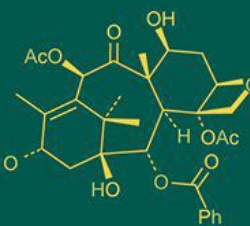
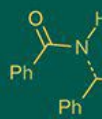
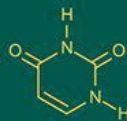


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Integrated nutrient management improves yield and fruit quality of banana (*Musa sp.*) cv. sabri in northern Tripura, India: yield gap analysis, technology development and adoption

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Abstract

Banana (*Musa* spp.) is one of the most important fruit crops cultivated in tropical regions and contributes significantly to the livelihood of farmers. However, productivity in many regions remains below the potential level due to imbalanced fertilization and poor nutrient management. The present study was conducted in Northern Tripura to evaluate integrated nutrient management (INM) practices for sustainable yield and fruit quality improvement in banana cv. Sabri along with yield gap analysis and impact assessment. The experiment was conducted in a Randomized Block Design with nine treatments and three replications. Among the treatments, T7 (FYM 10 kg + Vermicompost 2 kg + Biofertilizers + 75% NPK) recorded the highest pseudostem height (325.4 cm), number of fingers per bunch (152.4), bunch weight (18.25 kg) and fruit yield (33.20 t ha⁻¹). Demonstration yield was significantly higher compared to farmers' practice (20.40 t ha⁻¹). Yield gap analysis revealed an extension gap of 12.89 t ha⁻¹ and a technology index of 7.53 % and 53.57% of the farmers belonged to the high adoption category. Impact assessment showed significant improvement in productivity, profitability and adoption of improved nutrient management practices. The results indicate that integrated nutrient management is an effective strategy to enhance sustainable banana production in Northern Tripura.

Keywords: Banana, Integrated nutrient management, Yield gap analysis, Impact assessment, Sabri cultivar

Introduction

Banana (*Musa* spp.) is one of the most important fruit crops in tropical and subtropical regions and plays a key role in global food and nutritional security (Robinson and Galán-Saúco 2010; Dadzie and Orchard 1997) [35, 9]. It is cultivated in more than 130 countries over approximately 5 million hectares with an annual production exceeding 120 million tonnes (FAOSTAT 2023; Aurore *et al.* 2009). India is the world's largest producer of banana, contributing nearly one-fourth of global production and occupying a prominent position in the horticultural economy of the country (NHB 2022; Singh *et al.* 2018) [25, 45]. Banana cultivation also provides livelihood opportunities for millions of small and marginal farmers (Tripathi *et al.* 2012; Hazarika and Ansari 2010) [52, 13].

Banana is a highly nutrient-exhaustive crop requiring large quantities of macro- and micronutrients for optimum growth, biomass production, and fruit development (Lahav and Turner 1983; Robinson and Galán-Saúco 2010) [35]. Continuous cultivation without adequate nutrient replenishment leads to nutrient depletion, soil degradation, and declining productivity (Bharadwaj and Omanwar 1994; Roy *et al.* 2006) [5, 36]. In many banana-growing areas, excessive dependence on chemical fertilizers has resulted in reduced soil fertility, low nutrient use efficiency, and environmental concerns (Palm *et al.* 2001; Vanlauwe *et al.* 2010) [26, 53].

Integrated Nutrient Management (INM), which involves the combined use of organic manures, chemical fertilizers, and biofertilizers, has been widely recommended as a sustainable strategy to improve soil fertility and crop productivity (Roy *et al.* 2006; Kuttamani *et al.* 2013) [36, 20]. Organic inputs such as farmyard manure, compost, and vermicompost improve soil organic matter, structure, and microbial activity (Biswas *et al.* 2012; Chivenge *et al.* 2011) [6, 8], while biofertilizers such as *Azospirillum* and phosphate-solubilizing bacteria enhance nutrient availability and nutrient use efficiency (Subba Rao 2001; Vessey 2003) [50, 57].

Several studies have reported that integrated nutrient management significantly improves banana growth, yield, and fruit quality compared with the sole use of chemical fertilizers (Patil and Shinde 2013; Pattar *et al.* 2018) [27, 29]. The integration of organic and inorganic nutrient sources enhances bunch weight, fruit size, and quality parameters such as total soluble solids and pulp-to-peel ratio (Kuttamani *et al.* 2013; Chhuria 2016) [20, 7]. Moreover, integrated nutrient management improves soil microbial activity and nutrient cycling, thereby promoting sustainable crop production systems (Varatharajan *et al.* 2022; Wang *et al.* 2025) [54, 58].

In north-eastern India, particularly in Tripura, banana is an important horticultural crop cultivated under diverse agro-climatic conditions (Hazarika and Ansari 2010) [13]. The variety Sabri is particularly popular because of its high market demand and superior fruit quality. However, productivity in the region remains low due to several constraints such as:

- improper fertilization practices
- lack of scientific nutrient management

- poor sucker treatment
- disease incidence such as Fusarium wilt and Sigatoka leaf spot

To address these constraints, integrated nutrient management technologies were identified and refined through participatory approaches involving farmers and scientists. Therefore, the present study aimed to evaluate integrated nutrient management practices for banana cultivation in Northern Tripura along with yield gap analysis, technology development and impact assessment.

Materials and Methods

Experimental Location: The present study was conducted in farmers' fields of Northern Tripura under irrigated conditions. The experimental site is geographically located at 24.32° N latitude and 92.18° E longitude. The area falls under the humid tropical climatic zone of North-Eastern India. The region experiences a warm and humid climate with an annual rainfall ranging from 2000 to 2500 mm, most of which is received during the southwest monsoon period from June to September. The temperature generally ranges from 22 °C to 34 °C during the cropping season. The soils of the experimental fields are predominantly sandy loam to clay loam in texture, moderately fertile, slightly acidic in reaction, and suitable for the cultivation of various field and vegetable crops. Adequate irrigation facilities are available in the study area, which support crop production during dry spells and ensure proper crop growth and development.

Soil Characteristics: Soil Properties Before and After Experiment

Soil parameter	Before experiment	After experiment
Soil texture	Sandy loam	Sandy loam
Soil pH	5.5	5.8
Organic carbon (%)	0.68	0.74
Available Nitrogen (kg/ha)	280	305
Available Phosphorus (kg/ha)	22	27
Available Potassium (kg/ha)	190	210

Experimental Design: The experiment was conducted at the experimental farm of KVK North Tripura during 2013-14 and 2014-15 using a Randomized Block Design (RBD). A total of nine treatments were evaluated with three

replications. The crop was planted at a spacing of 2 m × 2 m to maintain uniform plant growth and proper field layout for the experiment. 2.4 Treatments.

Treatment	Nutrient composition
T1	Farmer practice (Control)
T2	FYM 10 kg/plant + Recommended NPK (460 g Urea + 310 g SSP + 625 g MOP)
T3	FYM 10 kg + Vermicompost 2 kg + 75% NPK
T4	FYM 10 kg + Azotobacter + PSB + 75% NPK
T5	FYM 10 kg + Neem cake 1 kg + 100% NPK
T6	FYM 10 kg + Poultry manure 3 kg + 75% NPK
T7	FYM 10 kg + Vermicompost 2 kg + Biofertilizers + 75% NPK
T8	FYM 10 kg + Green manure + 75% NPK
T9	FYM 10 kg + Micronutrient mixture + 100% NPK

Fertilizers were applied in three split doses at 3rd, 5th and 7th month after planting.



Fig 1 & 2: Assessment of Integrated Nutrient Management for Sustainable Yield and Fruit Quality Improvement in Banana



Sucker Treatment

Healthy and uniform banana suckers were selected for planting. Prior to planting, the suckers were subjected to different treatments to reduce the incidence of pests and diseases and to ensure better establishment in the field. The treatments included Neem formulation @ 5 ml per litre of water, Mancozeb (Dithane M-45) @ 2 g per litre of water, and cow dung slurry. These treatments were applied according to the treatment schedule of the experiment (Fig. 3).

The selected suckers were dipped in the respective treatment solutions for about 2 minutes to allow proper coverage and protection against soil-borne pathogens and pests. After dipping, the treated suckers were kept under shade and allowed to dry for 24 hours before planting. This process helped the treatment materials adhere properly to the suckers and reduced the chances of rotting after planting.

Observations Recorded: Observations related to growth parameters were recorded during the crop growth period. The important growth parameters included days to shooting, pseudostem height, and number of suckers per plant. These parameters helped in assessing the vegetative growth and development of banana plants under different sucker treatments. Yield parameters were also recorded at the time of harvest to evaluate the productivity of the crop. The parameters included number of hands per bunch, number of fingers per bunch, fruit weight, bunch weight, and total yield per hectare. These observations provided information about the effect of treatments on fruit development and overall yield performance. An economic analysis was carried out to determine the profitability of the different treatments. The analysis included calculation of gross cost of cultivation, gross return, net return, and benefit-cost (B: C) ratio. These

parameters helped in evaluating the economic feasibility and suitability of the treatments for adoption by farmers.

Yield Gap Analysis: Three levels of yield has been taken into consideration and documented:

- **Potential yield (YP):** yield under best-managed conditions for Sabri Banana
- **Demonstration yield (YD):** yield under OFT/FLD with recommended INM
- **Farmers' yield (YF):** yield under existing farmer practice

Standard indicators

- **Total yield gap** = $YP - YF$
- **Technology gap** = $YP - YD$
- **Extension gap** = $YD - YF$
- **Technology index (%)** = $\frac{(YP - YD)}{YP} \times 100$
- **Yield increase over farmer practice (%)** = $\frac{(YD - YF)}{YF} \times 100$

The adoption quotient (AQ):

$$AQ = \frac{\text{Score obtained}}{\text{Maximum obtainable score}} \times 100$$

Statistical Analysis (ANOVA): The experimental data were analyzed using Randomized Block Design (RBD) as described by Ronald A. Fisher. Analysis of variance (ANOVA) was performed to determine the significance of treatment effects on different growth and yield parameters of banana (*Musa sp.*) var. Sabri. The significance of differences among treatment means was tested using F-test at 5% level of probability. Standard error of mean (SEm) and Critical Difference (CD) were calculated.

Result and Discussion

Table 1: Effect of Integrated Nutrient Management on Growth Parameters of Banana

Treatment	Days to shooting	Pseudostem height (cm)	Girth of pseudostem (cm)	No. of leaves at shooting	No. of suckers
T1 Farmer practice	319.2	286.5	56.4	11.2	3.9
T2 FYM + 100% NPK	305.5	310.7	61.3	12.8	5.6
T3 FYM + VC + 75% NPK	301.4	314.6	62.5	13.1	5.9
T4 FYM + Biofertilizer + 75% NPK	298.8	318.4	63.0	13.4	6.1
T5 FYM + Neem cake + 100% NPK	300.7	316.2	62.1	13.0	5.8
T6 FYM + Poultry manure + 75% NPK	297.9	319.8	63.4	13.5	6.2
T7 FYM + Vermicompost + Biofertilizer + 75% NPK	292.6	325.4	65.2	14.1	6.8
T8 FYM + Green manure + 75% NPK	299.5	317.2	62.6	13.2	5.9
T9 FYM + Micronutrient + 100% NPK	296.7	320.3	63.9	13.6	6.3

Statistical values

Parameter	SEm	CD (5%)	CV (%)
Days to shooting	2.15	6.42	3.2
Pseudostem height	4.30	12.84	4.1
Girth	1.20	3.60	3.8
Leaves at shooting	0.45	1.32	4.5
No. of suckers	0.32	0.95	5.1

Table 2: Effect of INM on Yield Attributes

Treatment	Hands per bunch	Fingers per bunch	Fruit length (cm)	Fruit weight (g)	Bunch weight (kg)
T1	8.5	122.2	16.4	90.1	10.20
T2	8.6	138.0	18.1	105.3	14.53
T3	8.9	142.6	18.5	110.7	15.26
T4	9.1	145.2	19.0	113.6	16.10
T5	8.8	140.4	18.3	108.2	14.95
T6	9.2	147.3	19.3	115.8	16.82
T7	9.6	152.4	20.1	120.6	18.25
T8	9.0	144.7	18.7	112.4	15.70
T9	9.3	148.5	19.5	116.2	17.10

Statistical values

Parameter	SEm	CD (5%)	CV (%)
Hands per bunch	0.25	0.74	3.9
Fingers per bunch	4.12	12.30	4.6
Fruit length	0.60	1.80	3.8
Fruit weight	3.10	9.20	4.1
Bunch weight	0.75	2.20	4.3

Table 3: Effect of INM on Yield and Economic Parameters

Treatment	Yield (t/ha)	Gross return (₹/ha)	Net return (₹/ha)	B:C ratio
T1	20.40	326400	243680	3.94
T2	29.06	464960	367000	4.70
T3	30.12	482000	378540	4.85
T4	31.28	500480	392320	4.95
T5	30.55	488800	383460	4.88
T6	31.94	510960	401200	5.05
T7	33.20	531200	420640	5.25
T8	30.85	493600	386200	4.90
T9	32.40	518400	408200	5.10

Statistical values

Parameter	SEm	CD (5%)	CV (%)
Yield	0.98	2.90	3.8
Gross return	14520	43200	4.1
Net return	12150	36180	4.3

ANOVA Table (RBD)

For Yield

Source of variation	DF	Sum of Squares	Mean Square	F value
Replication	2	2.14	1.07	1.12
Treatments	8	182.56	22.82	18.64
Error	16	19.60	1.22	
Total	26	204.30		

Treatment effects were significant at 5% level.

Discussion

Effect of Integrated Nutrient Management on Growth Parameters:

The results revealed that integrated nutrient management significantly influenced the vegetative growth of banana var. Sabri. Among the treatments, T7 (FYM 10 kg + Vermicompost 2 kg + Biofertilizers + 75% NPK) recorded the highest pseudostem height, girth, number of leaves and sucker production. The improvement in vegetative growth may be attributed to the combined application of organic and inorganic nutrient sources which enhanced nutrient availability and improved soil physical properties. Integrated nutrient management provides a continuous supply of nutrients, improves soil microbial activity and increases nutrient use efficiency. Similar results were reported by Patil and Shinde (2013) [28] who observed that banana plants require large quantities of nutrients and balanced fertilization significantly improves plant growth and yield. Recent research also supports these findings. Mahapatra *et al.* (2020) [22] reported that integrated nutrient management significantly increased pseudostem height, leaf area and vegetative growth of banana due to improved nutrient availability and enhanced microbial activity in the rhizosphere. Similarly, Kumar and Singh (2023) [31] found that the combined use of vermicompost and biofertilizers improves nutrient uptake efficiency and promotes vigorous vegetative growth in banana. The positive effect of organic manures such as FYM and vermicompost may also be due to their ability to improve soil structure, water-holding capacity and microbial activity. Organic sources release nutrients slowly and maintain nutrient availability throughout the crop growth period. In addition, biofertilizers such as *Azotobacter* and *PSB* enhance nitrogen fixation and phosphorus solubilization, leading to improved nutrient uptake by plants. These findings are consistent with those reported by Murray (1960) [24] and later researchers who stated that increased nitrogen availability promotes leaf emergence and vegetative growth in banana plants. Furthermore, integrated nutrient management has been reported to maintain soil fertility and provide optimum nutrient supply for sustained crop productivity. Bhardwaj and Omanwar (1994) [5] also reported that combined use of organic and inorganic fertilizers improves soil nutrient status and enhances plant growth compared to the use of chemical fertilizers alone.

Effect on Yield Attributes: Integrated nutrient management treatments significantly improved yield attributes such as number of hands per bunch, number of fingers per bunch, fruit weight and bunch weight. The treatment T7 recorded the highest bunch weight and fruit size, indicating better nutrient availability and improved physiological activity of plants. The increase in yield components may be attributed to enhanced nutrient uptake and improved photosynthetic efficiency resulting from balanced nutrient supply. Previous studies have also reported that integrated nutrient management significantly enhances yield attributes in banana. Pattar *et al.* (2018) [29] observed that application of recommended NPK along with

FYM, phosphate-solubilizing bacteria (PSB) and *Azospirillum* significantly increased number of hands per bunch, finger weight and total yield of banana. The beneficial effect of vermicompost in the present study could be due to the presence of growth-promoting substances such as humic acids and plant growth regulators which stimulate root growth and nutrient absorption. Similar observations were reported by Tejinder and Dhaliwal (2009) [63] who found that application of organic manures along with biofertilizers improved fruit weight and bunch characteristics in banana.

In addition, the synergistic effect of organic manures and inorganic fertilizers enhances nutrient availability and reduces nutrient losses from the soil. This integrated approach ensures balanced nutrition throughout the crop growth period and improves yield attributes.

Effect on Yield: The highest yield of banana was obtained under T7 treatment, which recorded significantly higher yield compared to farmer practice. The increase in yield under integrated nutrient management treatments may be due to improved soil fertility, higher nutrient availability and enhanced microbial activity in the rhizosphere. Organic manures not only supply nutrients but also improve soil structure and microbial activity, which leads to better root development and nutrient uptake.

Earlier studies have also confirmed the positive effect of integrated nutrient management on banana yield. Kuttamani and Somasundaram (2010-2012) [19] reported that integrated nutrient management significantly increased growth, yield and nutrient uptake in banana compared to chemical fertilizers alone.

Similarly, Chhuria *et al.* (2016) [7] reported that application of biofertilizers along with recommended fertilizer doses improved soil fertility and produced the highest yield in banana cv. Grand Naine. Recent studies have also confirmed the beneficial effects of integrated nutrient management on banana productivity. Sharma *et al.* (2021) [38] reported that application of vermicompost combined with 75% recommended NPK significantly increased bunch weight and fruit yield in banana. Likewise, Prasad *et al.* (2023) [31] observed that integrated nutrient management improved nutrient availability, increased photosynthetic efficiency and resulted in higher bunch weight and fruit yield compared to sole application of chemical fertilizers.

The higher yield recorded under T7 treatment may also be due to improved nutrient availability from different sources. Banana is a heavy feeder crop and requires large quantities of nitrogen, phosphorus and potassium for optimum growth and yield. According to Anonymous (2004) [2], production of one tonne of banana fruit requires approximately 7-8 kg nitrogen, 0.7-1.5 kg phosphorus and 17-20 kg potassium, highlighting the importance of balanced nutrient management.

Therefore, the combined application of FYM, vermicompost, biofertilizers and chemical fertilizers in the present study ensured balanced nutrition and resulted in higher yield and productivity.

Contribution of KVK through Front Line Demonstrations (FLDs): Front Line Demonstrations (FLDs) are one of the most effective extension tools used by Indian Council of Agricultural Research and Krishi Vigyan Kendra for transferring newly developed technologies to

farmers' fields. In the present study, KVK implemented FLDs on Integrated Nutrient Management (INM) in banana var. Sabri during the period 2015-16 to 2020-21 under the schemes of ICAR and ATMA. A total of 11 villages covering 20.0 ha area were included in the demonstrations.

Year	Technology Dissemination	Scheme	No. of villages	Area (ha)
2015-16 to 2020-21	Integrated Nutrient Management in Banana var. Sabri	FLDs (ATMA & ICAR, State Agri Dept)	11	20.0

The demonstrations aimed to showcase the effectiveness of integrated nutrient management practices involving balanced fertilizer application, organic manures, and biofertilizers for improving productivity and profitability of banana cultivation. The results of the demonstrations clearly indicated that adoption of improved nutrient management practices significantly enhanced yield and economic returns compared with the farmers' traditional practices.

The success of the demonstrations was largely due to regular technical guidance, training programmes, field visits and farmer-scientist interactions conducted by KVK scientists. These extension activities improved farmers' knowledge and confidence regarding improved cultivation practices, thereby facilitating rapid adoption of the technology.



Fig 4-6: Frontline Demonstrations of the standardised Technology.

Impact of FLDs on Horizontal Spread of Technology

The Front-Line Demonstrations had a substantial impact on the horizontal spread of integrated nutrient management technology in banana cultivation. Prior to the demonstrations, the area under improved banana cultivation

in the target villages was only 28 ha. However, after the successful implementation of FLDs and dissemination of the technology, the area increased to 60 ha, resulting in an expansion of 32 ha.

Variety	Area before demo (ha)	Area after demo (ha)	Change in area (ha)	Impact (%)
INM in Banana var. Sabri (2022- 2025)	28	60	32	214.29

This represents an impact increase of 214.29%, indicating a remarkable adoption of the demonstrated technology by farmers. The significant increase in cultivated area reflects

the effectiveness of FLDs as a powerful extension approach for accelerating the adoption of improved agricultural technologies.





Fig 7- 13: large-scale adoption Horizontal spread of the development of technology in the farmers field

The horizontal spread of the technology occurred mainly due to the visible performance of the demonstration plots, which encouraged neighbouring farmers to adopt the improved practices. Farmers were able to observe the higher productivity, better fruit quality and improved economic returns from the demonstration fields. Such field-level evidence plays a critical role in motivating farmers to adopt new technologies.

Similar findings were reported by several researchers who stated that FLDs significantly enhance the adoption of improved agricultural technologies through practical field demonstrations and farmer participation. Recent extension studies also highlight the importance of Front Line Demonstrations in improving technology adoption. Meena *et al.* (2023) [60] reported that FLDs increased crop

productivity by 30-60% through improved management practices and farmer awareness. Similarly, Yadav *et al.* (2023) [60] found that demonstration-based extension programmes significantly enhance farmers' knowledge, skill development and adoption of improved agricultural technologies.

Yield Gap Analysis: Yield gap analysis is an important indicator used to evaluate the effectiveness of agricultural technologies under farmers' field conditions. In the present study, the potential yield of banana was recorded as 36.00 t ha⁻¹, while the average demonstration yield was 33.29 t ha⁻¹. In contrast, the farmers' practice produced only 20.40 t ha⁻¹.

Potential yield (t ha ⁻¹)	Demonstration yield (t ha ⁻¹)	Local check / Farmers' yield (t ha ⁻¹)	% Increase	Extension gap (t ha ⁻¹)	Technology gap (t ha ⁻¹)	Technology index (%)
36.00	33.29	20.40	63.19	12.89	2.71	7.53

The demonstration plots recorded a 63.19% increase in yield over the local farmers' practice, clearly demonstrating the superiority of the integrated nutrient management technology. The extension gap, defined as the difference between demonstration yield and farmers' yield, was calculated as 12.89 t ha⁻¹. This gap highlights the considerable scope for increasing banana productivity through improved extension efforts and effective dissemination of scientific cultivation practices.

The technology gap, which represents the difference between potential yield and demonstration yield, was 2.71 t ha⁻¹. The presence of this gap indicates that although the improved technology significantly enhanced yield, there is still scope for further improvement under farmers' conditions. Factors such as variations in soil fertility, climatic conditions, and management practices may have

contributed to this difference.

The technology index, which measures the feasibility of the demonstrated technology under farmers' conditions, was recorded as 7.53%. A lower technology index indicates higher feasibility and adaptability of the technology. Therefore, the relatively low technology index observed in this study suggests that the integrated nutrient management practice is highly suitable and adoptable for banana cultivation in the region.

Categorization of Farmers According to Adoption Level

To assess the extent of adoption of integrated nutrient management practices in banana cultivation, 140 farmers from demonstration villages were surveyed. The adoption quotient (AQ) was calculated

Category	Adoption Quotient (AQ)	Number of farmers	Percentage (%)
Low adoption	< 35	20	14.29
Medium adoption	35-65	45	32.14
High adoption	> 65	75	53.57
Total	—	140	100

Mean adoption score = 66.48

Standard deviation = 15.32

The results revealed that 53.57% of the farmers belonged to the high adoption category, indicating a strong acceptance of integrated nutrient management technology among banana growers in Northern Tripura.

Overall Interpretation: The results of the study clearly

indicate that integrated nutrient management (INM) significantly improved the growth, yield and profitability of banana (*Musa sp.*) cv. Sabri under the agro-climatic conditions of Northern Tripura. Among the treatments evaluated, T7 (FYM 10 kg + Vermicompost 2 kg + Biofertilizers + 75% NPK) recorded the highest fruit yield

(33.20 t ha⁻¹), which was substantially higher than the farmers' practice (20.40 t ha⁻¹). Yield gap analysis revealed an extension gap of 12.89 t ha⁻¹ and a technology index of 7.53%, indicating the high feasibility of the demonstrated technology under farmers' field conditions.

The adoption study conducted among 140 farmers showed that 53.57% of the farmers belonged to the high adoption category, demonstrating strong acceptance of the integrated nutrient management technology. The results highlight the effectiveness of Front Line Demonstrations (FLDs) in promoting improved nutrient management practices and bridging the gap between research and farmers' fields.

Impact Assessment on Farmers' Income and Livelihood:

The introduction of integrated nutrient management technology through FLDs had a significant positive impact on farmers' income and livelihood. The improved treatment recorded a yield of 33.20 t ha⁻¹, compared with 20.40 t ha⁻¹ under farmers' practice, resulting in a yield increase of 63.19%.

Economic analysis revealed that adoption of INM practices increased the gross return to ₹5,31,200 ha⁻¹ and net return to ₹4,20,640 ha⁻¹, compared with ₹3,26,400 ha⁻¹ and ₹2,43,680 ha⁻¹ under traditional practices. The benefit-cost ratio improved from 3.94 to 5.25, indicating higher profitability. The increased income improved farmers' financial stability, encouraged expansion of banana cultivation and strengthened livelihood security in the study area.

Overall, the impact assessment clearly indicates that the adoption of integrated nutrient management technology significantly improved farmers' productivity, income and livelihood security. The successful demonstration of the technology also encouraged neighbouring farmers to adopt the improved practices, thereby increasing the overall area under scientific banana cultivation in the region.

Conclusion

The study demonstrates that integrated nutrient management significantly enhances the productivity and profitability of banana (*Musa sp.*) cv. Sabri in Northern Tripura. The treatment T7 (FYM + Vermicompost + Biofertilizers + 75% NPK) recorded the highest yield and economic returns. Yield gap analysis indicated substantial scope for increasing banana productivity through improved nutrient management practices. The high adoption level among farmers and the positive impact on income confirm that integrated nutrient management is a technically feasible, economically viable and environmentally sustainable approach for banana cultivation. Therefore, wider dissemination of this technology through training programmes and large-scale demonstrations can significantly contribute to improving banana production and farmers' livelihood in the region.

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