultivar × treatment means represent the two distinct orchards

Among individual orchard–treatment combinations, V2N6 yielded 78.34 kg tree^{-1} (21.76 t ha^{-1}) with an average fruit weight of 638.92 g, while V1N6 yielded 67.67 kg tree^{-1} (approximately 18.80 t ha^{-1}). The greatest fruit number per tree was recorded for V1N5 (236.50). These results indicate that fruit mass and fruit number made different contributions to yield in the two orchard contexts.

Greater fruit retention and fruit mass under N6 accompanied the treatment's larger mean canopy and higher panicle count. Together, these observations are consistent with a contribution of nutrient availability and assimilate supply during fruit development to harvested yield. Sathe and Patil (2014) reported mango production responses to vermiwash, while Kumar *et al.* (2020) examined fruit retention under calcium- and boron-containing treatments. Published mango studies have also found responses to organic amendments (Ram *et al.*, 2019) and to vermicompost combined with melatonin (Mosa *et al.*, 2026). The observations in Table 3 show the combined importance of fruit number, fruit size and retention for final productivity; Boraiah *et al.* (2017) similarly documented yield responses to jeevamrutha in a different horticultural crop.

3.4 Fruit Biochemical Quality and Postharvest Attributes

Fruit quality and postharvest characteristics showed distinct responses to the treatments (Table 4). Alphonso had higher mean total soluble solids (TSS; 20.14 versus 15.73 °Brix) and total sugars (17.80% versus 13.17%), while Totapuri had higher mean titratable acidity (0.51% versus 0.36%), measured firmness (405.93 versus 250.88 N) and shelf life (15.70 versus 8.94 days). Across nutrient treatments, N6 recorded the highest mean TSS (19.59 °Brix), total sugars (17.71%), firmness (481.73 N) and shelf life (14.83 days), with the lowest acidity (0.11%). N5 recorded similar mean TSS (19.47 °Brix) and shelf life (13.76 days); the differences were smaller than the corresponding 5% critical differences. The acidity value under N6 was lower than the N5 mean of 0.24%.

Among orchard–treatment combinations, the lowest titratable acidity occurred in V2N6 (0.10%), and the highest recorded TSS and total sugars occurred in V1N6 (23.29 °Brix and 19.87%). V2N6 had the highest numerical firmness and shelf life (561.89 N and 17.90 days). The tabulated analysis indicates a treatment-by-orchard difference for acidity, whereas the corresponding interaction critical differences for the other quality traits were non-significant.

Variation in soluble solids, sugars and acidity is relevant to flavour development, whereas firmness and shelf life are related to postharvest handling and ripening. Cell-wall modifications are recognised contributors to fruit softening (Brummell & Harpster, 2001). Humic substances and vermicompost-derived compounds have been evaluated as plant biostimulants (Canellas *et al.*, 2015; Suthar, 2010), providing possible context for the fruit-quality responses to liquid organic inputs. Mango studies by Ram *et al.* (2019) and Rathod *et al.* (2025) likewise reported treatment-related differences in fruit quality. Table 4 captures the combination of higher soluble solids, lower acidity and greater measured firmness under N6 in the studied orchards.

Table 4. Fruit biochemical quality and postharvest attributes of Alphonso and Totapuri mango under six nutrient-management treatments

Treatment	TSS (Brix)	Total sugars (%)	Titratable acidity (%)	Fruit firmness (N)	Shelf life (days)
Factor 1: Variety (V)					
V_1	20.14	17.80	0.36	250.88	8.94
V_2	15.73	13.17	0.51	405.93	15.70
S.Em ±	**0.52**	**0.51**	**0.01**	**9.63**	**0.48**
C.D. @ 5%	**1.50**	**1.47**	**0.03**	**27.70**	**1.38**
Factor 2: Nutrient-management treatment (N)					
N_1	15.96	13.32	0.82	181.43	9.83
N_2	17.59	14.91	0.47	295.64	11.94
N_3	18.25	16.01	0.33	360.25	12.86
N_4	16.76	14.35	0.62	231.86	10.69
N_5	19.47	16.63	0.24	419.50	13.76
N_6	19.59	17.71	0.11	481.73	14.83
S.Em ±	**0.90**	**0.88**	**0.02**	**16.67**	**0.83**
C.D. @ 5%	**2.57**	**2.51**	**0.05**	**47.44**	**2.36**
Variety × nutrient-management interaction (V × N)					
V_1N_1	17.73	15.37	0.75	101.26	6.53
V_1N_2	19.31	17.23	0.37	203.65	8.35
V_1N_3	20.14	18.66	0.24	299.74	9.58
V_1N_4	18.40	16.65	0.50	151.72	7.04
V_1N_5	21.96	19.04	0.17	347.34	10.38
V_1N_6	23.29	19.87	0.13	401.57	11.75
V_2N_1	14.18	11.27	0.90	261.63	13.13
V_2N_2	15.88	12.59	0.56	387.63	15.53
V_2N_3	16.36	13.36	0.43	420.77	16.14
V_2N_4	15.12	12.05	0.74	312.01	14.34
V_2N_5	16.97	14.21	0.32	491.65	17.15
V_2N_6	15.89	15.56	0.10	561.89	17.90
S.Em ±	**1.27**	**1.25**	**0.02**	**23.58**	**1.17**
C.D. @ 5%	**NS**	**NS**	**0.07**	**NS**	**NS**

Note. V1 = Alphonso orchard; V2 = Totapuri orchard; TSS = total soluble solids; N = newtons; SEm = standard error of the mean; CD = critical difference at 5%; NS = non-significant. Cultivar and cultivar × treatment means describe separate orchard blocks

4. Conclusion

The six nutrient-management treatments produced distinct responses in vegetative characteristics, flowering, fruit retention, harvested yield and fruit quality in the two Bengaluru mango orchards. Five foliar applications of 5% jeevamrutha (N6) recorded the

largest treatment means for final tree height (4.01 m), panicles per tree (89.24), fruit retention (23.47%), fruit weight (470.60 g) and yield (73.01 kg tree^{-1}; approximately 20.28 t ha^{-1}). N6 also recorded high TSS (19.59 °Brix) and total sugars (17.71%) and the lowest mean acidity (0.11%). The Totapuri orchard under N6 had the highest observed yield of an individual cultivar–treatment combination (78.34 kg tree^{-1}; 21.76 t ha^{-1}), while vermicompost tea (N5) generally followed N6 for several productivity and quality traits. The results identify jeevamrutha as a promising nutrient-management input for evaluation in additional mango orchard environments.

5. Limitations of the Study

The study encompassed one production season and two distinct orchard blocks, with cultivar fully aligned with orchard site. Contrasts between cultivars therefore also reflect local growing conditions. Baseline canopy dimensions, input nutrient compositions and application volumes, detailed fruit-volume and firmness-test protocols, and storage conditions were not characterised. These factors affect comparisons with orchard systems using different input preparations and fruit-assessment procedures. Multi-season and multi-orchard investigations with standardised measurements would establish the stability and broader applicability of the observed treatment responses.

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Declaration of AI Use

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Competing Interests

Authors have declared that no competing interests exist.

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