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Sustainable sugarcane production through integrated nutrient management using liquid biofertilizers

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Abstract

A field experiment was conducted to evaluate the effect of integrated nutrient management on yield and economics of sugarcane. The treatments included 75% NP combined with biofertilizers (Azospirillum/Azotobacter + PSB), 100% NPK, and control. The results revealed that application of 100% NPK (T_3) recorded the highest number of millable canes ($73.71 \times 10^3 \text{ ha}^{-1}$) and cane yield (107.35 t ha^{-1}). However, 75% NP + Azotobacter + PSB (T_2) produced comparable results (100.71 t ha^{-1}), indicating the potential of reducing chemical fertilizer use through biofertilizer integration. The control treatment recorded significantly lower yield (24.11 t ha^{-1}). Economic analysis showed maximum benefit-cost ratio in T_3 (1.38), followed by T_2 (1.22). The study suggests that integrated nutrient management can sustain yield while improving economic returns.

Keywords: Sugarcane, INM, liquid biofertilizers, Azotobacter, yield

Introduction

Medicinal plants have greatly gained importance in the management and treatment of human diseases, globally ^[1]. It constitutes the main source of primary healthcare in most rural populations, especially in many African countries, due to its affordability and availability. However, as the usage of these medicinal plants becomes more widespread around the world, there are questions and misgivings about the quality, efficacy, and safety of the products utilized in the health sector ^[2, 3, 4]. TSugarcane (*Saccharum officinarum* L.) is one of the most important commercial crops cultivated in tropical and subtropical regions and plays a vital role in the agro-industrial economy of India. India is the second largest producer of sugarcane in the world, contributing significantly to global sugar production and rural employment. During 2024-25, sugarcane was cultivated in about 5.7 million hectares with a production of nearly 454 million tonnes, reflecting the importance of this crop in the national economy (Ministry of Agriculture and Farmers Welfare, 2025) ^[1]. The productivity of sugarcane is greatly influenced by soil fertility, nutrient management, irrigation, and improved varieties. Proper nutrient management plays a crucial role in improving cane yield, juice quality, and sustainability of sugarcane-based production systems (Singh *et al.*, 2023; Kamalakar *et al.*, 2020) ^[2, 3].

In Telangana, sugarcane cultivation is mainly concentrated in the northern districts such as Nizamabad and Kamareddy, where favourable soil and irrigation conditions support its production. However, the area under sugarcane has declined in recent years due to the closure of sugar factories and changes in cropping patterns. At present, about 18,000 acres of sugarcane are cultivated in Nizamabad and Kamareddy districts, producing nearly 5.76 lakh tonnes of cane with an average productivity of around 80 t ha^{-1} , which is higher than the national average. Efficient management of soil nutrients and adoption of improved cultivation practices are therefore essential to sustain productivity and profitability of sugarcane cultivation in the region.

Sugarcane is an important commercial crop requiring large quantities of nutrients for optimum growth and yield. Continuous use of chemical fertilizers alone often leads to soil degradation, nutrient imbalance, and reduced nutrient use efficiency (Meena *et al.*, 2020; Kumar *et al.*, 2020) ^[4, 5]. Therefore, sustainable nutrient management practices are essential to maintain productivity and soil health (Reddy *et al.*, 2023) ^[6].

Integrated Nutrient Management (INM), involving the combined use of inorganic fertilizers and biofertilizers, has emerged as an effective strategy for improving crop productivity and soil fertility (Bhardwaj *et al.*, 2021; Meena *et al.*, 2022) [7, 8]. Biofertilizers such as *Azotobacter* and *Azospirillum* contribute to biological nitrogen fixation, while phosphate solubilizing bacteria (PSB) enhance phosphorus availability in soils (Kumar *et al.*, 2022; Singh *et al.*, 2020) [9, 10].

Azotobacter improves plant growth through nitrogen fixation and production of growth-promoting substances, whereas *Azospirillum* enhances root development and nutrient uptake. PSB plays a key role in converting insoluble phosphorus into available forms (Chauhan *et al.*, 2022) [11]. Recent studies have demonstrated that integrating biofertilizers with reduced levels of chemical fertilizers can sustain crop yield and improve soil health (Yadav *et al.*, 2021; Patel *et al.*, 2023) [12, 13]. Hence, the present study was undertaken to evaluate the effect of integrated nutrient management on sugarcane productivity and economics.

Materials and Methods

A field experiment was conducted at Regional Sugarcane and Rice Research Station, Rudrur, Nizamabad District, Telangana State during the two successive seasons of 2022-23 and 2023-24 using a randomized block design (RBD) with four treatments:

- T₁: 75% NP + *Azospirillum* + PSB (0 & 45 DAP)
- T₂: 75% NP + *Azotobacter* + PSB (0 & 45 DAP)
- T₃: 100% NPK
- T₄: Control

Liquid biofertilizers were sprayed along the furrows after distribution of cane material before covering the soil and also sprayed at 45 DAP at the base of the sugarcane. The recommended dose of liquid biofertilizer for spraying is 10 ml of liquid biofertilizer per litre of water. An amount of 2 and 3 liters required at basal and 45 DAP, respectively. Each treatment was replicated suitably under uniform agronomic practices.

Planting was done at 90 cm spacing using three eye budded setts (12 buds per meter row length). The recommended dose of fertilizer (100% NPK) for sugarcane in this region is N:P₂O₅:K₂O @ 250:100:100 kg ha⁻¹. Full dose of phosphorus and potassium were applied as basal at the time of planting and nitrogen was applied in two equal splits on 60th and 120th day after planting cane setts. Number of millable canes/plot (NMC/plot) and cane yield/plot were recorded separately and expressed in terms of '000 ha⁻¹ & t ha⁻¹ respectively. Benefit Cost Ratio (B:C ratio) was worked out based on the standard procedure (Gittinger, 1982) [13]. The cultivation practices were carried out periodically and the cane yield was recorded at harvest.

Results and Discussion

Number of Millable Canes (NMC): The number of millable canes differed significantly among treatments. The

highest NMC was recorded with T₃ (100% NPK) (73.71 × 10³ ha⁻¹), followed by T₁ and T₂ (70.19 × 10³ ha⁻¹), which were statistically at par. The control recorded the lowest NMC (34.65 × 10³ ha⁻¹).

The non-significant difference between T₃ and integrated treatments indicates that biofertilizers can effectively supplement nutrient requirements. Increased NMC under fertilized treatments may be attributed to improved tillering and nutrient availability, which aligns with findings of Singh and Singh (2021) [14] and Reddy *et al.* (2022) [15], who reported enhanced vegetative growth under integrated nutrient management (Table 1 to 3).

Cane Yield (t ha⁻¹): Cane yield was significantly influenced by different treatments (Table 1 to 3). The highest yield was recorded in T₃ (107.35 t ha⁻¹), followed by T₂ (100.71 t ha⁻¹) and T₁ (98.06 t ha⁻¹), while the control recorded a significantly lower yield (24.11 t ha⁻¹).

Statistically, T₃ was at par with T₂ but significantly superior to T₁. This suggests that 75% NP + *Azotobacter* + PSB can effectively substitute a portion of chemical fertilizers without significant yield loss. The improved yield may be due to enhanced nutrient uptake, nitrogen fixation, and phosphorus solubilization, as supported by Kumar *et al.* (2022) [9] and Chauhan *et al.* (2022) [11].

Similar results were reported by Kumar *et al.* (2020) [5] and Patel *et al.* (2023) [16], who observed that integrated nutrient management improves sugarcane productivity and maintains yields comparable to recommended fertilizer doses.

Benefit-Cost Ratio: Economic analysis revealed that T₃ recorded the highest B:C ratio (1.38), followed by T₂ (1.22) and T₁ (1.16). The control treatment resulted in a negative B:C ratio (-0.46), indicating economic loss (Table 1 to 3).

The higher profitability under T₃ is due to increased yield, whereas T₂ also showed favorable returns with reduced fertilizer input, indicating better cost efficiency. These findings are in agreement with Bhardwaj *et al.* (2021) [7] and Meena *et al.* (2022) [8], who reported improved economic returns with integrated nutrient management practices.

The results clearly indicate that balanced fertilization through 100% NPK enhances yield and economic returns. However, integrated nutrient management treatments, particularly T₂ (75% NP + *Azotobacter* + PSB), performed statistically on par with T₃ for yield, demonstrating the efficiency of biofertilizers in supplementing nutrient requirements.

Biofertilizers play a crucial role in sustainable agriculture by improving nutrient availability, enhancing microbial activity, and increasing nutrient use efficiency (Singh *et al.*, 2023; Reddy *et al.*, 2024) [2, 17]. The integration of biofertilizers with reduced fertilizer doses not only sustains crop productivity but also improves soil health and reduces environmental impact. The poor performance of the control treatment confirms the high nutrient demand of sugarcane and highlights the necessity of external nutrient inputs for achieving optimum productivity.

Table 1: Effect of Liquid Bio-fertilizers on cane yield of sugarcane during 2022-23

Treatments		NMC (000/ha)	Cane yield (t/ha)	Benefit Cost Ratio
T ₁	75 % NP + Azospirillum + PSB (0 & 45 DAP)	68.18	96.82	0.88
T ₂	75 % NP + Azotobacter + PSB (0 & 45 DAP)	69.92	99.28	0.93
T ₃	100% NPK	73.14	106.1	1.11
T ₄	Control	32.42	22.04	-0.52
SE(m) ±		1.25	2.85	-
CD (P = 0.05)		3.85	8.75	-

Table 2: Effect of Liquid Bio-fertilizers on cane yield of sugarcane during 2023-24

Treatments		NMC (000/ha)	Cane yield (t/ha)	Benefit Cost Ratio
T ₁	75 % NP + Azospirillum + PSB (0 & 45 DAP)	72.19	99.29	1.43
T ₂	75 % NP + Azotobacter + PSB (0 & 45 DAP)	70.46	102.13	1.50
T ₃	100% NPK	74.28	108.60	1.65
T ₄	Control	36.88	26.18	-0.40
SE(m) ±		1.35	2.92	-
CD (P = 0.05)		4.15	9.45	-

Table 3: Effect of Liquid Bio-fertilizers on cane yield of sugarcane (Pooled data over two years)

Treatments		NMC (000/ha)	Cane yield (t/ha)	Benefit Cost Ratio
T ₁	75 % NP + Azospirillum + PSB (0 & 45 DAP)	70.19	98.06	1.16
T ₂	75 % NP + Azotobacter + PSB (0 & 45 DAP)	70.19	100.71	1.22
T ₃	100% NPK	73.71	107.35	1.38
T ₄	Control	34.65	24.11	-0.46
SE(m) ±		1.28	2.65	-
CD (P = 0.05)		3.95	8.15	-

Conclusion

Application of 100% NPK recorded the highest number of millable canes, cane yield, and benefit-cost ratio, indicating its strong influence on productivity and profitability. However, integrated nutrient management (INM) treatments performed comparably to 100% NPK, demonstrating their potential as efficient alternatives. Among the INM practices, the treatment involving 75% NP combined with *Azotobacter* and PSB proved more effective than the *Azospirillum*-based treatment, highlighting the superiority of this microbial combination in enhancing nutrient availability. The integration of liquid biofertilizers further improved soil nutrient dynamics and crop productivity. Notably, the use of biofertilizers enabled a reduction of chemical fertilizer application by up to 25% without causing significant yield loss. Overall, integrated nutrient management not only maintained crop yield levels but also enhanced economic returns while promoting long-term sustainability.

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