



Organic and integrated nutrient management strategies to enhance physico-biochemical quality of cashew (*Anacardium occidentale* L.) cv. BPP-8

Amit Kumar^{1,2*}, Pramod Kumar Panda³, Raghabananda Nayak⁴ and Nihar Ranjan Sahoo⁵

¹Department of Fruit Science and Horticulture Technology, Odisha University of Agriculture and Technology, Bhubaneswar 751003, Odisha, India

ABSTRACT

This present study was conducted during 2020-21 at Cashew Research Station, AICRP on Cashew, Ranasinghpur, Bhubaneswar under Odisha University of Agriculture and Technology. The experiment was laid out in a Randomized Block Design with three replications comprising eight nutrient management treatments involving different organic nutrient sources and integrated nutrient combinations. The treatments included T₁ (100% N as FYM), T₂ (100% N as FYM + bio-fertilizer consortium), T₃ (50% N as FYM + bio-fertilizer consortium), T₄ (100% N as vermicompost + bio-fertilizer consortium), T₅ (recycling of organic residue with 20% cow dung slurry), T₆ (in situ green leaf manuring to meet 100% N requirement), T₇ (25% N as FYM + recycling organic residue + in situ green leaf manuring + bio-fertilizer consortium) and T₈ [recommended dose of fertilizer (500:250:250 g plant⁻¹) + 10 kg FYM], which served as the conventional nutrient management control. The results revealed significant effects of nutrient management practices on both physical and biochemical quality attributes of cashewnut. Treatment T₇ recorded comparatively superior values for girth (widest: 14.40 cm; narrowest: 9.71 cm), specific gravity (1.27), juice extraction (63.85%), pH (5.20), ascorbic acid content (288.30 mg 100 g⁻¹) and reducing sugars (9.86%) while, T₈ recorded the highest cashew apple weight (63.23 g), apple length (6.70 cm), nut weight (8.20 g), total soluble solids (13.56 °Brix), total titratable acidity (0.64%) and the lowest phenol content (411 mg GAE 100 g⁻¹). The study demonstrated that integrated organic nutrient management improved several biochemical quality parameters, whereas the recommended fertilizer dose combined with FYM enhanced certain physical traits, highlighting the potential of optimized nutrient management strategies for improving fruit quality, productivity and sustainability in cashew cultivation.

Key words: Cashew apple quality, integrated nutrient management, bio-fertilizers, organic nutrient sources, sustainable cashew cultivation.

INTRODUCTION

Cashew (*Anacardium occidentale* L.) is an important export-oriented plantation crop widely cultivated in tropical regions of India and plays a vital role in the livelihood security of small and marginal farmers in coastal and degraded lands. Introduced by the Portuguese in the sixteenth century, it is popularly known as the “rich man’s food but poor man’s crop” and the “zero cholesterol nut” (Nair, 11). Cashew kernels are highly nutritious, containing 21% protein, 47% fat and 22% carbohydrates, while the cashew apple contains 10-30% sugar and is utilized for production of ethanol and other value-added products (Mangalassery *et al.*, 9; Singh *et al.*, 16). India contributed about 24% of global cashew production during 2023-24. The crop occupies 11.99 lakh ha with a production of 7.94 lakh tonnes and

productivity of 674 kg ha⁻¹, whereas Odisha covers 2.23 lakh ha with 1.26 lakh MT production and productivity of 562 kg ha⁻¹ (DCCD, 5). Despite large cultivation area, productivity in Odisha remains lower than the national target.

Excessive dependence on inorganic fertilizers has improved short-term yield but has also caused soil degradation, nutrient imbalance and decline in tree vigour. Organic and integrated nutrient management practices have gained importance due to their beneficial effects on soil health, nutrient cycling, biodiversity and sustainable productivity. Organic inputs improve soil organic matter, microbial activity and nutrient-use efficiency, while integrated nutrient management ensures balanced nutrient supply and reduces dependence on chemical fertilizers (Verma *et al.* 20). Rymbai (14) also reported that organic cultivation enhances soil fertility and long-term productivity in perennial fruit crops.

Although cashew has high economic importance, limited studies are available on the influence of organic and integrated nutrient management on the physico-biochemical quality of cashew apple

*Corresponding author E-mail: amitworld701@gmail.com, Orcid Id : 0000-0001-7492-2655

²Department of Agriculture, Central University of South Bihar Gaya -824236, Bihar, India

³AICRP on Cashew,

^{4,5}AICRP on Post Harvest Technology, Odisha University of Agriculture and Technology, Bhubaneswar- 751003, Odisha, India

and nut. Therefore, the present investigation was undertaken to evaluate the effect of different nutrient management practices on quality parameters of cashew cv. BPP-8 under Odisha conditions for sustainable production and quality improvement.

MATERIALS AND METHODS

This present experiment was conducted at Cashew Research Station, AICRP on Cashew, Ranasinghpur, Bhubaneswar under Odisha University of Agriculture and Technology during 2020-21. This study evaluated eight treatments to assess the effect of various organic nutrients on cashew cv. BPP-8. It comes under the subtropical region and is situated at 20° 15' North latitude and 82° 52' East longitudes. The soil of the experimental site is red laterite with pH ranges from 5.0 to 5.3. The minimum and maximum temperature of the location varies between 15 °C to 40°C.

The experiment followed a Randomized Block Design with three replications, where each replication consisted of four trees per treatment, giving a total of 12 trees per treatment. Treatments included: T1 (100% N as FYM) as control; T2 (100% N as FYM + bio-fertilizers consortium @ 200 g/tree/year); T3 (50% N as FYM + bio-fertilizers consortium @ 200 g/tree/year); T4 (100% N as vermicompost + bio-fertilizers consortium @ 200 g/tree/year); T5 (recycling organic residue with 20% cow dung slurry, equivalent to 20% residue weight as cow dung); T6 (in situ green leaf manuring to meet 100% N); T7 (25% N as FYM + recycling organic residue + in situ green leaf manuring + bio-fertilizers consortium @ 200 g/tree/year); and T8 (recommended dose of fertilizer, 500:250:250 g/plant + 10 kg FYM).

All nutrient sources were applied once during the monsoon period, following the harvest of cashew. The proper and standardized time of application was the first week of July, ensuring optimum moisture conditions for incorporation and nutrient uptake. The recommended dose of fertilizer (500:250:250 g N:P:K per plant) was applied to the designated treatment in a uniform manner across the entire basin area of each plant to facilitate efficient root contact and nutrient absorption. The biofertilizer microbial consortium was procured from ICAR-IIHR, Hesaraghatta, Bengaluru. A measured quantity of 200 g biofertilizer was thoroughly mixed with FYM in a 1:25 ratio and incubated at room temperature for 48 hours to enhance microbial activation. Subsequently, 5 kg of the enriched mixture (biofertilizer + FYM) was applied around each tree assigned to the respective treatments.

The physical parameters of cashew apples and nuts were meticulously measured. The total weight

of apples and nuts was divided by their respective numbers, with samples taken randomly from each treatment group to ensure unbiased results. Girth measurements at the widest and narrowest points were conducted using thread and slide calipers, with the average girth recorded in centimeters. The length of cashew apples was measured using slide calipers, with the average length expressed in centimeters. Specific gravity was determined by individually weighing cashew apples, submerging them in water and recording the volume of water displaced.

For the bio-chemical parameters analysis, the juice extraction percentage was calculated by extracting juice from cashew apples using a grinder juice extractor and squeezing the juice through muslin cloth. The volume of clear juice was measured to determine the extraction percentage. Total soluble solids (°Brix) were measured using a hand refractometer. The pH of the extracted juice was measured using a pH meter. Ascorbic acid content was estimated following the titration method described by Sadasivam and Theymoli (15). Total titratable acidity (%) was calculated by titrating the extracted juice with 0.01N NaOH using phenolphthalein as an indicator (AOAC, 1). Reducing sugars were measured using titrimetric procedures and total phenol content was determined using the Folin-Ciocalteu reagent method as outlined by Malick and Singh (8).

Statistical analysis was performed considering four trees as the experimental unit, and observations were recorded tree-wise to avoid pseudo-replication. Ten fruits sampled per tree were used only to compute a representative mean and were not treated as independent replicates. Data were analyzed using ANOVA as described by Panse and Sukhatme (13). Treatment significance was tested with the F-test, and mean separation was carried out using DMRT at $p < 0.05$ in XLSTAT (2014.5.03). DMRT was chosen for its sensitivity in detecting treatment differences, with results comparable to LSD or Tukey methods. Correlation analysis was also conducted to assess relationships among growth and fruit quality traits. Graphs illustrating treatment effects were prepared using R Studio.

RESULTS AND DISCUSSION

Cashews of different organic nutrient treatments revealed significant variations in various physical and bio-chemical parameters during the period of investigation. The data presented in Table 1 depicts the physical parameters like cashew apple weight, girth at the widest point, girth at the narrowest point, length of apple, specific gravity, juice extraction and weight of nut. Among the eight treatments evaluated, the maximum weight of cashew apple was recorded

Table 1: Effect of organic nutrients on quality of physical parameter on cashew apple and nut.

Treatment	Weight of cashew apple (g)	Girth at widest point (cm)	Girth at narrowest point (cm)	Length of cashew apple (cm)	Specific gravity	Nut weight (g)
T1-100% N as FYM	56.72 ^c	13.80 ^a	9.02 ^a	6.36 ^a	1.18 ^a	7.64 ^a
T2-100% N as FYM + Bio-fertilizers consortium @200 g tree/year)	60.88 ^{ab}	13.88 ^a	9.47 ^a	6.52 ^a	1.22 ^a	8.01 ^a
T3-50% N as FYM + Bio-fertilizers consortium @200 g tree/year)	55.39 ^{cd}	13.66 ^a	8.98 ^a	6.12 ^a	1.20 ^a	7.63 ^a
T4-100% N as Vermicompost + Bio-fertilizers consortium @200 g tree/year)	58.09 ^{bc}	13.65 ^a	9.25 ^a	6.48 ^a	1.24 ^a	7.87 ^a
T5- Recycling of organic residue with the addition of 20% cow dung slurry (20% weight of organic residue as cow dung)	54.14 ^{de}	13.74 ^a	9.16 ^a	6.13 ^a	1.15 ^a	7.19 ^a
T6- <i>In situ</i> green leaf manuring to meet 100% N	52.82 ^e	13.60 ^a	8.92 ^a	6.40 ^a	1.18 ^a	7.44 ^a
T7-25% N as FYM + Recycling organic residue + <i>In situ</i> green leaf Manuring+ Bio- fertilizers consortium @200 g/tree/year)	62.15 ^a	14.40 ^a	9.71 ^a	6.64 ^a	1.27 ^a	8.12 ^a
T8- Recommended Dose of Fertilizer (500:250:250g/plant) + 10kg FYM as control	63.23 ^a	14.33 ^a	9.67 ^a	6.70 ^a	1.22 ^a	8.20 ^a
Mean	57.91	13.88	9.27	6.42	1.21	7.76
SE(m)±	0.62	0.30	0.16	0.20	0.06	0.21
CD (@ 5%)	1.87	0.92	0.49	0.61	0.18	0.64
CV (%)	1.85	3.77	3.02	5.47	8.54	4.70

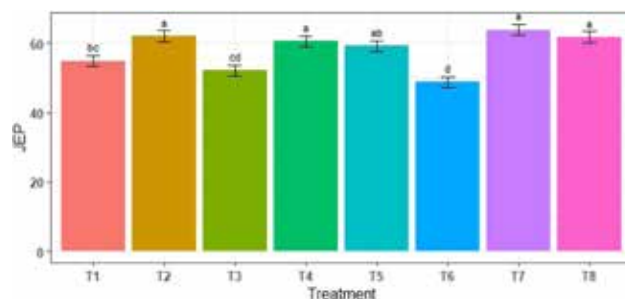
at 63.23g (T₈) followed by 62.15g (T₇) and the minimum in T₆ (52.82g). Cashew apple girth at the widest and narrowest point was recorded significantly maximum in T₇ (14.40cm & 9.71cm) and minimum in treatment T₆ (13.60cm & 8.92cm) respectively. Cashew apple length ranged from minimum of 6.12 cm (T₃) to maximum of 6.70 (T₈).

The treatment T₇ recorded the significant maximum specific gravity T₇ (1.27) and lowest specific gravity was recorded in treatment T₅ (1.15) among the different treatments. Treatment T₈ recorded significantly the highest nut weight 8.20g followed by 8.12g (T₇) and lowest nut weight (g) was recorded for T₅ (7.19g) among the treatments.

The juice extraction percentage is treated as one of the important aspects which will decide the quantum of products to be prepared or developed. In Fig. 1, the treatment T₇ recorded a significantly maximum of juice extraction of 63.85% and the treatment T₆ recorded significantly minimum juice extraction (48.76%) among the tested treatments. Similar variations on juice extraction percentage were reported by Panda and Bhusan (12) and Mohapatra *et al.* (10) in cashew.

The increase in physical parameters might be due to its dual role in nitrogen fixation and production

of phytohormone and increased uptake of nutrients. However, organic source nutrient management showed low yield as compared to the recommended dose of fertilizer as cashew grown in Odisha is in rainfed condition and receives rainfall only during the monsoon and the rest of the period remain dry. Organic fertilizers need moisture for proper decomposition and realizing nutrients. Due to the lack of moisture content in the field, microbial activity is reduced leading to less availability of available nutrients to the plant which ultimately reduces the plant yield as compared to the recommended dose of fertilizer. The above results conform with the findings

**Fig. 1.** Effect of organic nutrient treatments on juice extraction percentage (JEP) of cashew.

of Talang *et al.* (18) in mango, Mohapatra *et al.* (10) and Gajbhiye *et al.* (6) in cashew.

The data presented in Table 2 on cashew apple bio-chemical properties revealed that among the eight treatments evaluated, the TSS ranged from a minimum of 11.77 °Brix (T_5) to a maximum of 13.56 °Brix (T_8). Treatments that recorded TSS included T_7 (12.85 °Brix), T_1 (12.51 °Brix) and T_3 (12.33 °Brix). This shows that inorganic fertilizer can be substituted for FYM or vermicompost to maintain the same quality for an organic product which is nowadays required for health benefits. The present finding is confirmatory with the finding of Mohapatra *et al.* (10), Gajbhiye *et al.* (6) in cashew and Chauhan *et al.* (3) in dragon.

From the perusal of table 2, it was found that effect of the treatments has no significant difference on pH of cashew apple juice. However, the highest pH was recorded in treatment T_7 (5.20), closely followed by T_4 (5.18) and treatment minimum pH was recorded in T_6 (5.02). The lowest pH is the desirable characteristic for keeping the quality of juice. The comparison among organic treatments T_2 , T_4 and T_6 reveal that green leaf manuring has a role in producing apple juice of low pH value as compared to FYM or vermi-compost application. The present finding is confirmatory with the finding of Mohapatra *et al.* (10).

Among the eight treatments, the significantly highest acidity percentage was recorded in treatment T8 (0.64%) followed by T1 (0.58%) and the minimum acidity was recorded in T7 (0.45%). The highest ascorbic acid content was recorded in T_7 (288.30mg/100g) which is at par with T_2 (277.90mg/100g) and T_4 treatment (274.66mg/100g) in Fig. 2. Significantly the lowest ascorbic acid content was observed in T_6 (201mg/100g) which indicates that only green leaf manuring can not be a recommended cultural practice in comparison to FYM or vermicompost application along with bio-fertilizer consortium so far as ascorbic acid content is concerned. The high ascorbic acid content in cashew

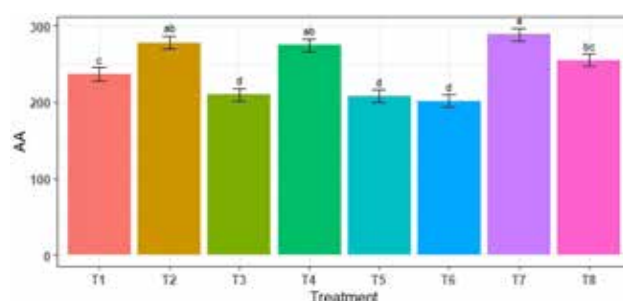


Fig. 2. Effect of organic nutrient treatments on ascorbic acid (AA) of cashew.

Table 2: Effect of organic nutrients on quality of bio-chemical parameters on cashew apple.

Treatment	TSS (°Brix)	pH	Acidity (%)	Reducing sugar (%)	Phenol content (mg GAE/100g)
T1-100% N as FYM as control	12.51 ^{ab}	5.06 ^a	0.58 ^a	8.15 ^b	513.5 ^b
T2-100% N as FYM + Bio-fertilizers consortium @200 g tree/year)	13.42 ^a	5.12 ^a	0.52 ^a	8.78 ^b	519 ^b
T3-50% N as FYM + Bio-fertilizers consortium @200 g tree/year)	12.33 ^{ab}	5.10 ^a	0.50 ^a	8.37 ^b	475.5 ^b
T4-100% N as Vermicompost + Bio-fertilizers consortium @200 g tree/year)	13.26 ^a	5.18 ^a	0.48 ^a	8.42 ^b	673 ^c
T5- Recycling of organic residue with the addition of 20% cow dung slurry (20% weight of organic residue as cow dung)	11.77 ^b	5.13 ^a	0.50 ^a	8.26 ^b	462.5 ^{ab}
T6- <i>In situ</i> green leaf manuring to meet 100% N	11.85 ^b	5.08 ^a	0.54 ^a	8.62 ^b	512.5 ^b
T7-25% N as FYM + Recycling organic residue + <i>In situ</i> green leaf Manuring+ Bio- fertilizers consortium @200 g/tree/year)	12.85 ^{ab}	5.20 ^a	0.45 ^a	9.86 ^a	472.8 ^b
T8-Recommended Dose of Fertilizer (500:250:250g/plant) + 10kg FYM as control	13.56 ^a	5.02 ^a	0.64 ^a	9.78 ^a	411.5 ^a
Mean	12.69	5.11	0.53	8.78	504.04
SE(m) ±	0.23	0.08	0.03	0.16	10.11
CD (@5%)	0.70	0.24	0.10	0.49	30.65
CV %	3.17	2.71	10.53	3.20	3.47

apple juice is a desirable characteristic for its better utilization. In an earlier study, Mohapatra *et al.* (10) reported a similar finding of ascorbic acid in cashew. The reducing sugar content of cashew apple varied significantly among the treatments. The highest value (9.86%) was observed in T₇, followed by T₈ (9.78%), while the lowest reducing sugar content (8.15%) was recorded in T₅.

From Table 2, it is clear that organic treatments have a considerable effect on the total phenolic content of cashew apples. The total phenolic content varies from 411.5 mg GAE/100g (T₈) to 673.0 mg GAE/100g (T₄). The highest value is noted in the treatment (T₄) where all the nitrogen is applied through a vermicompost source along with Bio-fertilizers consortiums. The lowest value (411.5mg GAE/100g) is observed in the inorganic treatment plot *i.e.*, T₈. It is observed that the highest value is obtained in (T₄) treatment followed by FYM treatment along with or in combination with bio-fertilizer. The lowest content of total phenolics is measured in the treatment where fertilizer is applied from an inorganic source. The result of the present study is the same as the research result of Sousa *et al.* (17). The higher content of phenolic compounds by organic fertilizer may be due to the effect of organic manure inducing acetate shikimate pathway resulting in higher production of phenolic compounds. A similar trend was also reported by Thangasamy and Lawande (19) in the onion crop, where, the author observed more amount of phenolic content by integrated use of organic and inorganic fertilizers.

The highest reducing sugars and ascorbic acid content in cashew apples found in T₇ (25% N as FYM + recycling organic residue + *In situ* green leaf manuring+ bio-fertilizers consortium @200 g/tree/year), which was superior to other treatments followed by T₂ (100% N as FYM + bio-fertilizers consortium @200 g tree/year). This result is similar to the findings of Rymbai (14) in citrus, Talang *et al.* (18) in mango, Athani *et al.* (2) in guava. This may be due to the effect of potassium on quality which can be explained by the fact that potassium improves photosynthetic activity and also help in better translocation of metabolites from leaves to fruit and bio-fertilizer is the agent for potassium solubilization reported by Maity *et al.* (7) in guava. Another thing is that the quality improvement in fruit is due to the proper supply of nutrients and induction of growth hormones, which stimulated cell division, cell elongation, increase in number and weight of the fruits, better root development and better translocation of water and deposition of nutrients. This may also be due to the improved fertilizer use

efficiency with the application of an organic source of nutrients and bio-fertilizer.

The data presented in Table 2 on cashew apple biochemical properties revealed that the highest TSS was recorded in T₈ (13.56 °Brix), while the lowest was observed in T₅ (11.77 °Brix). The highest TSS in T₈ was likely due to the balanced nutrient supply enhancing photosynthesis and carbohydrate accumulation, while the lowest TSS in T₅ may be attributed to slower nutrient release from recycled organic residue with cow dung slurry. The present finding is confirmatory with the finding of Mohapatra *et al.* (10), Gajbhiye *et al.* (6) in cashew and Chauhan *et al.* (3) in dragon.

From the perusal of table 2, it was found that effect of the treatments has no significant difference on pH of cashew apple juice. However, the highest pH was recorded in treatment T₇ (5.20) and treatment minimum pH was recorded in T₈ (5.02). The lowest pH is the desirable characteristic for keeping the quality of juice. The lowest pH observed in T₈ may be attributed to the higher availability of organic acids in treatments involving green leaf manuring, which contributes to maintaining the desirable acidity and quality of cashew apple juice. The present finding is confirmatory with the finding of Mohapatra *et al.* (10).

Among the eight treatments, the significantly highest acidity percentage was recorded in treatment T₈ (0.64%) followed by T₁ (0.58%) and the minimum acidity was recorded in T₇ (0.45%). Acidity was higher under inorganic fertilizer application. The increased acidity is likely due to the enhanced synthesis of organic acids stimulated by higher nitrogen availability, a trend similarly reported by Datta *et al.* (4) in aonla.

The highest ascorbic acid content was recorded in T₇ (288.30mg/100g) which is at par with T₂ (277.90mg/100g) and T₄ treatment (274.66mg/100g) in Fig. 2. Significantly the lowest ascorbic acid content was observed in T₆ (201mg/100g) which indicates that the higher ascorbic acid content in FYM- and vermicompost-based treatments can be attributed to their slow, sustained nutrient release, better moisture retention and enhanced microbial activity, which collectively support stronger metabolic processes and promote vitamin C synthesis in cashew apples, while the role of organic inputs in improving soil structure and nutrient availability reported by Mohapatra *et al.* (10) in cashew.

The reducing sugar content of cashew apple varied significantly among the treatments. The highest value (9.86%) was observed in T₇, followed by T₈ (9.78%), while the lowest reducing sugar content (8.15%) was recorded in T₅. From Table 2, it is clear

that organic treatments have a considerable effect on the total phenolic content of cashew apples. The total phenolic content varies from 411.5 mg GAE/100g (T_8) to 673.0 mg GAE/100g (T_4). The highest value is noted in the treatment (T_4) where all the nitrogen is applied through a vermicompost source along with Bio-fertilizers consortiums. The lowest value (411.5mgGAE/100g) is observed in the inorganic treatment plot *i.e.*, T_8 . It is observed that the highest value is obtained in (T_4) treatment followed by FYM treatment along with or in combination with bio-fertilizer. The lowest content of total phenolics is measured in the treatment where fertilizer is applied from an inorganic source. The higher content of phenolic compounds by organic fertilizer may be due to the effect of organic manure inducing acetate shikimate pathway resulting in higher production of phenolic compounds. The result of the present study is the same as the research result of Sousa *et al.* (17). A similar trend was also reported by Thangasamy and Lawande (19) in the onion crop, where, the author observed more amount of phenolic content by integrated use of organic and inorganic fertilizers.

The highest reducing sugars content in cashew apples found in T_7 (25% N as FYM + recycling organic residue + *In situ* green leaf manuring+ bio-fertilizers consortium @200 g/tree/year), which was superior to other treatments followed by T_2 (100% N as FYM + bio-fertilizers consortium @200 g tree/year). This may be due to the effect of potassium on quality which can be explained by the fact that potassium

improves photosynthetic activity and also help in better translocation of metabolites from leaves to fruit and bio-fertilizer is the agent for potassium solubilization reported by Maity *et al.* (7) in guava. Another thing is that the quality improvement in fruit is due to the proper supply of nutrients and induction of growth hormones, which stimulated cell division, cell elongation, increase in number and weight of the fruits, better root development and better translocation of water and deposition of nutrients. This may also be due to the improved fertilizer use efficiency with the application of an organic source of nutrients and bio-fertilizer. This result is also similar to the findings of Rymbai (14) in citrus, Talang *et al.* (18) in mango, Athani *et al.* (2) and Ram and Pathak (2007) in guava.

To assess the degree of interrelationship among various fruit physical and biochemical quality traits of cashew apple, Pearson's correlation coefficients were computed and presented in Table 3 and Fig. 3. The correlation matrix revealed strong and predominantly positive associations among most physical and quality parameters, indicating coordinated development of fruit attributes under integrated nutrient management practices.

Cashew apple weight (WCA) exhibited highly significant and positive correlations with girth at the narrowest point ($r = 0.936$), nut weight ($r = 0.945$), total soluble solids ($r = 0.884$), and juice extraction percentage ($r = 0.823$). These strong associations suggest that increases in fruit size are closely linked

Table 3: Pearson's correlation coefficients illustrating associations among physical and quality parameters of cashew fruit.

	WCA	GRTW	GRTN	LCA	SG	JE	NWT	TSS	PH	ACD	AAC	RS	PC
WCA	1.000	0.856	0.936	0.830	0.766	0.823	0.945	0.884	0.068	0.175	-0.128	0.798	-0.182
GRTW		1.000	0.902	0.739	0.605	0.696	0.744	0.531	0.015	0.179	-0.267	0.924	-0.526
GRTN			1.000	0.795	0.717	0.895	0.821	0.729	0.214	0.030	-0.116	0.871	-0.262
LCA				1.000	0.731	0.587	0.865	0.763	0.007	0.263	-0.146	0.809	-0.011
SG					1.000	0.604	0.864	0.716	0.503	-0.316	0.277	0.687	0.229
JE						1.000	0.647	0.691	0.408	-0.145	0.108	0.574	-0.012
NWT							1.000	0.913	0.058	0.159	-0.084	0.770	-0.033
TSS								1.000	0.009	0.234	-0.088	0.526	0.165
PH									1.000	-0.942	0.798	0.043	0.505
ACD										1.000	-0.814	0.129	-0.421
AAC											1.000	-0.308	0.600
RS												1.000	-0.448
PC													1.000

Where, WCA: Weight of cashew apple (g), GRTW: Girth at widest point (cm), GRTN: Girth at narrowest point (cm), LCA: Length of cashew apple (cm), SG: Specific Gravity, JE: Juice Extraction (%), NWT: Nut weight (g), TSS: Total Soluble Solids (°Brix), PH: pH, ACD: Acidity (%), AAC: Ascorbic acid (mg/100g), RS: Reducing Sugar (%), PC: Phenol content (mg GAE/100g).

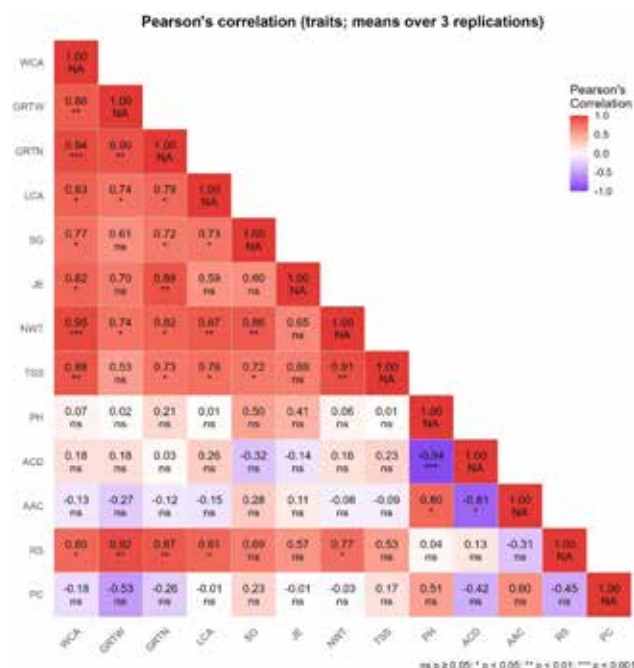


Fig. 3. Pearson's correlation coefficients illustrating associations among physical and quality parameters of cashew fruit.

with enhanced nut development, improved juice recovery and higher sweetness, all of which are key determinants of market and processing quality. The positive correlation between WCA and specific gravity ($r = 0.766$) further indicates that larger fruits possessed greater density and internal solidity, reflecting improved assimilate partitioning and balanced nutrient uptake.

Among the biochemical traits, ascorbic acid ($r = -0.128$) and phenol content ($r = -0.182$) showed weak or negative correlations with most physical parameters, indicating that the accumulation of these compounds is not directly dependent on fruit size or mass. This trend suggests a physiological dilution or metabolic trade-off effect, where rapid fruit enlargement and sugar accumulation may reduce the relative concentration of antioxidant compounds. Similar relationships have been reported in fruit crops, where primary growth processes and secondary metabolite synthesis are governed by distinct metabolic pathways. Strong positive correlations among girth, fruit length, nut weight and TSS further demonstrate that improvements in structural traits are closely associated with enhanced sweetness and nut development. These coordinated relationships indicate that integrated nutrient management promotes synchronized improvement of multiple quality attributes rather than isolated trait enhancement.

Treatments incorporating organic inputs such as farmyard manure, vermicompost, green leaf manuring, and bio-fertilizers particularly T7 and T8 strengthened the interdependence between physical and biochemical parameters, as illustrated in Fig. 3. This may be attributed to improved nutrient availability, enhanced microbial activity, and better root-soil interactions, leading to balanced plant metabolism. The correlation analysis supports the conclusion that integrated nutrient management primarily enhances cashew apple quality through improvements in fruit size, density, juice recovery, and sweetness, while antioxidant traits such as ascorbic acid and phenols respond more independently to nutrient regimes.

The study confirms that integrated nutrient management significantly influenced the physical and biochemical quality attributes of cashew cv. BPP-8. Among the treatments, T7 [25% N as FYM + recycling organic residue + in situ green leaf manuring + bio-fertilizer consortium @ 200 g tree⁻¹ year⁻¹] recorded comparatively superior performance for growth, juice recovery, ascorbic acid, reducing sugars and pH, indicating improved nutrient synchronization and soil biological activity while, T₈ [recommended dose of fertilizer (500:250:250 g tree⁻¹) + 10 kg FYM tree⁻¹], serving as the conventional nutrient management control, improved fruit size, nut weight, TSS and acidity, while reducing phenol content. The findings suggest that integrated organic nutrient management enhanced biochemical quality traits, whereas conventional nutrient management favored certain physical and yield-related parameters in cashew cv. BPP-8.

AUTHOR'S CONTRIBUTION

AK conducted the experiment, analyzed data, prepared figures and drafted the manuscript. PKP provided experimental guidance, laboratory facilities and assisted in writing. RN and NRS supported with lab facilities. All authors reviewed and approved the final manuscript

DECLARATION

The authors declare no competing interests.

ACKNOWLEDGEMENT

The authors acknowledge the support rendered by AICRP on Cashew, AICRP on Post Harvest Technology, Department of Fruit Science and Horticulture Technology, OUAT, Bhubaneswar and ICAR-Directorate of Cashew Research, Puttur, Karnataka for providing necessary facilities to carry out the research work.

REFERENCES

1. AOAC 2012. Official method of analysis: Association of Analytical Chemists. 19th Edn., Washington DC, pp. 121-130.
2. Athani, S.I., Ustad, A.I., Prabhuraj, H.S., Swamy, G.S.K., Patil, P.B. and Kotikal, Y.K. 2007. Influence of vermicompost on growth, fruit yield and quality of guava cv. Sardar. *Acta Hort.*, **735**(8): 381-385.
3. Chauhan, P., Kumar, A., Tripathi, S.K., Katiyar, H., Kumar, A., Verma, A.K. and Singh, S. 2024. Effect of organic manures and bio-fertilizers on growth, yield and quality of dragon fruit (*Hylocereus undatus* L.) under Western Uttar Pradesh conditions. *J. Sci. Res. Rep.*, **30**(11): 1106-1117.
4. Datta, S., Roy, S., Mandal, K.K., Hasan, M.A. and Bauri, F.K. 2024. Effect of organic and inorganic nutrients on growth, yield and quality of aonla (*Emblica officinalis* Gaertn.) cv. NA-7 in the red and laterite zones of West Bengal. *Int. J. Minor Fruits Med. Aromat. Plants*, **10**(1): 97-101.
5. Directorate of Cashew and Cocoa Development (DCCD) 2023-2024. Annual Report 2023-2024. Ministry of Agriculture and Farmers Welfare, Government of India, Kochi, Kerala.
6. Gajbhiye, R.C., Salvi, S.P. and Pawar, S.N. 2016. Effect of organic manures on growth and yield of cashew cv. Vengurla-4 under Konkan region of Maharashtra. *Asian J. Soil Sci.*, **11**(1): 159-165.
7. Maity, P.K., Das, D.C. and Kundu, S. 2006. Effect of different source of nutrients on yield and quality of guava cv. L-49. *J. Crop Weed*, **2**(2): 17-19.
8. Malick, C.P. and Singh, M.B. 1980. Plant Enzymology and Histo-enzymology. Kalyani Publishers, New Delhi.
9. Mangalassery, S., Adiga, J.D., Veena, G.L., Biniha, N.K. and Anil Kumar, K.S. 2024. Cashew (*Anacardium occidentale* L.). In: Soil Health Management for Plantation Crops: Recent Advances and New Paradigms. Springer Nature Singapore, Singapore, pp. 253-279.
10. Mohapatra, A., Dash, D.K., Tripathy, P. and Sethi, K. 2015. Impact of organic inputs on apple quality in cashew (*Anacardium occidentale* L.). *Int. J. Farm Sci.*, **5**(4): 127-133.
11. Nair, K.P. 2020. Cashew nut (*Anacardium occidentale* L.). In: Tree Crops: Harvesting Cash from the World's Important Cash Crops. Springer International Publishing, Cham, pp. 27-77.
12. Panda, C. and Bhusan, L.P. 2015. Varietal screening of cashew for physical parameters and preparation of ready-to-serve (RTS) beverage and jam. *Int. J. Farm Sci.*, **7**(2): 44-46.
13. Panse, V.G. and Sukhatme, P.V. 1985. Statistical Methods for Agricultural Workers. ICAR, New Delhi, pp. 296.
14. Rymbai, H. 2024. Organic cultivation of citrus (*Citrus* spp.). In: Ghosh, S.N., Hare, K. and Rymbai, H. (eds.), Organic Culture of Tropical and Subtropical Fruit Plants. Gyanavi Publishers & Distributors, pp. 131-176.
15. Sadasivam, S. and Theymoli, B. 1987. Practical Manual Biochemistry. Tamil Nadu Agricultural University, Coimbatore.
16. Singh, B., Kaur, G. and Rafiq, S. 2022. Cashew wastes: chemistry, processing and utilization. In: Handbook of Fruit Wastes and By-products. CRC Press, pp. 273-288.
17. Sousa, C., Pereira, D.M., Pereira, J.A., Bento, A., Rodrigues, M.A. and Lopes, G. 2008. Multivitamin analysis of cabbage (*Brassica oleracea* L. var. costata DC) phenolics: Influence of fertilizers. *J. Agric. Food Chem.*, **141**(5): 2231-2239.
18. Talang, H.D., Dutta, P., Mukhim, C. and Patil, S. 2017. Effect of integrated nutrient management on mango (*Mangifera indica* L.) cv. Himsagar. *J. Hort. Sci.*, **12**(1): 23-32.
19. Thangasamy, A. and Lawande, K.E. 2015. Integrated nutrient management for sustainable onion production. *Indian J. Hort.*, **72**(3): 347-352.
20. Verma, B.C., Pramanik, P. and Bhaduri, D. 2019. Organic fertilizers for sustainable soil and environmental management. In: Nutrient Dynamics for Sustainable Crop Production. Springer Singapore, pp. 289-313.

(Received : June, 2026; Revised : September, 2026;
Accepted : October, 2026)