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ASSESSMENT OF SOIL NUTRIENT STATUS IN GUAVA (*PSIDIUM GUAJAVA* L.) ORCHARD UNDER ULTRA-HIGH DENSITY PLANTING SYSTEM IN RAIPUR REGION OF CHHATTISGARH INDIA

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ABSTRACT

A field experiment was conducted during the year 2023-24 and 2024-25 in mrig bahar crop at research field of Precision Farming Development Centre (PFDC), Department of Fruit Science, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.). The objective is to estimate the soil fertility status in Guava field under ultra-high density planting system. The soil analysis the interaction effects further underscored this finding; with combinations such as T_{11} (V_2 N_4) (Lalit variety, combination of 75 % RDF + Cow urine @4lit plant^{-1}) achieving the highest values favourable soil nutrient profiles, including the highest levels of available nitrogen (241.86 kg ha^{-1}), phosphorus (16.49 kg ha^{-1}) and potassium (399.85 kg ha^{-1}), alongside relatively lower soil pH and electrical conductivity, which are beneficial for sustained soil fertility. Overall, the integration of Lalit variety with balanced nutrient management offers the most promising strategy for maintaining soil health and fertility in guava orchards.

***Key words*:** Guava, organic nutrient, fertilizers, varieties, ultra high-density planting

Introduction

Guava (*Psidium guajava* L.) is native to tropical regions of the Americas, particularly the area stretching from Mexico to Peru. It belongs to the Myrtaceae family, under the genus Psidium, which includes around 150 species of shrubs. However, *Psidium guajava* is the most extensively cultivated and globally recognized species (Singh *et al.*, 2013). The fruit was introduced to India by the Portuguese in the 17th century (Muthukumar and Selvakumar, 2017). Most commercially grown guava cultivars are diploid with a chromosome number of 2n = 22, while seedless varieties are triploid and generally exhibit poor fruit-bearing ability. Guava often referred to as the "Apple of the Tropics" or the "Poor Man's Apple," is a tropical fruit celebrated for its rich nutritional value. It is an excellent source of ascorbic acid (vitamin C), pectin, calcium, iron, phosphorus, and various other essential vitamins and minerals.

The concept of integrated nutrient management, which combines organic, inorganic, and bio-fertilizers, has gained prominence in response to the rising nutrient requirements associated with intensive farming. This strategy seeks to enhance soil fertility and ensure a consistent supply of nutrients to plants, thereby supporting sustainable crop productivity by utilizing all available nutrient sources effectively. Within this framework, organic manures, biofertilizers, and crop residues are considered economical and beneficial inputs for improving plant growth, yield, and fruit quality (Katiyar *et al*., 2012). Solely relying on balanced chemical fertilizers may be insufficient to maintain long-term soil health and productivity in guava orchards. However, studies have shown that combining inorganic fertilizers with biofertilizers, organic manures, crop residues, and vermicompost can significantly enhance both soil quality and crop yields (Singh *et al.*, 2011).

Soil quality is a fundamental factor influencing the sustainability and productivity of agricultural ecosystems

Table 1: Physico-chemical composition of experimental soil.

I. Physical properties			
Components	**Analytical values**	**Classification**	**Method used**
Sand (%)	21.42	Clay	International pipette method (Black, 1965)
Silt (%)	35.50		
Clay (%)	43.08		
II. Chemical analysis			
Soil pH	7.21	Neutral slightly alkaline	Carbon electrode pH meter method (Piper, 1967)
EC (dSm^{-1})	0.40	Normal	Electrical conductivity meter
Available N (kg/ha)	219.00	Low	Modified Kjeldahl method (Piper, 1966)
Available P (kg/ha)	14.72	Medium	Olsen's method (Olsen, 1954)
Available K (kg/ha)	360.40	High	Flame photometer method (Jackson, 1967)

(Dwivedi & Dwivedi, 2007). In intensive fruit cultivation systems, the continuous extraction of nutrients can lead to soil degradation, resulting in declining fertility and a reduction in fruit quality. The overuse and imbalance of inorganic fertilizers not only degrade the environment but also pose risks to plant health and human safety (Shanker *et al*., 2002). Horticultural systems heavily dependent on agrochemicals are becoming increasingly unsustainable due to the deterioration of soil health, contamination of surface and groundwater, and rising production costs, ultimately reducing farmers' profitability (Pimentel *et al*., 2005). Organic farming has emerged as a practical and sustainable alternative for cost-effective guava cultivation (Ram and Verma, 2017). To ensure both high productivity and profitability, strategies in horticultural crop management must emphasize reducing external inputs. Enhancing energy efficiency and minimizing resource use are key to maximizing returns per unit area (Singh *et al*., 2002).

Materials and Methods

Experimental Site and Climate

The present investigation was carried out at Precision Farming Development Centre (PFDC), Department of Fruit Science, College of Agriculture, IGKV, Raipur (C.G.) during the year of 2023-24 and 2024-25. The experimental site is situated at an altitude of 293 m above mean sea level, latitude 21.10ºN and longitude 82.08ºE. The average annual rainfall in the region is approximately 1200-1400mm, with the majority received during the monsoon season (June to September).

The soil in the experimental field was Vertisols, also known as clay, which is known in the area as "Kanhar" with good drainage and moderate fertility. The soil sample was collected up to a depth of 15 cm randomly from 4-5 places in the field for examination of physico-chemical compositions, and the obtained samples were thoroughly mixed to produce a composite sample. Table 1 summarises the results of the composite sample analysis.

Plant Material and Experimental Design

The study was conducted on guava (*Psidium guajava* L.) cultivar Shweta, Lalit and Lucknow-49. The plants were ten years old and planted under the Ultra High Density Planting (UHDP) system at spacing of 2.0 m × 1.0 m, accommodating 5,000 plants per hectare.

Preparation of organic manure

Vermiwash was collected from tetravermi bed demonstration center, Precision Farming Development Centre (PFDC), Department of Fruit Science, I.G.K.V., Raipur and fresh vermiwash was filtered with muslin cloth and used for fertigation in plants. Vermiwash used for experiment, was prepared by earthworm and farm waste. For preparation of Vermiwash, 1 litre of vermiwash was mixed in 5 litre of water.

Cow urine was collected from Dairy farm, IGKV, Raipur and fermented for a week than used for fertigation in plants. For preparation of 1 litre of cow urine was mixed with 5 litre of water.

Cow dung was collected from Dairy farm, IGKV, Raipur and 1 kg of cow dung was mixed in 5 litre of water than used for soil application.

Fertilizer application

During the crop period from flowering to maturity stage different water soluble fertilizer grades (19:19:19 and 12:61:0) in splits doses were applied on guava plants as per requirements. Remaining nitrogen and phosphorus dose was supplemented through urea and phosphoric acid, respectively through drip irrigation system. For proper growth and yield water soluble fertilizers was applied from June to September and the number of application of fertigation was twice in a week. The plants were ten years old and planted under the Ultra High Density Planting (UHDP) system at spacing 2×1 m, Recommended Dose of Fertilizers (RDF) of guava is 100% =640:900:250 g $plant^{-1}$ and 75%= 480:675:188 g $plant^{-1}$.

Table 2: Main effect on response of organic manures with fertilizers on soil parameters of guava orchard.

TREATMENTS		Soil pH			Electrical conductivity (dSm^{-1})		
VARIETIES		2023	2024	MEAN	2023	2024	MEAN
V_1	SHWETA	8.18^{b}	8.19^{b}	8.19^{b}	0.43^{ab}	0.44^{a}	0.44^{a}
V_2	LALIT	8.17^{c}	8.18^{c}	8.18^{c}	0.42^{b}	0.43^{ab}	0.43^{ab}
V_3	LUCKNOW-49 (L-49)	8.19^{a}	8.20^{a}	8.19^{a}	0.44^{a}	0.44^{a}	0.44^{a}
SE(m) ±		**0.001**	**0.002**	**0.002**	**0.001**	**0.001**	**0.001**
C.D. (0.005)		**0.004**	**0.006**	**0.005**	**0.003**	**0.002**	**0.003**
NUTRIENTS MANAGEMENT PRACTICES							
N_1	CONTROL	8.13^{f}	8.13^{f}	8.13^{f}	0.41^{d}	0.41^{d}	0.41^{e}
N_2	100%RDF	8.23^{a}	8.24^{a}	8.24^{a}	0.45^{a}	0.46^{a}	0.46^{a}
N_3	100%RDF+CU@2lit	8.21^{b}	8.22^{b}	8.22^{b}	0.44^{ab}	0.45^{ab}	0.45^{ab}
N_4	75% RDF+CU @4lit	8.20^{bc}	8.21^{bc}	8.20^{c}	0.44^{ab}	0.45^{ab}	0.45^{ab}
N_5	100%RDF+CDS@2lit	8.16^{de}	8.17^{de}	8.17^{ef}	0.42^{cd}	0.43^{cd}	0.43^{cd}
N_6	75% RDF+CDS @4lit	8.15^{e}	8.16^{e}	8.16^{f}	0.42^{cd}	0.43^{cd}	0.42^{de}
N_7	100%RDF+VW@2lit	8.19^{c}	8.20^{c}	8.19^{cd}	0.43^{bc}	0.44^{bc}	0.44^{bc}
N_8	75% RDF+VW@4lit	8.17^{d}	8.18^{d}	8.18^{de}	0.43^{bc}	0.44^{bc}	0.43^{cd}
SE(m) ±		**0.002**	**0.003**	**0.003**	**0.001**	**0.001**	**0.001**
C.D. (0.005)		**0.006**	**0.010**	**0.009**	**0.004**	**0.003**	**0.003**

Results and Discussion

The Chemical analysis of soil samples collected before the experiment and after the final harvest from various treatments was conducted to assess changes in soil parameters. The recorded data on soil pH, electrical conductivity (EC), available nitrogen (N), available phosphorus (P) and available potassium (K) are presented in Table 2 to 5. The results clearly indicate that the application of different combinations of chemical fertilizers and organic amendments had a significant influence on the soil characteristics evaluated.

Soil pH

The soil pH measured after harvest for guava varieties Shweta, Lalit and Lucknow-49, as influenced by different nutrient combinations. Regarding the main effect of organic manures combined with fertilizers, the lowest soil pH was recorded in variety V_2 – Lalit, with values of 8.17 and 8.18 during 2023–24 and 2024–25 and a pooled average of 8.18. In contrast, the highest soil pH was observed in V_3 – Lucknow-49 (8.19, 8.20 and 8.19), followed by V_1 – Shweta (8.18, 8.19 and 8.19). Among the nutrient combinations, treatment N_2 (100% RDF) exhibited the highest soil pH (8.23, 8.24 and 8.24 across both years and the mean), followed by N_3 (100% RDF + CU @ 2 lit plant^{-1}) with values of 8.21, 8.22 and 8.22. The lowest soil pH was consistently recorded in the control treatment N_1 (8.13 in both years and in pooled data).

A significant interaction between nutrient management and guava varieties was also observed. The highest soil pH was recorded in the V_3N_2 (Lucknow-49 + 100% RDF) treatment combination (8.25 across all years), closely followed by V_1N_2 (Shweta + 100% RDF) and V_2N_2 (Lalit + 100% RDF), with pH values ranging from 8.22 to 8.25. In contrast, the lowest pH (8.13) was consistently observed in all control combinations (V_1N_1, V_2N_1 and V_3N_1). This trend may be attributed to the acidic nature of organic manures, which upon mineralization release various compounds (*e.g.,* methane, carbon dioxide, ammonium, nitrites, nitrates, phosphates and sulfates) through microbial activity. The formation of these compounds is often associated with the release of hydrogen ions (Hz), contributing to a decrease in soil pH (Boyd, 2000), Naik and Babu (2007), Sharma *et al.* (2009), Ram *et al*., (2007), Singh (2007), Atom (2013) and Sahu (2014) who reported the beneficial effects of organic manures in guava cultivation.

Electrical conductivity (dSm^{-1})

The main effect of organic manures combined with fertilizers studied significant influence on soil electrical conductivity among the guava varieties. The lowest electrical conductivity was consistently recorded in V_2 – Lalit, with values of 0.42 and 0.43 dSm^{-1} during 2023–24 and 2024–25 and a pooled mean of 0.43 dSm^{-1}. Conversely, the highest values were noted in V_3 – Lucknow-49, averaging 0.44 dSm^{-1}, which was statistically at par with V_1 – Shweta (0.43, 0.44 and 0.44 dSm^{-1} across both years and pooled mean). Among the nutrient treatments, N_2 (100% RDF) resulted in the highest electrical conductivity, with readings of 0.45, 0.46 and 0.46 dSm^{-1} for 2023–24, 2024–25 and the pooled data, respectively. This was closely followed by N_3 (100% RDF + CU @ 2 lit plant^{-1}) and N_4 (75% RDF + CU @ 4

Table 3: Main effect on response of organic manure with fertilizers on soil parameters of guava orchard.

TREATMENTS		Available nitrogen (kg ha^{-1})			Available phosphorus (kg ha^{-1})			Available potash (kg ha^{-1})		
VARIETIES		**2023**	**2024**	**MEAN**	**2023**	**2024**	**MEAN**	**2023**	**2024**	**MEAN**
V_1	SHWETA	231.44^{b}	231.89^{b}	231.66^{b}	15.18^{b}	15.20^{b}	15.19^{b}	380.20^{b}	380.95^{b}	380.57^{b}
V_2	LALIT	232.85^{a}	233.56^{a}	233.20^{a}	15.61^{a}	15.63^{a}	15.62^{a}	383.72^{a}	385.22^{a}	384.47^{a}
V_3	LUCKNOW-49 (L-49)	229.10^{c}	229.55^{c}	229.32^{c}	14.75^{c}	14.76^{c}	14.76^{c}	376.83^{c}	378.20^{c}	377.52^{c}
SE(m) ±		**0.166**	**0.237**	**0.159**	**0.005**	**0.005**	**0.004**	**0.185**	**0.310**	**0.172**
C.D. (0.005)		**0.474**	**0.676**	**0.453**	**0.015**	**0.014**	**0.012**	**0.528**	**0.886**	**0.491**
NUTRIENTS MANAGEMENT PRACTICES										
N_1	CONTROL	201.80^{f}	200.32^{g}	201.06^{f}	14.02^{h}	14.04^{h}	14.03^{h}	342.43^{g}	343.76^{g}	343.10^{g}
N_2	100%RDF	232.26^{e}	232.92^{f}	232.59^{e}	14.62^{g}	14.64^{g}	14.63^{g}	371.52^{f}	372.63^{f}	372.07^{f}
N_3	100%RDF+CU@2lit	236.09^{b}	237.12^{b}	236.61^{b}	15.63^{b}	15.66^{b}	15.64^{b}	390.05^{b}	391.27^{b}	390.66^{b}
N_4	75% RDF+CU @4lit	237.95^{a}	239.18^{a}	238.57^{a}	16.00^{a}	16.02^{a}	16.01^{a}	393.64^{a}	394.97^{a}	394.31^{a}
N_5	100%RDF+CDS@2lit	235.13^{c}	235.82^{cde}	235.47^{cd}	15.34^{d}	15.36^{d}	15.35^{d}	386.73^{c}	387.96^{c}	387.35^{c}
N_6	75% RDF+CDS @4lit	236.24^{b}	236.90^{bc}	236.57^{b}	15.58^{c}	15.60^{c}	15.59^{c}	389.86^{b}	391.09^{b}	390.48^{b}
N_7	100%RDF+VW@2lit	234.29^{d}	235.15^{e}	234.72^{d}	14.99^{f}	15.01^{f}	15.00^{f}	382.46^{e}	383.57^{e}	383.01^{e}
N_8	75% RDF+VW@4lit	235.24^{c}	235.91^{cd}	235.58^{c}	15.24^{e}	15.26^{e}	15.25^{e}	385.31^{d}	386.42^{d}	385.86^{d}
SE(m) ±		**0.271**	**0.387**	**0.259**	**0.009**	**0.008**	**0.007**	**0.302**	**0.507**	**0.281**
C.D. (0.005)		**0.774**	**1.104**	**0.740**	**0.025**	**0.023**	**0.020**	**0.862**	**1.447**	**0.802**

lit plant^{-1}), both showing values of 0.44, 0.45 and 0.45 dSm^{-1}. The lowest conductivity was observed in the control treatment N_1, with consistent values of 0.41 dSm^{-1} across both years and pooled mean.

The interaction effect between integrated nutrient management and guava varieties had a significant influence on soil electrical conductivity (dSm^{-1}). The highest electrical conductivity values were recorded in the combination V_3N_2 (Lucknow-49 + 100% RDF), with values of 0.46, 0.47 and 0.47 dSm^{-1} in 2023–24, 2024–25 and the pooled mean, respectively. This was statistically at par with combinations V_1N_2 (Shweta + 100% RDF) at 0.45, 0.46 and 0.46 dSm^{-1}, V_3N_3 (Lucknow-49 + 100% RDF + CU @ 2 lit plant^{-1}) at 0.45, 0.46 and 0.46 dSm^{-1} and V_3N_4 (Lucknow-49 + 75% RDF + CU @ 4 lit plant^{-1}) at 0.45, 0.45 and 0.45 dSm^{-1}.

In contrast, the lowest electrical conductivity value of 0.41 dS m^{-1} was observed in the control treatments across all varieties: V_1N_1 (Shweta + Control), V_2N_1 (Lalit + Control) and V_3N_1 (Lucknow-49 + Control). It is noteworthy that there remains a lack of well-established scientific literature directly correlating specific fertilization packages with variations in soil electrical conductivity, indicating the need for further research in this domain. Naik and Babu (2007), Sharma *et al.*, (2009), Ram *et al.* (2007), Singh (2007), Atom (2013) and Sahu (2014) who also reported the beneficial effects of organic in guava cultivation.

Available nitrogen (kg ha^{-1})

A significant influence of organic manures in combination with fertilizers was observed on soil nitrogen

Table 4: Interaction effect on response of organic manures with fertilizers on soil parameters of guava orchard.

T	TN	S			EC		
		2023	**2024**	**MEAN**	**2023**	**2024**	**MEAN**
T_0	V_1N_1	8.13^{ij}	8.13^{j}	8.13^{k}	0.41^{e}	0.41^{f}	0.41^{f}
T_1	V_1N_2	8.23^{ab}	8.25^{a}	8.24^{ab}	0.45^{ab}	0.46^{ab}	0.46^{ab}
T_2	V_1N_3	8.22^{bc}	8.22^{bc}	8.22^{bcd}	0.44^{bc}	0.45^{bc}	0.45^{bc}
T_3	V_1N_4	8.20^{cd}	8.20^{cde}	8.20^{cdef}	0.44^{bc}	0.45^{bc}	0.45^{bc}
T_4	V_1N_5	8.16^{fgh}	8.17^{fgh}	8.17^{ghi}	0.42^{de}	0.43^{de}	0.43^{de}
T_5	V_1N_6	8.15^{ghi}	8.16^{ghi}	8.16^{hij}	0.42^{de}	0.43^{de}	0.43^{de}
T_6	V_1N_7	8.19^{de}	8.19^{ef}	8.19^{efg}	0.43^{cd}	0.44^{cd}	0.44^{cd}
T_7	V_1N_8	8.17^{efg}	8.18^{efg}	8.18^{fgh}	0.43^{cd}	0.44^{cd}	0.44^{cd}
T_8	V_2N_1	8.13^{ij}	8.13^{j}	8.13^{k}	0.41^{e}	0.41^{f}	0.41^{f}
T_9	V_2N_2	8.22^{bc}	8.23^{ab}	8.23^{abc}	0.44^{bc}	0.45^{bc}	0.45^{bc}
T_{10}	V_2N_3	8.19^{de}	8.22^{bc}	8.21^{cde}	0.43^{cd}	0.44^{cd}	0.44^{cd}
T_{11}	V_2N_4	8.18^{def}	8.20^{cde}	8.19^{efg}	0.43^{cd}	0.44^{cd}	0.44^{cd}
T_{12}	V_2N_5	8.15^{ghi}	8.16^{ghi}	8.16^{hij}	0.41^{e}	0.42^{ef}	0.42^{ef}
T_{13}	V_2N_6	8.14^{hij}	8.15^{hij}	8.15^{ijk}	0.41^{e}	0.42^{ef}	0.42^{ef}
T_{14}	V_2N_7	8.17^{efg}	8.19^{ef}	8.19^{efg}	0.42^{de}	0.43^{de}	0.43^{de}
T_{15}	V_2N_8	8.16^{fgh}	8.17^{fgh}	8.17^{ghi}	0.42^{de}	0.43^{de}	0.43^{de}
T_{16}	V_3N_1	8.13^{ij}	8.13^{j}	8.13^{k}	0.41^{e}	0.41^{f}	0.41^{f}
T_{17}	V_3N_2	8.25^{a}	8.25^{a}	8.25^{a}	0.46^{a}	0.47^{a}	0.47^{a}
T_{18}	V_3N_3	8.22^{bc}	8.23^{ab}	8.23^{abc}	0.45^{ab}	0.46^{ab}	0.46^{ab}
T_{19}	V_3N_4	8.20^{cd}	8.21^{bcd}	8.21^{cde}	0.45^{ab}	0.45^{bc}	0.45^{bc}
T_{20}	V_3N_5	8.17^{efg}	8.18^{efg}	8.18^{fgh}	0.43^{cd}	0.43^{de}	0.43^{de}
T_{21}	V_3N_6	8.16^{fgh}	8.17^{fgh}	8.17^{ghi}	0.43^{cd}	0.43^{de}	0.43^{de}
T_{22}	V_3N_7	8.19^{de}	8.20^{cde}	8.20^{cdef}	0.44^{bc}	0.45^{bc}	0.45^{bc}
T_{23}	V_3N_8	8.18^{def}	8.19^{ef}	8.19^{efg}	0.44^{bc}	0.44^{cd}	0.44^{cd}
SE(m) ±		**0.004**	**0.006**	**0.005**	**0.002**	**0.002**	**0.002**
C.D. (0.005)		**0.011**	**0.017**	**0.015**	**0.007**	**0.006**	**0.006**

T: Treatments; **TN:** Treatment Notations; **S:** Soil pH; **EC:** Electrical conductivity (dS m^{-1})

Table 5: Interaction effect on response of organic manures with fertilizers on soil parameters of guava orchard.

T	TN	Available nitrogen (kg ha^{-1})			Available phosphorus (kg ha^{-1})			Available potash (kg ha^{-1})		
		2023	**2024**	**MEAN**	**2023**	**2024**	**MEAN**	**2023**	**2024**	**MEAN**
T_0	V_1N_1	201.39^{v}	200.05^{uv}	200.72^{v}	14.03^{p}	14.07^{o}	14.06^{p}	342.51^{t}	343.51^{t}	343.01^{u}
T_1	V_1N_2	232.82^{opqr}	$233.48^{lmnopqr}$	233.15^{opqrs}	14.73^{m}	14.75^{l}	14.74^{m}	371.30^{q}	371.97^{r}	371.64^{r}
T_2	V_1N_3	236.87^{de}	237.87^{cde}	237.37^{de}	15.51^{f}	15.53^{f}	15.52^{f}	389.17^{efg}	389.83^{defg}	389.50^{efg}
T_3	V_1N_4	238.66^{bc}	239.33^{bc}	238.99^{bc}	15.95^{c}	15.98^{c}	15.96^{c}	392.43^{c}	393.10^{c}	392.76^{c}
T_4	V_1N_5	235.27^{fghijk}	235.94^{fghijk}	235.61^{ghijk}	15.43^{h}	15.44^{g}	15.43^{g}	387.49^{hi}	388.15^{ghl}	387.82^{hi}
T_5	V_1N_6	236.49^{defg}	237.15^{defgh}	236.82^{efgh}	15.49^{fg}	15.53^{f}	15.51^{f}	390.41^{d}	391.41^{d}	390.91^{d}
T_6	V_1N_7	234.51^{ijklm}	235.17^{ijklm}	234.84^{jklm}	15.09^{k}	15.10^{j}	15.10^{k}	382.79^{mn}	383.45^{nop}	383.12^{no}
T_7	V_1N_8	235.49^{fghij}	236.16^{efghij}	235.83^{fghij}	15.19^{j}	15.21^{i}	15.20^{j}	385.51^{jk}	386.18^{ijklm}	385.84^{jkl}
T_8	V_2N_1	203.41^{u}	201.41^{u}	202.41^{u}	14.34^{o}	14.36^{n}	14.37^{o}	346.06^{q}	347.40^{q}	346.73^{t}
T_9	V_2N_2	233.25^{lmnopq}	233.92^{lmnopq}	233.58^{lmnopq}	15.11^{k}	15.14^{j}	15.13^{k}	374.58^{p}	375.91^{q}	375.25^{q}
T_{10}	V_2N_3	238.94^{b}	240.27^{b}	239.60^{b}	16.16^{b}	16.18^{b}	16.17^{b}	395.53^{b}	397.20^{b}	396.36^{b}
T_{11}	V_2N_4	240.69^{a}	243.0^{a}	241.86^{a}	16.47^{a}	16.50^{a}	16.49^{a}	398.85^{a}	400.85^{a}	399.85^{a}
T_{12}	V_2N_5	236.53^{def}	237.20^{defg}	236.86^{defg}	15.45^{gh}	15.47^{g}	15.46^{g}	389.23^{ef}	390.90^{def}	390.07^{def}
T_{13}	V_2N_6	237.82^{bcd}	238.48^{bcd}	238.15^{cd}	15.82^{d}	15.85^{d}	15.83^{d}	392.65^{c}	393.98^{c}	393.32^{c}
T_{14}	V_2N_7	235.74^{efghi}	236.74^{defghi}	236.24^{efghi}	15.57^{e}	15.59^{e}	15.58^{e}	384.90^{l}	386.23^{ijkl}	385.57^{klm}
T_{15}	V_2N_8	236.42^{efgh}	237.42^{def}	236.92^{def}	15.93^{c}	15.96^{c}	15.94^{c}	387.98^{fgh}	389.31^{defgh}	388.65^{gh}
T_{16}	V_3N_1	200.62^{w}	199.49^{uv}	200.06^{v}	13.67^{q}	13.70^{p}	13.69^{q}	338.72^{u}	340.38^{u}	339.55^{v}
T_{17}	V_3N_2	230.71^{t}	231.37^{t}	231.04^{t}	14.02^{p}	14.03^{o}	14.03^{p}	368.67^{r}	370.00^{r}	369.33^{s}
T_{18}	V_3N_3	232.47^{pqrs}	$233.23^{nopqrst}$	232.85^{pqrs}	14.44^{n}	14.46^{m}	14.45^{n}	385.46^{jk}	386.79^{ijk}	386.13^{jk}
T_{19}	V_3N_4	234.52^{ijkl}	235.20^{ijkl}	234.86^{jkl}	14.77^{m}	14.78^{l}	14.78^{m}	389.65^{e}	390.98^{de}	390.32^{de}
T_{20}	V_3N_5	233.59^{lmnop}	234.32^{klmnop}	233.96^{lmno}	15.23^{j}	15.26^{h}	15.25^{i}	383.49^{lm}	384.82^{klmn}	384.15^{n}
T_{21}	V_3N_6	234.41^{ijklmn}	235.08^{ijklmn}	234.75^{jklmn}	15.57^{e}	15.59^{e}	15.58^{e}	386.54^{hij}	387.87^{hij}	387.20^{ij}
T_{22}	V_3N_7	232.63^{opqrs}	$233.53^{lmnopqr}$	233.08^{opqrs}	14.96^{l}	14.97^{k}	14.97^{l}	379.69^{o}	381.02^{p}	380.35^{p}
T_{23}	V_3N_8	233.83^{lmno}	234.16^{klmnop}	233.99^{lmno}	15.31^{i}	15.32^{h}	15.31^{h}	382.43^{mn}	383.76^{lmno}	383.10^{no}
SE(m) ±		**0.469**	**0.670**	**0.449**	**0.015**	**0.014**	**0.012**	**0.523**	**0.878**	**0.487**
C.D. (0.005)		**1.340**	**1.913**	**1.282**	**0.043**	**0.040**	**0.035**	**1.494**	**2.507**	**1.390**

T: Treatments; **TN:** Treatment Notations;

levels across different guava varieties. Among them, variety V_2 (Lalit) registered the highest available nitrogen, with values of 232.85 kg ha^{-1} in 2023–24, 233.56 kg ha^{-1} in 2024–25 and a pooled mean of 233.20 kg ha^{-1}. This was followed by V_1 (Shweta), which recorded 231.44, 231.89 and 231.66 kg ha^{-1}, respectively. The lowest nitrogen levels were recorded in V_3 (Lucknow-49) with values of 229.10, 229.55 and a mean of 229.32 kg ha^{-1}. As for the effect of nutrient combinations, the N_4 treatment (75% RDF + cow urine @ 4 litre plant^{-1}) resulted in the highest nitrogen availability, with 237.95 kg ha^{-1} in 2023–24, 239.18 kg ha^{-1} in 2024–25 and a mean of 238.57 kg/ha, followed by N_3 (100% RDF + CU @ 2 litres plant^{-1}) with 236.09, 237.12 and 236.61 kg ha^{-1}. on the other hand, the lowest nitrogen content was observed under the N_1 (Control) treatment, recording 201.80 kg ha^{-1} in 2023–24, 200.32 kg ha^{-1} in 2024–25 and a mean of 201.06 kg ha^{-1}.

The interaction between integrated nutrient management and guava varieties exhibited a significant influence on soil nitrogen availability. The treatment combination V_2N_4 (Lalit + 75% RDF + cow urine @ 4 litres plant^{-1}) resulted in the highest available nitrogen levels, with 240.69 kg ha^{-1} in 2023–24, 243.00 kg ha^{-1} in 2024–25 and a mean value of 241.86 kg ha^{-1}. This was closely followed by V_2N_3 (Lalit + 100% RDF + cow urine @ 2 litres plant^{-1}), which recorded 238.94, 240.27 and 239.60 kg ha^{-1}, respectively. In contrast, the lowest nitrogen content was observed in the V_3N_1 treatment (Lucknow-49 + Control), with values of 200.62 kg ha^{-1} in 2023–24, 199.49 kg ha^{-1} in 2024–25 and a mean of 200.06 kg ha^{-1}.

The enhanced nitrogen availability in treatments incorporating cow urine alongside inorganic fertilizers can be attributed to the high nitrogen content of organic materials such as cow dung and vermiwash. These organic amendments stimulate microbial activity, particularly nitrogen-fixing microorganisms, thereby accelerating organic matter decomposition and improving nitrogen mineralization

Available phosphorus (kg ha^{-1})

Among the guava varieties assessed, V_2 – Lalit recorded the significantly highest levels of available phosphorus, with 15.61 kg ha^{-1} in 2023–24, 15.63 kg ha^{-1} in 2024–25 and a mean value of 15.62 kg ha^{-1}. This was followed by V_1 – Shweta, which recorded 15.18, 15.20 and 15.19 kg ha^{-1}, respectively. In contrast, the lowest phosphorus availability was found in V_3 – Lucknow-49, with 14.75 kg ha^{-1}, 14.76 kg ha^{-1} and a mean of 14.76 kg ha^{-1}.

The impact of different nutrient combinations on phosphorus availability was also significant. The treatment N_4 (75% RDF + cow urine@ 4 litres plant^{-1}) resulted in the highest available phosphorus, with 16.00 kg ha^{-1} in 2023–24, 16.02 kg ha^{-1} in 2024–25 and a mean value of 16.01 kg ha^{-1}. This was followed by N_3 (100% RDF + cow urine @ 2 litres plant^{-1}), which recorded 15.63, 15.66 and 15.64 kg ha^{-1}, respectively. Conversely, the lowest phosphorus levels were observed under the N_1 (Control) treatment, with 14.02 kg ha^{-1}, 14.04 kg ha^{-1} and a mean of 14.03 kg ha^{-1}.

A significant interaction effect was observed between integrated nutrient management and guava varieties on available phosphorus content. The highest phosphorus availability was found in treatment T_{11} the combination V_2N_6 (Lalit + 75% RDF + cow urine @ 4 litres plant^{-1}), which recorded 16.47 kg ha^{-1} in 2023–24, 16.50 kg ha^{-1} in 2024–25 and a mean value of 16.49 kg ha^{-1}. This was followed by the treatment T_{10} (V_2N_3), which recorded 16.16, 16.18 and 16.17 kg ha^{-1}, respectively. On the other hand, the lowest phosphorus availability was observed in V_3N_1 (Lucknow-49 + Control), with 13.67 kg ha^{-1}, 13.70 kg ha^{-1} and a mean of 13.69 kg ha^{-1}.

The observed increase in available phosphorus in the soil can be attributed to the production of organic acids from the application of phosphate-solubilizing bacteria (PSB). These acids act as chelating agents, helping to release phosphorus into the soil solution by breaking down insoluble phosphorus compounds, thus making it more available to plants. Moreover, biofertilizers, such as PSB, are known to mobilize adsorbed and insoluble phosphorus precipitates in the soil through a combination of cellular activity and biochemical processes (Boyd, 2000).

Available potassium (kg ha^{-1})

The combined application of organic manures and fertilizers had a significant impact on available potassium in the soil after harvest across the different guava varieties. Among the varieties, V_2 – Lalit recorded the highest available potassium, with values of 383.72 kg ha^{-1} in 2023–24, 385.22 kg ha^{1} in 2024–25 and a mean of 384.47 kg ha^{-1}, followed by V_1-Shweta, which recorded 380.20, 380.95 and 380.57 kg ha^{-1}. In contrast, the lowest potassium availability was observed in V_3 – Lucknow-49, with 376.83 kg ha^{-1}, 378.20 kg ha^{-1} and mean of 377.52 kg ha^{-1} during the same period. In terms of nutrient combinations, the N_4 treatment (75% RDF + cow urine @ 4 litres plant^{-1}) resulted in the highest available potassium, with values of 393.64 kg ha^{-1} in 2023–24, 394.97 kg ha^{-1} in 2024–25 and a mean of 394.31 kg ha^{-1}, followed by N_3 (100% RDF + cow urine @ 2lit plant^{-1}), which recorded 390.05, 391.27 and 390.66 kg ha^{-1}. On the other hand, the lowest potassium availability was found in the N_1 (Control) treatment, with values of 342.43 kg ha^{1}, 343.76 kg ha^{-1} and a mean of 343.10 kg ha^{-1} across both years.

The interaction effect of integrated nutrient management and guava varieties indeed showed a significant influence on the availability of potassium (K) in the soil after harvest. The highest available potassium was recorded in the T_{11} treatment combination V_2N_4 (Lalit + 75% RDF + cow urine @ 4 litres plant^{-1}), with values of 398.85 kg ha^{-1} (2023–24), 400.85 kg ha^{-1} (2024–25) and a pooled mean of 399.85 kg ha^{-1}, followed by T_{10} (V_2N_3) with 395.53 kg ha^{-1}, 397.20 kg ha^{-1} and 396.36 kg ha^{1}. In contrast, the lowest available potassium was observed in V_3N_1 (Lucknow-49 + Control), with values of 338.72 kg ha^{-1}, 340.38 kg ha^{--1} and a pooled mean of 339.55 kg ha^{--1}. The enhanced availability of potassium in the soil can be attributed to the combined application of inorganic fertilizers and cow urine. Cow urine not only provides essential nutrients but also plays a significant role in improving the overall nutrient dynamics of the soil. As cowdung is naturally rich in potassium, its application directly increases the potassium content in the soil. Additionally, the incorporation of organic manures, such as cow urine, increases the concentration of hydrogen (Hz) ions in the soil, which improves the cation exchange capacity (CEC) of soil colloids. This enhancement of CEC enables the greater retention and availability of potassium ions (Kz) in the soil, making it more accessible to plants (Boyd, 2000).

Conclusion

The soil analysis the interaction effects further underscored this finding; with combinations such as T_{11} (V2N4) (Lalit variety, combination of 75 % RDF + Cow urine @4lit plant^{-1}) achieving the highest values favourable soil nutrient profiles, including the highest levels of available nitrogen (241.86 kg ha^{-1}), phosphorus (16.49 kg ha^{-1}) and potassium (399.85 kg ha^{-1}), alongside relatively lower soil pH and electrical conductivity, which are beneficial for sustained soil fertility. Overall, the integration of Lalit variety with balanced nutrient management offers the most promising strategy for maintaining soil health and fertility in guava orchards.

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