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Integrated nutrient management practices in *Mrig bahar* crop of guava under high density plantation

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Abstract
The research on the impact of integrated nutrient management practices on the cultivation and fruit quality of mrig-bahar guava crop (*Psidium guajava* L.) in high-density plantations was conducted in 2022-23 on 5-year-old guava plants (cv. L-49) at the experimental farm of the Department of Fruit Science, College of Horticulture and Forestry, Neri, Hamirpur (HP). The study included five treatments that combined the use of vermicompost and inorganic fertilizers with biofertilizers. Throughout the study, it was observed that the vegetative growth parameters, flowering and fruiting parameters, yield, as well as the leaf and soil nutrient status, were significantly improved with the integrated nutrient management practices compared to the control. The greatest enhancements in plant height, tree spread, fruit set, fruit retention, and yield were achieved with the application of 80% RDF + 4 kg vermicompost + NBF consortium. The biochemical quality parameters such as TSS, pectin content, total sugars, reducing sugars, and non-reducing sugars showed significant improvements with the application of 60% RDF + 8 kg vermicompost + NBF consortium. The highest levels of soil nitrogen (281.00 kg ha^{-1}), phosphorus (21.50 kg ha^{-1}), and potassium content (258.88 kg ha^{-1}) were obtained with the application of 80% RDF + 4 kg vermicompost + NBF consortium, while the total culturable count was highest in the rhizosphere of plants treated with 20% RDF + 15 kg vermicompost + NBF consortium.

Keywords: Nutrient management practices, *Mrig bahar* crop, guava under, density plantatio

Introduction
The guava fruit, scientifically known as *Psidium guajava* L., belongs to the Myrtaceae family. It is commonly referred to as the "poor man's apple" or the "apple of tropics" due to its nutritional value, which is comparable to commercially important temperate fruits like apples (Khan *et al*., 2013) [7]. This fruit crop is highly valued in tropical and subtropical regions for its exquisite taste and nutritional benefits. Guava is rich in pectin, thiamine, riboflavin, vitamin C, vitamin E, and small amounts of vitamin A and B, as well as carbohydrates, oils, and protein. India holds the title of being the largest producer of guava worldwide, followed by China and Kenya. In India, guava cultivation covers an area of 3,07,000 hectares, with a production of 45.16 lakh tons. Guava has three distinct flowering seasons in tropical climates, known as ambe-bahar, mrig-bahar, and hast-bahar, which correspond to February-March, June-July, and October-November, respectively. The harvesting seasons for guava are in July-August, November-December, and March-April, respectively. However, in North India, there are only two flowering seasons, ambe-bahar and mrig-bahar, with fruits being harvested during the rainy and winter seasons, respectively. The rainy season crop of guava is generally of lower quality due to an insipid taste and severe infestation by fruit flies. The mrig-bahar crop, obtained during the winter season, is preferred as it is of better quality and less prone to fruit fly infestation. To ensure proper growth and development, guava plants require adequate nutrients, which are primarily supplied through inorganic fertilizers. However, the indiscriminate use of chemical fertilizers in horticultural crops has had negative impacts on soil fertility, biodiversity, groundwater, and human health over the past few decades. Since guava fruits are mostly consumed fresh, it is crucial for them to be free from chemical residues. Therefore, it is essential to find economically attractive and potential sources of plant nutrients in balanced proportions to maintain fertility and productivity.

The integrated nutrient management (INM) system is designed to enhance soil fertility and increase crop productivity sustainably. It involves a combination of inorganic fertilizers, organic manure, and biofertilizers tailored to the specific needs of the farming system, ecological factors, and economic conditions. Vermicompost, produced by earthworms, is a nutrient-rich source containing growth hormones, enzymes, vitamins, and essential nutrients like nitrogen, phosphorous, potassium, and more. Biofertilizers, such as arbuscular mycorrhizae and Trichoderma viride, play a crucial role in providing primary nutrients to crops through symbiotic relationships with plant roots. The study aims to evaluate the impact of these practices on growth, yield, fruit quality, and soil properties.

Materials and Methods

The study was carried out in the year 2022-2023 at the experimental farm of the Department of Fruit Science, College of Horticulture and Forestry, Neri, Hamirpur, located at an elevation of 667 m above mean sea level. The experimental site is positioned at 31° 69’ 60” N latitude and 76° 48’ 80” E longitude, representing a sub-montane sub-tropical low hill agro-climatic zone. This zone experiences hot and dry summers along with cold winters, with the Southwest monsoon bringing the highest rainfall in July and August. The study utilized guava plants of the Lukhnow – 49 cultivar, aged five year and spaced at 2x2 m. To transition the crop to *mrig bahar*, the flowers of the *ambe-bahar* crop were pruned in the first week of May. The plants underwent stress for a month through restricted irrigation and nutrient application. The soil at the experimental farm is sandy loam with moderately high organic carbon content. The initial soil parameters including pH, electrical conductivity, organic carbon, extractable nitrogen, extractable phosphorous, and extractable potassium are detailed in table 1.

Table 1: Initial chemical properties of the soil of experimental farm

pH	6.91
EC	0.111 dS m^{-1}
Organic carbon	0.82%
Soil N	254.72 kg ha^{-1} (Low)
Soil P	16.776 kg ha^{-1} (Medium)
Soil K	234.33 kg ha^{-1} (Medium)

The experiment was laid in Randomized Block Design with five treatments, each replicated five times.

Table 2: Treatment Detail

	Treatments
T_1	80% RDF + Vermicompost @ 4 kg $plant^{-1}$ + NBF* consortium
T_2	60% RDF + Vermicompost @ 8 kg $plant^{-1}$ + NBF* consortium
T_3	40% RDF + Vermicompost @ 12 kg $plant^{-1}$ + NBF* consortium
T_4	20% RDF + Vermicompost @ 15 kg $plant^{-1}$ + NBF* consortium
T_5	Control: 100% RDF [25 kg FYM + 250 g N, 200 g P_2O_5, 450 g K_2O $plant^{-1}$]

***NBF consortium:** Neri Bio fertilizer consortium (Arbuscular Mycorrhiza @ 500 g $plant^{-1}$ + Phosphate solubilizing bacteria @ 100 g $plant^{-1}$ + *Trichoderma viride* @ 100 g $plant^{-1}$)

RDF (Recommended dose of fertilizers) for five-year-old guava plant: 25 kg FYM + 250 g N, 200 g P_2O_5, 450 g K_2O $plant^{-1}$ as per the package of practices of Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni.

Time of application of the treatments

The selected plants were treated with inorganic fertilizers, namely nitrogen, phosphorous, and potassium, in three separate doses. The first dose of inorganic fertilizers, along with organic sources and biofertilizers, was applied before flowering in the last week of June. The remaining two doses were applied during fruit setting and fruit development. Additionally, a control treatment involving soil application was also applied in three equal doses in June, August, and September.

Method of application of treatments

The inorganic fertilizers were applied as a basal application, thoroughly mixed with the soil and organic sources, and then covered with mulch. The biofertilizers were mixed with vermicompost and applied to the basin of the selected plants, along with 1/3rd of the inorganic fertilizers during the first application.

Observations and measurements

Growth, yield and fruit quality

To assess the impact of the treatments, observations were made on vegetative growth, flowering, and fruiting characteristics. The increase in plant height was measured by comparing the initial and final measurements using a measuring tape.

The tree spread was measured in two directions (North-South and East-West) before and after the treatments. The average tree spread was calculated using the formula: Average canopy spread = (N-S) + (E-W) / 2, where N-S represents the tree spread in the North-South direction and E-W represents the tree spread in the East-West direction.

A digital hand refractometer was employed to measure the total soluble solids (TSS). The estimation of acidity and sugars (non-reducing, reducing, and total) was conducted using the methodology outlined in Ranganna's publication from 1986. Subsequently, the data collected for various parameters were computed, tabulated, and analyzed using MS-Excel and a statistical package

Available soil and total leaf N, P and K

Soil and leaf analysis was done both before and end of the experiment.

Table 3: Methods followed for chemical analysis of soil

Sr. No.	Soil property	Method used	Reference
1	pH	Potentiometric	Jackson (1973) [6]
2	Electrical Conductivity (dSm^{-1})	Conductimetric	Jackson (1973) [6]
3	Organic Carbon (%)	Rapid Titration Method	Walkley and Black (1934) [16]
4	Available Nitrogen (kg ha^{-1})	Alkaline Potassium Permanganate Method	Subbiah and Asija (1956) [14]
5	Available Phosphorous (kg ha^{-1})	Olsen’s Method	Olsen *et al.* (1954) [10]
6	Available Potassium (kg ha^{-1})	Neutral 1 N Ammonium Acetate Method	Merwin and Peach (1951) [9]
7	Total Culturable Count (cfu g^{-1})	Serial Dilution Standard Spread Plate Technique	Subbarao (1999) [17]
8	Phosphorous Solubilizing Bacteria (cfu g^{-1})	Serial Dilution Standard Spread Plate Technique	Hu *et al.* (2006) [5]

The analysis of variance (ANOVA) procedure and Randomized Block Designs proposed by Gomez and Gomez (1984) [4] were used for analysis

Results and Discussion

The integrated nutrient management practices had a significant effect on the vegetative growth of *mrig-bahar* crop of guava. The highest increment in the plant height (74.00 cm) and tree spread in north south direction (89.40 cm) as well as in east west direction (91.70 cm) were recorded with the application of 80% RDF + 4 kg Vermicompost + NBF consortium. The shoot extension growth and increase in trunk girth were enhanced in all the treatments comprising the integrated nutrient application over control. maximum number of flowers per branch (10.20), highest fruit set (71.84%) and fruit retention (65.46%), maximum number of fruits per plant at harvest (41.40), highest yield (8.25 kg tree^{-1}) was recorded in the plants given the application of T_1 (80% RDF + 4 kg Vermicompost + NBF consortium) while the lowest of these were reported in T_5 (100% RDF). The treatments containing a combination of organic sources and inorganic fertilizers along with biofertilizers had significant effect on the vegetative growth of the plants. This effect may be attributed to the combined use of organic sources and inorganic fertilizers as well as biofertilizers in a balanced proportion which enhanced the mineral uptake by the plants. The vermicompost increase the carbon content in the soil which served as the food for microorganisms in the soil and the microorganisms in turn mineralized several complex nutrients in the soil (Vyas *et al*., 2022) [15]. Godage *et al*. (2013) [3] also recorded the highest increase in the vegetative growth of the guava plants with similar treatments. The results are also in accordance with Meena *et al*. (2014) [8] and Shukla *et al*. (2014) [13] as they also recorded maximum increase in the vegetative growth of guava plants with the combined application of NPK, vermicompost and biofertilizers as compared to other treatments.

The application of 80% RDF + 4 kg Vermicompost + NBF consortium resulted in the highest physical quality fruits, with a fruit length of 8.82 cm, fruit breadth of 8.80 cm, fruit weight of 199.40 g, and fruit volume of 194.40 cm3. Additionally, this treatment recorded the highest TSS (13.54º Brix), TSS: Acid ratio (35.91), total sugars, reducing and non-reducing sugars, and the lowest titratable acidity. The integrated use of organic and inorganic sources of nutrients, along with biofertilizers, significantly improved the physical quality parameters of guava fruits. These findings are consistent with the results obtained by Godage *et al*. (2013) [3], who also observed similar improvements in guava fruits with the application of specific nutrient combinations. The integrated nutrient management approach also led to significant improvements in the nutrient status of the soil, with maximum available nitrogen, phosphorous, and potassium content observed in the rhizospheres of plants treated with 80% RDF + 4 kg Vermicompost + NBF consortium. Similarly, the nutrient status of leaves was significantly improved with this treatment, recording the highest total leaf nitrogen, phosphorous, and potassium content. These results align with the findings of Sharma *et al*. (2013) [12] and Shukla *et al*. (2014) [13], who also observed improvements in soil nutrient content with specific nutrient management practices.

Table 4: Effect of integrated nutrient management practices on growth, flowering and yield of *mrig-bahar* crop of guava

Treatment	Tree Height (cm)	Shoot Extension Growth (cm)	Trunk Girth (cm)	Tree spread (cm)	Days from 1st flower to full bloom	Days from fruit set to maturity	No. of flowers per branch	Fruit Set (%)	Fruit retention (%)	Total no. of fruits	Yield (kg / tree)
T_1 (80% RDF + 4 kg Vermicompost + NBF consortium)	74.00	41.00	1.25	90.55	31.20	122.00	10.20	71.84	65.46	41.40	8.25
T_2 (60% RDF + 8 kg Vermicompost + NBF consortium)	70.30	37.20	1.20	85.20	31.70	124.70	9.60	70.25	62.10	38.20	7.39
T_3 (40% RDF + 12 kg Vermicompost + NBF consortium)	64.60	32.20	1.15	80.12	33.60	127.90	8.40	68.82	60.67	35.60	6.78
T_4 (20% RDF + 15 kg Vermicompost + NBF consortium)	61.70	29.20	1.09	74.25	35.10	130.00	7.60	67.86	59.02	34.60	6.53
T_5 (100% RDF)	56.40	28.00	1.05	63.05	36.20	131.00	7.40	66.29	54.07	31.50	5.87
CD $_{(0.05)}$	2.18	2.67	0.04	3.19	2.33	1.63	1.36	1.31	2.14	2.19	0.41

Table 5: Effect of integrated nutrient management practices on physico-chemical properties of fruits of *mrig-bahar* crop of guava

Treatment	Fruit length (cm)	Fruit width (cm)	Fruit wt. (g)	Fruit volume (cm^3)	Fruit firmness (kg)	TSS (ºBrix)	Titratable Acidity (%)	TSS: Acid Ratio	Ascorbic Acid (mg/100 g)	Reducing Sugars (%)	Non-Reducing Sugars (%)	Total Sugars (%)	Pectin Content (%)
T_1 (80% RDF + 4 kg Vermicompost + NBF consortium)	8.82	8.80	199.40	194.40	4.44	12.96	0.42	30.78	189.77	5.00	3.36	8.54	0.77
T_2 (60% RDF + 8 kg Vermicompost + NBF consortium)	8.32	8.22	193.35	189.65	4.48	13.54	0.38	35.91	188.29	5.34	3.64	9.17	0.78
T_3 (40% RDF + 12 kg Vermicompost + NBF consortium)	7.94	7.76	190.30	187.30	4.52	12.10	0.48	25.32	184.66	4.76	3.01	7.93	0.72
T_4 (20% RDF + 15 kg Vermicompost + NBF consortium)	7.58	7.46	188.85	183.80	4.57	11.60	0.53	21.82	187.73	4.52	2.83	7.50	0.69
T_5 (100% RDF)	7.30	7.16	186.25	180.70	4.93	10.74	0.59	18.17	189.09	4.05	2.66	6.85	0.68
CD $_{(0.05)}$	0.27	0.30	5.95	5.22	0.04	0.76	0.02	2.42	NS	0.18	0.28	0.29	0.02

Table 6: Effect of integrated nutrient management practices on soil properties of *mrig-bahar* crop of guava

Treatment	Soil pH	Soil Electrical Conductivity (dSm^{-1})	Soil Organic Carbon (%)	Soil N (kg/ha)	Soil P (kg/ha)	Soil K (kg/ha)	Leaf N (%)	Leaf P (%)	Leaf K (%)	Total Culturable Count (cfu g^{-1})	P Solubilizing Bacteria (cfu g^{-1})
T_1 (80% RDF + 4 kg Vermicompost + NBF consortium)	6.95	0.141	1.37	281.00	21.50	258.88	1.82	0.37	1.78	1.13×10^7	5.75×10^5
T_2 (60% RDF + 8 kg Vermicompost + NBF consortium)	6.97	0.138	1.39	275.28	20.30	255.62	1.79	0.35	1.72	1.17×10^7	6.05×10^5
T_3 (40% RDF + 12 kg Vermicompost + NBF consortium)	6.98	0.133	1.42	271.43	19.67	251.84	1.74	0.33	1.66	1.63×10^7	6.75×10^5
T_4 (20% RDF + 15 kg Vermicompost + NBF consortium)	6.99	0.129	1.47	267.81	19.59	249.30	1.72	0.32	1.64	2.03×10^7	7.25×10^5
T_5 (100% RDF)	6.93	0.144	1.28	260.44	18.46	244.69	1.70	0.27	1.57	1.01×10^7	3.35×10^5
CD $_{(0.05)}$	0.03	0.001	0.02	3.93	0.53	2.64	0.005	0.009	0.03	--	--

Conclusion

The results of the recent studies demonstrate that the joint use of organic fertilizers, vermicompost, and biofertilizers greatly enhanced vegetative growth, flowering, fruiting, yield, quality, soil NPK status, and benefit to cost ratio. The highest improvements were seen with T1 treatment (80% RDF + 4 kg Vermicompost + NBF consortium), with T_2 treatment (60% RDF + 8 kg Vermicompost + NBF consortium) showing comparable results in many growth and quality aspects.

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