International Journal of Economic Plants

https://ojs.pphouse.org/index.php/IJEP

Crossref

IJEP September 2026, 13(5): 01-08

Article IJEP7217b

Research Article

Natural Resource Management

Doi: HTTPS://DOI.ORG/10.23910/2/2026.7217b

Influence of Integrated Nutrient Management on Soil Nutrient Status and Economics of Guava Cultivation

Mohit Pal and V. K. Tripathi*

Dept. of Fruit Science, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, U.P. (208 002), India

Corresponding Author

V. K. Tripathi
e-mail: drvktripathicsa@gmail.com

Article History

Received on 23rd May, 2026
Received in revised form on 03rd August, 2026
Accepted in final form on 18th August, 2026
Published on 26th August, 2026

Abstract

The present investigation was conducted during June to February for two consecutive years i.e., 2024–25 and 2025–26, in the Department of Fruit Science, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, to evaluate the influence of integrated nutrient management (INM) on soil nutrient status and economics of guava (*Psidium guajava* L.) cv. L-49. Ten treatments comprising vermicompost, dry leaf or paddy straw mulch, Panchagavya, Jivamrit, Amritpani, Azotobacter, and phosphate-solubilizing bacteria (PSB) were evaluated in a randomized block design with three replications. Treatment T_9-Vermicompost (1.0 kg tree^{-1})+dry leaf mulch+Panchagavya (5%)+PSB (50 g tree^{-1})+Azotobacter (50 g tree^{-1}) recorded the highest available phosphorus (41.54 kg ha^{-1}), bacterial population (7.61×10^6 CFU g^{-1}), and fungal population (5.72×10^4 CFU g^{-1} soil). fruit yield (13.83 and 15.22 t ha^{-1}), gross returns (₹ 276,642 and ₹ 417,124 ha^{-1}) and net returns (₹ 164,104 and ₹ 304,586 ha^{-1}) during the first and second years, respectively. Treatment T_8 recorded the highest available potassium (215.27 kg ha^{-1}), T_3 recorded the highest soil pH (7.33) and organic matter (1.11%), whereas T_2 recorded the highest available nitrogen (207.00 kg ha^{-1}). The highest benefit: cost ratio was obtained with T_{10}-Vermicompost (1.0 kg tree^{-1})+paddy straw mulch+Jivamrit (20%)+PSB (50 g tree^{-1})+Azotobacter (50 g tree^{-1}) (1.57 and 2.73). Correlation and principal component analyses confirmed the positive influence of integrated nutrient management on soil nutrient dynamics. Overall, integrated nutrient management proved effective in improving soil fertility, productivity and profitability of guava cultivation in the plains of north India.

Keywords: Guava, integrated nutrient management, economic, biofertilizers, soil fertility

1. Introduction

Guava (*Psidium guajava* L.), a fruit of the family Myrtaceae, is one of the most important tropical and subtropical fruit crops owing to its remarkable adaptability, high productivity and exceptional nutritional value. This fruit is an excellent source of vitamin C, dietary fiber, pectin, minerals and antioxidant compounds such as lycopene and polyphenols, making it a valuable component of human nutrition and food security (Gupta et al., 2018). Besides its nutritional significance, guava contributes substantially to farmers' income due to its regular bearing habit, comparatively low production costs, and year-round market demand (Deep et al., 2025). However, sustaining high productivity and fruit quality under intensive cultivation has become increasingly challenging due to declining soil fertility, nutrient depletion and climate-induced stresses. The adoption of sustainable nutrient management practices has become imperative for maintaining soil productivity and ensuring profitable guava cultivation (Kumar et al., 2025). Balanced nutrient management is pivotal in perennial fruit crops, where long-term nutrient extraction often exceeds replenishment. Conventional production systems relying predominantly on chemical fertilizers have enhanced short-term productivity but have also contributed to deterioration of soil structure, depletion of soil organic matter, reduced microbial diversity, and nutrient imbalance, thereby lowering nutrient use efficiency (Xing et al., 2025; Maity et al., 2026). Integrated Nutrient Management (INM), which combines organic manures, biofertilizers, organic liquid formulations and mulching, has emerged as a sustainable strategy for restoring soil fertility while maintaining crop productivity. Such integrated approaches improve nutrient cycling, enhance biological activity, increase nutrient availability and reduce dependence on inorganic fertilizers (Tripathi et al., 2013; Tripathi et al., 2025). Among organic nutrient sources, vermicompost is recognized for its ability to improve soil aggregation, increase organic matter content, enhance nutrient mineralization and supply readily available macro- and micronutrients (Tripathi et al., 2025; Pratap and Tripathi, 2025). Biofertilizers such as *Azotobacter* and phosphate-solubilizing bacteria (PSB) further enhance soil fertility through biological nitrogen fixation, phosphate solubilization, production of phytohormones and stimulation of root proliferation, thereby improving nutrient uptake and crop performance (Anushi et al., 2025). Traditional organic formulations, including Panchagavya, Jivamrit and Amritpani, have attracted considerable attention because of their rich microbial populations, enzymes, growth-promoting substances, and essential nutrients that stimulate microbial activity, improve nutrient availability, and promote plant growth (Chouhan and Tripathi, 2024). Likewise, organic mulches such as dry leaves and paddy straw conserve soil moisture, moderate soil temperature, suppress weed growth and gradually contribute organic matter upon decomposition, thereby improving soil pH, organic matter, available nitrogen, phosphorus, potassium and micronutrient availability, including bacterial and fungal (Tyagi and Singh, 2025). In particular, studies that simultaneously evaluate post-harvest soil pH, organic matter, available nitrogen, phosphorus, potassium, bacteria and fungi, together with fruit yield, cost of cultivation, gross returns, net returns, and benefit-cost ratio are scarce under Indian agro-climatic conditions (Dwivedi, 2013). Furthermore, a comparative evaluation of different combinations of organic nutrient sources and beneficial microorganisms is essential to identify economically viable nutrient management strategies that enhance soil fertility while sustaining orchard productivity. Addressing this knowledge gap is critical to developing environmentally sustainable, resource-efficient production systems for perennial fruit crops. Therefore, the present investigation was undertaken to evaluate the influence of ten integrated nutrient management treatments involving vermicompost, dry leaf mulch, paddy straw mulch, Panchagavya, Jivamrit, Amritpani, *Azotobacter*, phosphate-solubilizing bacteria (PSB) and their various combinations on soil pH, organic matter, available nitrogen, phosphorus, potassium and microbial population following harvest. In addition, the study assessed their effects on fruit yield, cultivation cost, gross returns, net benefit, and benefit-cost ratio to identify an integrated nutrient management strategy capable of improving soil health and enhancing the economic sustainability of guava cultivation.

2. Materials and Methods

The present investigation was conducted during June to February for two consecutive years i.e., 2024–25 and 2025–26, at Kalyanpur Nursery, Department of Fruit Science, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, Uttar Pradesh, India. The experimental site was situated in the subtropical region between 25.26°–26.58° N latitude and 79.31°- 80.34° E longitude at an altitude of 135 m above mean sea level. The experiment was carried out on healthy and uniform guava (*Psidium guajava* L.) cv. L-49 plants were maintained under recommended orchard management practices. The experiment consisted of 10 integrated nutrient management (INM) treatments, laid out in a Randomized Block Design (RBD) with 3 replications. The treatments comprised: T_1-Control, T_2-Vermicompost (1.5 kg tree^{-1})+Mulching with dry leaves+Amritpani (20%)+Azotobacter (50 g tree^{-1}), T_3-Vermicompost (1.0 kg tree^{-1})+Mulching with dry leaves+Panchagavya (5%)+Azotobacter (50 g tree^{-1}), T_4-Vermicompost (1.0 kg tree^{-1})+Mulching with paddy straw+Jivamrit (20%)+Azotobacter (50 g tree^{-1}), T_5-Vermicompost (1.5 kg tree^{-1})+Mulching with dry leaves+Amritpani (20%)+PSB culture (50 g tree^{-1}), T_6-Vermicompost (1.0 kg tree^{-1})+Mulching with dry leaves+Panchagavya (5%)+PSB culture (50 g tree^{-1}), T_7-Vermicompost (1.0 kg tree^{-1})+Mulching with paddy straw+Jivamrit (20%)+PSB culture (50 g tree^{-1}), T_8-Vermicompost (1.5 kg tree^{-1})+Mulching with dry leaves+Amritpani (20%)+PSB culture (50 g tree^{-1})+Azotobacter (50 g tree^{-1}), T_9-Vermicompost (1.0 kg tree^{-1})+Mulching with dry leaves+Panchagavya (5%)+PSB culture (50 g tree^{-1})+ Azotobacter (50 g tree^{-1}) and T_{10}-Vermicompost (1.0 kg tree^{-1})+Mulching with paddy straw+Jivamrit (20%)+PSB culture (50 g tree^{-1})+Azotobacter (50 g tree^{-1}). Vermicompost and biofertilizers were uniformly applied to the root zone of each plant according to the respective treatment combinations and incorporated into the soil. Organic mulching materials (dry leaves and paddy straw) were spread uniformly around the basin of each tree to conserve soil moisture and suppress weed growth. Panchagavya (5%) was applied as a foliar spray, whereas Amritpani (20%) and Jivamrit (20%) were applied as soil drenches before flowering and again during the fruit-setting stage using a pneumatic foot sprayer during the morning hours. Following the fruit harvest, soil samples were collected from the active root zone of each treatment for chemical analysis. The samples were air-dried, ground gently, passed through a 2 mm sieve, and analyzed according to standard analytical procedures. Soil pH was determined using a digital pH meter in a soil–water suspension (1:2.5), while Walkley and Black wet oxidation method was used to estimate the organic matter content. Available nitrogen was determined by the alkaline permanganate method, available phosphorus by the Olsen extraction method, and available potassium using a flame photometer after neutral normal ammonium acetate extraction. Soil microbial populations were estimated using the serial dilution and spread plate technique. Bacterial counts were determined on Nutrient Agar Medium (NAM) following incubation at 28±2°C for 24–48 h, while fungal populations were enumerated on Potato Dextrose Agar (PDA) after incubation at 25±2°C for 5–7 days. Colony-forming units (CFU) were expressed as CFU g^{-1} soil following the procedure described by Aneja (2003). Fruit yield was recorded at harvest by weighing the total fruits harvested from each tree using a digital balance and expressed as tonnes per hectare (t ha^{-1}). Economic analysis was conducted by estimating the cultivation costs for each treatment, including expenditures on inputs and field operations. Gross returns were calculated based on the prevailing market price of guava fruits, while net benefit was obtained by subtracting the cost of cultivation from the gross returns. The benefit-to-cost (B: C) ratio was computed by dividing gross returns by total cultivation costs. The experimental data were subjected to analysis of variance (ANOVA) appropriate for a Randomized Block Design following the procedure described by Panse and Sukhatme (1985). Treatment means were compared using Duncan's Multiple Range Test (DMRT) at the 5% probability level ($p \leq 0.05$). Pearson's correlation analysis was performed to assess relationships among soil properties and economic parameters, and Principal Component Analysis (PCA) was conducted to identify the major variables contributing to treatment variation. All statistical analyses were performed using RStudio (Version 2026.04.0).

3. Results and Discussion

Integrated nutrient management treatments significantly influenced soil pH (Table 1). The highest soil pH (7.33) was recorded in T_3-Vermicompost (1.0 kg $tree^{-1}$)+dry leaf mulch+Panchagavya (5%)+*Azotobacter*, which was statistically at par with T_5 (7.13), T_7 (7.06) and T_4 (7.05), whereas the lowest pH (6.40) was observed in the control (T_1). Overall, integrated nutrient management treatments shifted soil reaction towards near-neutral conditions compared with the untreated control. The increase in soil pH under integrated nutrient management might be attributed to the combined application of vermicompost, biofertilizers and organic formulations, which improved soil buffering capacity. Decomposition of vermicompost released basic cations (Ca^{2+}, Mg^{2+} and K^{+}) that neutralized soil acidity, while humic substances enhanced cation exchange capacity and stabilized soil reaction. Panchagavya and *Azotobacter* stimulated microbial activity, accelerating organic matter decomposition and nutrient cycling. In addition, dry leaf mulch conserved soil moisture and reduced nutrient losses, creating favourable conditions for microbial processes (Mesfin et al., 2023)

Organic matter content differed significantly among treatments. The highest organic matter (1.11%) was recorded in T_3, followed by T_2 (1.03%), T_9 (0.98%) and T_{10} (0.92%), whereas the lowest value (0.66%) was observed in T_5, which was statistically similar to T_4 (0.67%) and T_7 (0.68%). The higher organic matter content under T_3 was attributed to the continuous addition of vermicompost, dry leaf mulch and Panchagavya, which supplied organic residues for microbial decomposition and humus formation. Enhanced microbial activity promoted by Panchagavya and *Azotobacter* accelerated the conversion of organic residues into stable soil organic matter, while mulching reduced oxidation losses by conserving soil moisture and moderating soil temperature. Consequently, a greater accumulation of soil organic matter.

Available nitrogen varied significantly among treatments. The highest nitrogen content (207.00 kg ha^{-1}) was recorded in T_2, followed by T_3 (201.50 kg ha^{-1}) and T_5 (196.00 kg ha^{-1}), whereas the lowest value (176.50 kg ha^{-1}) was observed in T_9. The control recorded 188.00 kg ha^{-1} available nitrogen. The superior nitrogen status under T_2 was primarily due to the synergistic action of vermicompost, *Azotobacter*, Amritpani

Table 1: Influence of different integrated nutrient management treatments on soil nutrient content (Pooled over two years)

Treatment	Soil pH	Organic matter (%)	Available nitrogen (kg ha^{-1})	Available phosphorus (kg ha^{-1})	Available potassium (kg ha^{-1})	Bacterial population (CFU g^{-1} soil)	Fungal population (CFU g^{-1} soil)
T_1	6.40±0.21^{f}	0.88±0.03^{e}	188.00±3.19^{de}	29.02±0.83^{e}	149.35±1.92^{g}	4.34±0.15^{i}	2.58±0.06^{j}
T_2	6.74±0.24^{de}	1.03±0.02^{b}	207.00±0.68^{a}	37.20±0.22^{b}	155.94±3.47^{g}	5.23±0.05^{g}	3.20±0.06^{h}
T_3	7.33±0.14^{a}	1.11±0.02^{a}	201.50±1.41^{ab}	34.20±0.48^{cd}	200.73±5.88^{bc}	4.86±0.05^{h}	2.87±0.03^{i}
T_4	7.05±0.21^{abc}	0.67±0.02^{g}	190.00±1.75^{cd}	40.48±0.62^{a}	174.62±4.23^{f}	5.88±0.10^{f}	3.97±0.09^{f}
T_5	7.13±0.04^{ab}	0.66±0.03^{g}	196.00±2.21^{bc}	33.41±1.98^{cd}	170.39±2.68^{f}	5.39±0.08^{g}	3.57±0.05g
T_6	6.42±0.18^{f}	0.72±0.02^{f}	190.50±5.32^{cd}	34.90±0.33^{c}	204.61±5.61^{b}	6.50±0.18^{d}	4.67±0.14^{d}
T_7	7.06±0.09^{abc}	0.68±0.00^{g}	181.50±7.93^{ef}	32.56±1.18^{d}	186.52±4.62^{e}	6.16±0.21^{e}	4.30±0.09^{e}
T_8	6.53±0.14^{ef}	0.84±0.01^{e}	188.50±5.58^{cde}	37.18±1.08^{b}	215.27±3.88^{a}	6.86±0.21^{c}	4.99±0.12^{c}
T_9	6.89±0.15^{bcd}	0.98±0.03^{c}	176.50±3.17^{f}	41.54±1.82^{a}	190.82±3.81^{de}	7.61±0.14^{a}	5.72±0.14^{a}
T_{10}	6.83±0.05^{cd}	0.92±0.01^{d}	181.50±4.67^{ef}	30.32±0.79^{e}	196.00±3.02^{cd}	7.26±0.06^{b}	5.36±0.05^{b}
Grand mean	6.84	0.85	190.1	35.08	184.43	6.01	4.12
SEm±	0.09	0.01	2.42	0.65	2.41	0.08	0.06
CD (p=0.05)	0.27	0.04	7.19	1.92	7.15	0.24	0.16

and dry leaf mulch. *Azotobacter* contributed biologically fixed atmospheric nitrogen and synthesized growth-promoting substances that stimulated root proliferation and microbial activity. Vermicompost acted as a slow-release nutrient source while improving soil structure and microbial habitat. Amritpani provided readily available carbon and beneficial microorganisms that accelerated mineralization of organic nitrogen into plant-available forms. Dry leaf mulch conserved soil moisture and reduced nitrogen losses from volatilization and runoff. These findings were consistent with microbial mineralization and biological nitrogen fixation, in which increased microbial activity enhanced nitrogen transformation and availability. Comparable results have been reported by Bahuguna et al. (2021) and Lazcano and Domínguez (2022).

Significant differences were observed in available phosphorus. The highest phosphorus content was recorded in T_9 (41.54 kg ha^{-1}), which was statistically equivalent to T_4 (40.48 kg ha^{-1}), while the lowest was recorded in the control (29.02 kg ha^{-1}). The higher available phosphorus under T_9 was attributed to the combined application of PSB, *Azotobacter*, Panchagavya and vermicompost. Phosphate-solubilizing bacteria enhanced phosphorus availability by secreting organic acids that solubilized insoluble phosphates, whereas vermicompost released humic substances that reduced phosphorus fixation. Panchagavya stimulated microbial activity, and mulching maintained favourable soil moisture for microbial processes, collectively improving phosphorus availability. Similar improvements in available phosphorus under integrated nutrient management have been reported by Ghosh et al. (2021).

Available potassium was significantly influenced by integrated nutrient management treatments. The highest potassium content (215.27 kg ha^{-1}) was recorded in T_8, followed by T_6 (204.61 kg ha^{-1}) and T_3 (200.73 kg ha^{-1}), whereas the lowest value (149.35 kg ha^{-1}) was observed in the control. The substantial increase in potassium under T_8 was due to the integrated application of vermicompost, PSB, Azotobacter, Amritpani, and dry leaf mulch. Vermicompost contained appreciable quantities of exchangeable potassium that were gradually released during decomposition. Organic acids generated during microbial degradation reduced potassium fixation by clay minerals and facilitated the release of non-exchangeable potassium into the soil solution. Mulching enhanced moisture retention, thereby promoting weathering of potassium-bearing minerals and microbial activity. These results supported the potassium release hypothesis, which stated that organic matter decomposition and microbial metabolites enhance potassium desorption and mineral weathering. Similar observations have been reported by Li et al. (2026).

3.7.1. Bacterial population (CFU g^{-1} soil)

The pooled analysis over two years revealed a significant effect of integrated nutrient management (INM) treatments on soil bacterial population (Table 1). The highest bacterial population was recorded in T_9-Vermicompost (1.0 kg tree^{-1})+Dry leaf mulch+Panchagavya (5%)+PSB (50 g tree^{-1})+Azotobacter (50 g tree^{-1}) with 7.61×10^6 CFU g^{-1} soil, which was significantly superior to all other treatments. It was followed by T_{10} (7.26×10^6 CFU g^{-1} soil) and T_8 (6.86×10^6 CFU g^{-1} soil), whereas the lowest bacterial population (4.34×10^6 CFU g^{-1} soil) was observed in the control (T_1). The grand mean bacterial population was 6.01×10^6 CFU g^{-1} soil. The increased bacterial population under integrated treatments might be attributed to the combined effects of vermicompost, biofertilizers, organic liquid formulations, and mulches, which supplied organic substrates, improved nutrient availability, and created favourable rhizosphere conditions for microbial growth. Similar findings have been reported under integrated nutrient management by Mushtaq et al. (2021), Zainuddin et al. (2022), Ruparelia et al. (2022), Anushi et al. (2024), and Sonkar et al. (2025). These amendments supplied essential nutrients and organic substrates that stimulated bacterial proliferation by creating a favourable rhizosphere environment. Enhanced microbial activity improved nutrient cycling, soil fertility, and plant growth, highlighting the importance of integrating organic amendments and beneficial microorganisms to sustain soil biological health and agricultural productivity.

3.7.2. Fungal population (CFU g^{-1} soil)

Integrated nutrient management treatments significantly affected soil fungal populations (Table 1). The maximum fungal population (5.72×10^4 CFU g^{-1} soil) was recorded in T_9, followed by T_{10} (5.36×10^4 CFU g^{-1} soil) and T_8 (4.99×10^4 CFU g^{-1} soil), while the minimum (2.58×10^4 CFU g^{-1} soil) was recorded in the control (T_1). The pooled mean fungal population was 4.12×10^4 CFU g^{-1} soil. The higher fungal population under integrated treatments was likely due to continuous organic matter addition via vermicompost and mulches, coupled with beneficial microorganisms in biofertilizers and organic formulations, which enhanced microbial proliferation and nutrient mineralization. These results indicated that integrated nutrient management improved soil biological health by stimulating fungal activity (Anushi et al., 2024; Devi et al., 2020).

The correlation coefficients among soil physico-chemical properties, available nutrients and microbial populations were presented in Figure 1. Soil pH exhibited weak positive correlations with organic matter(r=0.069), available nitrogen (r=0.165), available phosphorus (r=0.167) and available potassium (r=0.040). In contrast, weak negative correlations were observed with bacterial population (r=-0.113) and fungal population (r=-0.145). Organic matter showed positive associations with available nitrogen (r=0.287), available phosphorus (r=0.047) and available potassium (r=0.036), whereas slight negative correlations were recorded with bacterial (r=-0.090) and fungal populations (r=-0.136). Available nitrogen was negatively correlated with available potassium (r=-0.304), bacterial population (r=-0.682) and

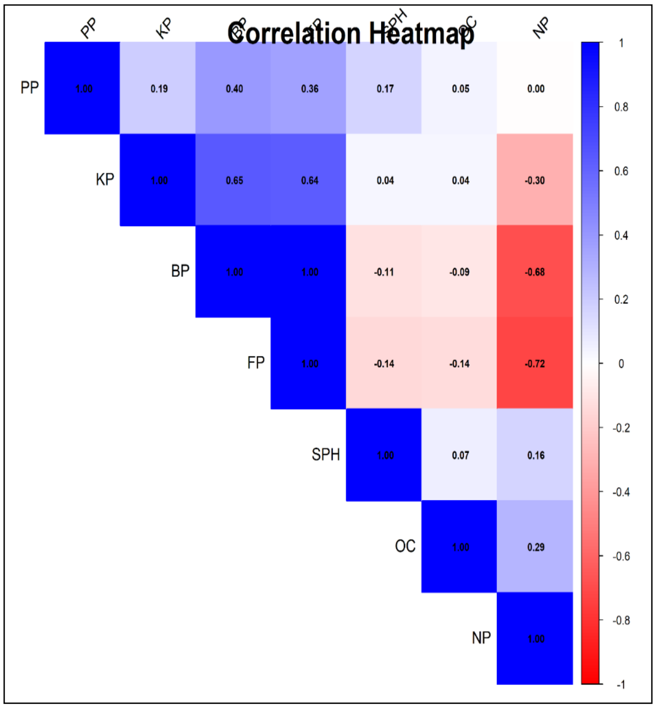

Figure 1: Correlation coefficients among soil physio-chemical properties and available nutrients

fungal population (r=-0.721), while its relationship with available phosphorus was negligible (r=-0.001). Available phosphorus showed positive correlations with available potassium (r=0.191), bacterial population (r=0.397) and fungal population (r=0.364). Likewise, available potassium was strongly and positively associated with bacterial (r=0.647) and fungal populations (r=0.638). The strongest positive correlation was observed between bacterial and fungal populations (r=0.997), indicating a close association between the two microbial groups under integrated nutrient management. The correlation analysis demonstrated that integrated nutrient management enhanced soil biological activity and nutrient dynamics through interconnected microbial processes. The weak positive association between soil pH and major nutrients suggests that maintaining a near-neutral soil reaction creates favourable conditions for nutrient availability and microbial function. The positive relationship between organic matter and available nitrogen indicated that incorporating vermicompost and organic amendments promoted microbial decomposition of organic residues and gradual nutrient mineralization. The positive correlations among available phosphorus, potassium, bacterial, and fungal populations suggest that enhanced microbial activity facilitated phosphorus solubilization, potassium mobilization, and nutrient cycling in the rhizosphere. Similarly, the strong positive association between available potassium and bacterial and fungal populations indicated that organic matter decomposition and microbial metabolites accelerated the release of exchangeable potassium from soil minerals. The nearly perfect positive correlation between bacterial and fungal populations (r=0.997) reflected the synergistic response of soil microorganisms to integrated application of vermicompost, biofertilizers, organic liquid formulations and mulching, which collectively created a favourable environment for microbial proliferation and improved soil fertility. These findings were consistent with reports that integrated nutrient management enhanced microbial abundance and nutrient transformation, thereby improving soil health and nutrient availability (Bahuguna et al., 2021; Mesfin et al., 2023; Sonkar et al., 2025).

Principal Component Analysis (PCA) was performed to elucidate relationships among soil physicochemical properties, available nutrients, and integrated nutrient management (INM) treatments (Figures 2 and 3). The first two principal components (PC1 and PC2) explained 64.7% of

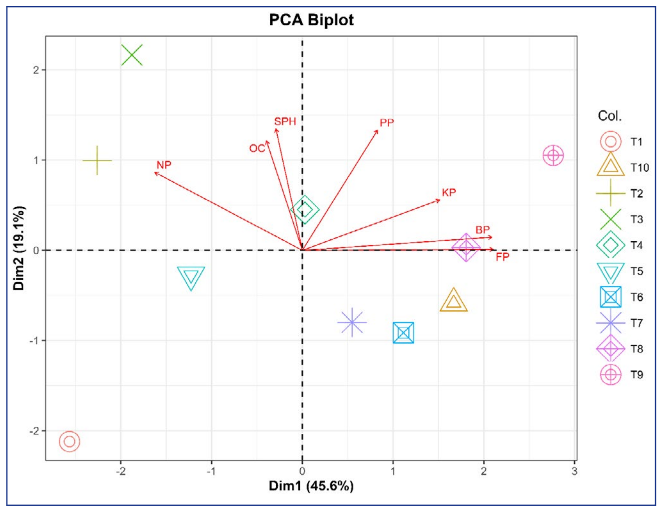

Figure 2: Principal component analysis (PCA) biplot showing the relationship between integrated nutrient management treatments and soil properties (Soil pH, organic matter, available nitrogen, available phosphorus, available potassium, and bacterial and fungus population)

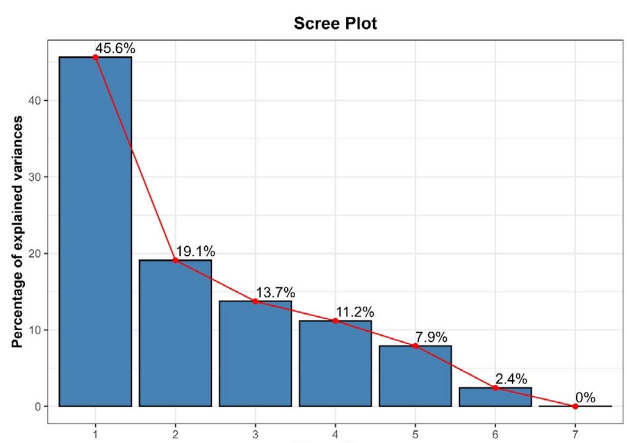

Figure 3: Scree plot showing the percentage of variance explained by each principal component

the total variation, with PC1 accounting for 45.6% and PC2 contributing 19.1%. The scree plot showed a sharp decline in the percentage of explained variance after PC2, suggesting that these two components adequately accounted for the variability among treatments. The PCA biplot revealed distinct clustering of the treatments according to their influence on soil properties. Treatments T_8-Vermicompost (1.5 kg tree^{-1}) +Dry leaf mulch+Amritpani (20%)+PSB+*Azotobacter* and T_9-Vermicompost (1.0 kg tree^{-1})+Dry leaf mulch+Panchagavya (5%)+PSB+*Azotobacter* were positioned in the positive quadrant of PC1 and showed close association with available potassium, boron and iron, indicating their superior performance in improving these nutrients. Treatment T_4-Vermicompost+Paddy straw mulch+Jivamrit+*Azotobacter* was closely associated with available phosphorus, whereas T_2 and T_3, containing *Azotobacter* with Amritpani or Panchagavya, were associated with available nitrogen, organic matter and soil pH. In contrast, the control (T_1) was located away from the nutrient vectors, indicating comparatively low soil fertility. The PCA demonstrated that integrated nutrient management effectively improved soil nutrient dynamics. Treatments T_8 and T_9 were closely associated with available potassium, bacteria, and fungi, indicating enhanced nutrient mineralization and micronutrient mobilization through the combined application of vermicompost, biofertilizers, and organic formulations. Treatments T_2 and T_3 were associated with soil pH, organic matter, and available nitrogen, reflecting improved biological nitrogen fixation and nutrient cycling, while T_4 was closely associated with available phosphorus, indicating enhanced phosphorus solubilization. The clear separation of the control from nutrient vectors confirmed the superiority of integrated nutrient management in improving soil fertility and overall soil health.

Integrated nutrient management treatments markedly influenced fruit yield and economic returns (Table 2). Fruit yield increased progressively under integrated nutrient management compared with the control during both years of study. The highest yield was recorded in T_9-Vermicompost (1.0 kg tree^{-1})+Dry leaf mulch+Panchagavya (5%)+PSB (50 g tree^{-1})+*Azotobacter* (50 g tree^{-1}) with 13.83 and 15.22 t ha^{-1} during Year 1 and Year 2, respectively, followed by T_{10} (13.38 and 14.46 t ha^{-1}) and T_8 (12.96 and 14.15 t ha^{-1}), whereas the lowest yield was recorded in the control (9.17 and 9.74 t ha^{-1}).

The cost of cultivation ranged from ₹ 85,000.00 ha^{-1} in the control (T_1) to ₹ 112,538.00 ha^{-1} in T_9, reflecting the additional expenditure incurred through the application of organic inputs, biofertilizers, and mulching materials. Despite higher cultivation costs, integrated nutrient management treatments generated substantially greater economic returns than the control. The maximum gross returns were obtained under T_9 (₹ 414,963.00 and ₹ 456,516.00 ha^{-1} during Year 1 and Year 2, respectively), followed by T_{10} (₹ 401,274.00 and ₹ 433,917.00 ha^{-1}) and T_8 (₹ 388,800.00 and ₹ 424,602.00 ha^{-1}). Similarly, the highest net benefit during Year 1 was recorded in T_9 (₹ 302,425.00 ha^{-1}), followed by T_{10} (₹ 297,076.00 ha^{-1}) and T_8 (₹ 282,934.00 ha^{-1}). During Year 2, T_9 again produced the maximum net benefit (₹ 343,978.00 ha^{-1}), followed by T_{10} (₹ 329,719.00 ha^{-1}) and T_8 (₹ 318,736.00 ha^{-1}). The benefit: cost ratio also improved considerably under integrated nutrient management treatments. During Year 1, the highest B: C ratio was recorded in T_{10} (2.85), followed by T_9 and T_7/T_8 (2.69 and 2.67, respectively). During Year 2, T_{10} again recorded the highest B: C ratio (3.16), followed by T_9 (3.06) and T_8 (3.01). The lowest B: C ratio was observed under T_3 (1.77 and 2.00 in Years 1 and 2, respectively), while the control treatment (T_1) recorded B: C ratios of 2.24 and 2.44. The superior yields and economic returns obtained under T_9 and T_{10} were attributed to the synergistic effects of vermicompost, biofertilizers (Azotobacter and PSB), organic formulations, and mulching, which enhanced soil fertility, nutrient availability, and

Table 2: Influence of different integrated nutrient management treatments on fruit yield and economics of guava cultivation

Treat-ment	Yield (t h^{-1})		Cost of cultivation (₹ ha^{-1})		Gross returns (₹ ha^{-1})		Net benefit (₹ ha^{-1})		B: C ratio	
	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2
T_1	9.17	9.74	85000.00	85000.00	275238.00	292185.88	190238.00	207185.88	2.24	2.44
T_2	9.78	10.39	103364.00	103364.00	293463.00	311584.55	190099.00	208220.55	1.84	2.01
T_3	10.16	10.99	110036.00	110036.00	304722.00	329614.30	194686.00	219578.30	1.77	2.00
T_4	10.44	11.12	101696.00	101696.00	313308.00	333558.00	211612.00	231862.00	2.08	2.28
T_5	11.72	12.67	103086.00	103086.00	351702.00	380052.00	248616.00	276966.00	2.41	2.69
T_6	11.97	12.37	109758.00	109758.00	359073.00	371223.00	249315.00	261465.00	2.27	2.38
T_7	12.41	13.46	101418.00	101418.00	372438.00	403947.00	271020.00	302529.00	2.67	2.98
T_8	12.96	14.15	105866.00	105866.00	388800.00	424602.00	282934.00	318736.00	2.67	3.01
T_9	13.83	15.22	112538.00	112538.00	414963.00	456516.00	302425.00	343978.00	2.69	3.06
T_{10}	13.38	14.46	104198.00	104198.00	401274.00	433917.00	297076.00	329719.00	2.85	3.16

nutrient use efficiency. Vermicompost improved soil physical properties, while biofertilizers promoted biological nitrogen fixation and phosphorus solubilization. Organic formulations stimulated microbial activity and nutrient mineralization, whereas mulching conserved soil moisture and reduced nutrient losses, thereby increasing productivity. Although cultivation costs increased, the substantially greater fruit yield resulted in higher gross returns, net benefits, and B: C ratio, confirming the economic advantage of integrated nutrient management in guava cultivation (Tripathi, 2024; Anushi and Tripathi, 2024; Sonkar and Tripathi, 2025, Sau et al., 2017).

4. Conclusion

Integrated nutrient management significantly improved soil fertility, nutrient availability, and economic returns in guava cultivation. The combined application of vermicompost, biofertilizers, organic liquid formulations, and mulching enhanced soil organic matter, available nitrogen, phosphorus, potassium, and microbial populations while maintaining favourable soil pH. Treatments T_9 and T_{10} produced higher fruit yield, gross returns, net returns, and benefit: cost ratio. Correlation and principal component analyses confirmed the synergistic effects of integrated nutrient management on soil fertility and productivity.

5. Acknowledgement

The authors gratefully acknowledge the Department of Fruit Science, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, Uttar Pradesh, India, for providing the necessary field, laboratory, and technical facilities to conduct this research. The authors also thank the staff of the department for their assistance during the experimental period. No external financial support or research grant was received for this study.

6. References

Aneja, K.R., 2003. Experiments in Microbiology and Plant Pathology. New Age International Pvt. Ltd., New Delhi. Available from: https://books.google.com.np/books?id=QYI4xk9kOIMC&printsec=frontcover#v=onepage&q&f=false.

Anushi, Tripathi, V.K., 2024. Impact of bio–fertilizer and organic mulch on the economics of cultivation of strawberry cv. Katrain Sweet. Plant Archives 24(2), 1867–1873. DOI: doi. 10.51470/PLANTARCHIVES.2024.v24.no.2.267.

Anushi, Tripathi, V.K., Kumar, S., Tripathi, R., Singh, A., 2025. Impact of bio–stimulants and organic mulch on vegetative growth, flowering and yield of strawberry cv. Katrain Sweet. SSRN Preprint. DOI: https://doi.org/10.2139/ssrn.5240635.

Bahuguna, A., Sharma, S., Yadav, J. 2021. Effect of different organic sources on physical, chemical and biological properties of soil in inceptisols of Varanasi. International Journal of Plant and Soil Sceince 33, 41–52. DOI: 10.9734/IJPSS/2021/v33i530436.

Chouhan, N.K., Tripathi, V.K., 2024. Influence of bio–enhancers and bio–fertilizers on growth and yield of winter season guava cv. L–49. Indian Journal of Horticulture 81(4), 405–411. DOI: 10.58993/ijh/2024.81.4.10.

Deep, P., Meher, B., Yadav, A., Sen, I., Mannepalli, B.K., Kamalvanshi, V., Kushwaha, S., 2025. Economic analysis and profitability of guava (*Psidium guajava* L.) cultivation in the alluvial plains of Prayagraj district, Uttar Pradesh, India. Journal of Scientific Research and Reports 31(11), 196–205. DOI: https://doi.org/10.9734/jsrr/2025/v31i113660.

Devi, R., Kaur, T., Kour, D., Rana, K.L., Yadav, A., Yadav, A.N., 2020. Beneficial fungal communities from different habitats and their roles in plant growth promotion and soil health. Microbial Biosystems 5(1), 21–47. DOI: 10.21608/mb.2020.32802.1016.

Dwivedi, V., 2013. Effect of integrated nutrient management on yield, quality and economics of guava. Annals of Plant and Soil Research 15(2), 149–151. Available from: https://gkvsociety.com/control/uploads/Effect–of–integrated–nutrient–management–on–yield–quality–and–economics–of–guava.pdf.

Ghosh, D., Mandal, M., Pattanayak, S.K., 2021. Long–term effect of integrated nutrient management on dynamics of phosphorous in an acid inceptisols of tropical India. Communications in Soil Science and Plant Analysis 52(19), 2289–2303. DOI: https://doi.org/10.1080/00103624.2021.1924186.

Gupta, M., Wali, A., Gupta, S.A., Annepu, S.K., 2018. Nutraceutical potential of guava. In: Bioactive Molecules in Food. Springer, 1–27p. DOI: https://doi.org/10.1007/978–3–319–54528–8_85–1.

Kumar, V., Tripathi, V.K., Gupta, S., 2025. Influence of integrated nutrient management on growth and flowering of winter season guava (*Psidium guajava*). Plant Archives 25(1), 2203–2208. DOI: https://doi.org/10.51470/PLANTARCHIVES.2025.v25.no.1.319.

Lazcano, C., Domínguez, J., 2011. The use of vermicompost in sustainable agriculture: Impact on plant growth and soil fertility. In: Miransari, M. (Ed.), Soil Nutrients. Nova Science Publishers, 1–23p. Available from: https://www.researchgate.net/publication/255687441_The_use_of_vermicompost_in_sustainable_agriculture_impact_on_plant_growth_and_soil_fertility.

Li, X., Cao, J., Li, D., Jin, K., Liu, Y., Li, W., 2026. Effects of different mulching practices on soil properties and soil microbial communities in tomato production. Frontiers in Microbiology 16, 1734062. DOI: https://doi.org/10.3389/fmicb.2025.1734062.

Maity, S., Bera, M., Chatterjee, G., Tripathi, S., 2026. Natural and organic input–based integrated nutrient management in agriculture: A 20–year systematic review on crop yield, soil health, carbon sequestration, and energy efficiency.

International Journal of Plant Production 20(3), 62. DOI: https://doi.org/10.1007/s42106–026–00444–9.

Mesfin, G., Zewide, I., Jembere, A., 2023. Physicochemical characterization of vermicompost and its effect on acidic soils in Ethiopia. The Scientific Temper 14(1), 37–49. DOI: https://doi.org/10.58414/SCIENTIFICTEMPER.2023.14.1.06.

Mushtaq, Z., Faizan, S., Hussain, A., 2021. Role of microorganisms as biofertilizers. In: Microbiota and Biofertilizers: A Sustainable Continuum for Plant and Soil Health, 83–98p. Available from: https://www.researchgate.net/publication/347400884_role_of_microorganisms_as_biofertilizers.

Panse, V.G., Sukhatme, P.V., 1985. Statistical methods for agricultural workers. Indian Council of Agricultural Research, New Delhi, 381. DOI: doi/full/10.5555/19561604178.

Pratap, R., Tripathi, V.K., 2025. Influence of vermicompost and biofertilizers on vegetative growth and yield of dragon fruit. Journal of Advances in Biology and Biotechnology 28(4), 318–326. DOI: https://doi.org/10.9734/jabb/2025/v28i42191.

Ruparelia, J., Rabari, A., Mitra, D., Panneerselvam, P., Das Mohapatra, P.K., Jha, C.K., 2022. Efficient applications of bacterial secondary metabolites for management of biotic stress in plants. Plant Stress 6, 100125. DOI: https://doi.org/10.1016/j.stress.2022.100125.

Sau, S., Mandal, P., Sarkar, T., Das, K., Datta, P., 2017. Influence of bio–fertilizer and liquid organic manures on growth, fruit quality and leaf mineral content of mango cv. Himsagar. Journal of Crop and Weed 13(1), 132–136. Available from: https://cwss.in/Journal/Complete_jurnal/Vol.13–No.1__26.pdf.

Sonkar, S., Tripathi, V.K., 2025. Economic analysis of organic strawberry production influenced by biofertilizers and biostimulants application. International Journal of Plant and Soil Science 37(3), 207–214. DOI: https://doi.org/10.9734/ijpss/2025/v37i35360.

Sonkar, S., Tripathi, V.K., Kumar, A., Kumar, A., Upadhyay, U., 2025. Effect of bio–enhancers and bio–fertilizer on soil parameters and microbial population. Plant Archives 25(1), 944–948. DOI: https://doi.org/10.51470/PLANTARCHIVES.2025.v25.no.1.142.

Tripathi, M.K., Shukla, S.K., Jaiswal, V.P., Sharma, L., Nagargade, M., Pathak, A.D., Ranka, A., 2025. Integration of mycorrhizae, *Azotobacter* and *Pseudomonas* spp. (PSB) with NPK and their effects on sugarcane crop and soil health in Uttar Pradesh, India. Sugar Tech 27(2), 340–356. DOI: https://doi.org/10.1007/s12355–024–01513–x.

Tripathi, V.K., Kumar, S., Gupta, A.K., 2015. Influence of Azotobacter and vermicompost on growth, flowering, yield and quality of strawberry cv. Chandler. Indian Journal of Horticulture 72(2), 201–205. DOI: 10.5958/0974–0112.2015.00039.0.

Tripathi, V.K., Kumar, S., Katiyar, P.N., Nayyer, M.A., 2013. Integrated nutrient management in Isabgol (*Plantago ovata* Forsk.). Progressive Horticulture 45(2), 302–305. Available from: https://indianjournals.com/article/pho–45–2–012.

Tripathi, V.K., Shukla, P., Anushi, 2024. Influence of biostimulants and organic mulch on soil microbial population in strawberry (*Fragaria×ananassa* Duch.). Biochemical and Cellular Archives 24(2), 2551–2555. DOI: https://doi.org/10.51470/bca.2024.24.2.2551.

Tyagi, K., Singh, Y., 2025. Effect of nitrogen and paddy straw application on soil properties of barley (*Hordeum vulgare* L.) crop under rainfed conditions. The Journal of Rural and Agricultural Research 25(1), 74–77. Available from: https://jraragra.in/Journals/2025Vol1/12.pdf.

Xing, Y., Wang, X., Mustafa, A., 2025. Exploring the link between soil health and crop productivity. Ecotoxicology and Environmental Safety 289, 117703. DOI: https://doi.org/10.1016/j.ecoenv.2025.117703.

Zainuddin, N., Keni, M.F., Ibrahim, S.A.S., Masri, M.M.M., 2022. Effect of integrated biofertilizers with chemical fertilizers on the oil palm growth and soil microbial diversity. Biocatalysis and Agricultural Biotechnology 39, 102237. Doi: 10.1016/j.bcab.2021.102237.