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Effect of Sett Soaking and Integrated Nutrient Management on Yield and Economic Analysis of Single-node Materials of Planting Sugarcane

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aims: To evaluate the effects of sett soaking treatments and integrated nutrient management (INM) on germination, growth, yield, quality, and economic returns of single-node planted sugarcane.
Study Design: Factorial Randomized Block Design (FRBD) with three replications.
Place and Duration of Study: Crop Research Farm, Sugarcane Research Institute, Dr. Rajendra Prasad Central Agricultural University, Pusa (Samastipur), during the spring season of 2021–22.

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Methodology: The experiment comprised four sett soaking treatments: no soaking (S1), overnight soaking in water (S2), overnight soaking in 50 ppm ethrel solution (S3), and overnight soaking in 100 ppm ethrel solution (S4). Five nutrient management treatments were evaluated: RDF alone (N1), RDF + vermicompost (VC) at 5 t/ha (N2), RDF + VC at 10 t/ha (N3), RDF + VC at 5 t/ha + PSB + Azotobacter (N4), and RDF + VC at 10 t/ha + PSB + Azotobacter (N5). Soil characteristics were loamy with sandy texture, calcareous, pH 8.2, and 0.43% organic carbon. Data on germination, tillering, millable cane count, dry matter accumulation, cane yield, sugar yield, and economics were recorded and analyzed.

Results: Overnight sett soaking in 50 ppm ethrel (S3) significantly improved germination (79.1%), tiller count (85.4×10^3/ha), millable canes (63.9×10^3/ha), dry matter accumulation (293.2 q/ha), cane yield (78.0 t/ha), and sugar yield (10.23 t/ha). S3 also registered the highest gross returns (₹261,233/ha), net returns (₹133,978/ha), and a B:C ratio of 1.12. Among nutrient treatments, RDF + VC at 10 t/ha + PSB + Azotobacter (N5) recorded the highest shoot population and yield attributes, whereas RDF alone (N1) produced the highest B:C ratio (1.5) due to lower input costs. RDF + VC at 5 t/ha + PSB + Azotobacter (N4) may become more profitable if vermicompost is produced on-farm, reducing expenditure.

Conclusion: Sett soaking in 50 ppm ethrel and integrated nutrient management significantly enhance yield and quality of single-node planted sugarcane. While ethrel soaking and enriched INM improve productivity, the economic viability depends on input costs, with N1 and N4 being more favorable under resource-efficient conditions.

Keywords: Sugarcane; sett soaking; ethrel; integrated nutrient management; yield and economics.

1. INTRODUCTION

Sugarcane (*Saccharum officinarum* L.) is a perennial C_4 grass belonging to the family Poaceae and represents one of the most important commercial crops cultivated in tropical and subtropical regions owing to its high biomass production potential and extensive industrial utility (Ungureanu et al., 2022; Raza et al., 2022). It contributes nearly 80 % of global sugar production and serves as a primary feedstock for bioethanol manufacture, cogeneration of energy, and several value-added by-products, thereby playing a vital role in the global bio-based economy. Globally, sugarcane is cultivated over approximately 23–27 million hectares, with an annual production exceeding 1.8–1.9 billion tonnes, and India ranks as the second largest producer after Brazil (FAO, 2023; Rana et al., 2023).

Despite its economic significance, sugarcane productivity is constrained by several agronomic factors, among which the high cost and bulky nature of conventional planting material remains a major limitation (Gouri et al., 2019). Under the traditional sett planting system, seed material alone accounts for nearly 25 % of the total cost of cultivation. The requirement of large quantities of seed cane necessitates extensive transportation and storage facilities, creating practical difficulties. Moreover, prolonged handling and storage adversely affect bud viability and germination. Traditional three-budded sett planting typically requires 6–8 t ha^{-1} of seed cane, contributing to 25–30 % of the total cultivation cost, while also increasing transportation expenses and the risk of disease transmission through seed cane (Otto et al*.,* 2022).

To overcome these limitations, single-bud or single-node planting systems have gained prominence in recent years as efficient alternatives to conventional sett planting. These systems substantially reduce seed requirement, enhance planting efficiency, and ensure uniform crop establishment, while achieving yields comparable to or higher than traditional methods. Single-bud-derived settlings have been reported to perform better than bud chips, exhibiting faster and more vigorous growth during the nursery phase (Parnidi & Hamida, 2021). Further it was demonstrated that single-bud plantlets raised in protrays are superior to polybag seedlings, bud chips, sprouts, tissue-cultured plants, and conventional setts. Consequently, single-bud-based planting systems offer a cost-effective and quality-oriented approach to sugarcane cultivation.

However, under subtropical agro-climatic conditions, poor and uneven bud germination continues to be a major challenge due to fluctuating temperatures, soil moisture stress, and physiological dormancy of buds (Pal et al., 2021). The application of plant growth regulators, particularly ethephon (2-chloroethyl phosphonic acid), an ethylene-releasing compound, has been reported to enhance bud sprouting, early tillering, and initial crop vigour by stimulating ethylene-mediated physiological processes during germination (Jain et al., 2011). Sett soaking with ethephon has also been shown to improve stand establishment, cane yield, and sugar recovery, especially under conditions of temperature and moisture stress (Shrivastava et al., 2009).

In addition to improved planting techniques, efficient nutrient management is essential for sustaining sugarcane productivity, as the crop is highly exhaustive and removes large quantities of nutrients from the soil. Integrated Nutrient Management (INM), involving the judicious combination of inorganic fertilizers with organic manures and biofertilizers, is widely advocated to enhance nutrient-use efficiency, soil fertility, and long-term sustainability of sugarcane-based production systems (Banerjee et al., 2018). Studies have shown that integrating mineral fertilizers with organic amendments such as vermicompost and press mud significantly improves soil organic carbon status, nutrient availability, and cane yield. Laxmi et al. (2011) reported higher cane yields with the combined use of vermicompost and inorganic fertilizers compared to sole chemical fertilization. Similarly, the integration of press mud and sugarcane trash with recommended fertilizer doses resulted in significant improvements in tiller production and the number, length, and weight of millable canes over the application of recommended fertilizers alone . Furthermore, the use of biofertilizers such as *Azotobacter*, *Azospirillum*, and phosphate-solubilizing bacteria enhances biological nitrogen fixation and phosphorus availability, leading to improved yield and quality of sugarcane (Tripati et al., 2025).

In view of the growing emphasis on cost-effective planting material and sustainable nutrient management, it is evident that both sett treatment strategies and INM practices are integral to improving sugarcane productivity, particularly under subtropical conditions. While single-node planting systems reduce seed requirement, their success largely depends on uniform bud sprouting and early crop vigour, which can be enhanced through appropriate sett soaking treatments. Simultaneously, the high nutrient demand of sugarcane necessitates balanced and integrated nutrient supply to sustain growth and yield. Therefore, the present study was undertaken to systematically evaluate the combined effects of sett soaking treatments and INM practices under single-node planting systems, with the objective of improving crop establishment, nutrient-use efficiency, yield performance, and profitability, while ensuring the long-term sustainability of sugarcane production systems under subtropical agro-climatic conditions.

2. MATERIALS AND METHODS

The field experiment was conducted during the spring seasons of 2021–2022 at the Sugarcane Research Farm, Crop Research Centre, Pusa (Samastipur), Bihar, located at 25°59′ N latitude, 85°40′ E longitude, and an elevation of 52.1 m above mean sea level. The region experiences a subtropical sub-humid climate with hot summers, cool winters, and moderate rainfall. The soil at the experimental site is sandy loam in texture, well-drained, alkaline, and calcareous, originating from alluvial deposits of the Gandak river.

Prior to experimentation, composite soil samples (0–30 cm depth) were collected to assess initial soil properties. The soil had a pH of 8.20 and electrical conductivity of 0.28 dS m^{-1}, measured in a 1:2.5 soil–water suspension, indicating non-saline conditions. It was low in organic carbon (0.43 %, Walkley & Black method). Available nitrogen, phosphorus, and potassium were 223 kg ha^{-1} (alkaline $KMnO_4$ method), 24.31 kg P_2O_5 ha^{-1} (Olsen's method), and 138.22 kg K_2O ha^{-1} (flame photometry), respectively. The soil contained 28.9 % free $CaCO_3$, determined by the rapid acid neutralization titration method, confirming its calcareous nature.

The experiment was laid out in a factorial randomized block design (FRBD) with three replications, comprising 20 treatment combinations across 60 plots, involving sett soaking and integrated nutrient management (INM) practices. Sett soaking treatments included no soaking (control), overnight soaking in water, overnight soaking in 50 ppm ethephon (Ethrel), and overnight soaking in 100 ppm ethephon (Ethrel), while nutrient management treatments comprised recommended dose of fertilizers (RDF) alone; RDF combined with vermicompost (VC) at 5 t ha^{-1}; RDF + VC at 10 t ha^{-1}; RDF + VC 5 t ha^{-1} combined with phosphate-solubilizing bacteria (PSB) and *Azotobacter*; and RDF + VC 10 t ha^{-1} combined with PSB and *Azotobacter*.

The sugarcane variety CoP 16437 (Rajendra Ganna-1) was planted following recommended agronomic practices, including land preparation, fungicidal treatment of seed material, split nitrogen application, scheduled irrigation, weed control, intercultural operations, earthing-up, and propping. The crop was harvested in January, and cane yield (t ha^{-1}) was recorded on a plot basis for analysis.

The representative sample technique was used to document agronomic characteristics of sugarcane at different growth stages. Observations were made in the field and laboratory, with selected plants clearly marked for tracking. Growth and yield parameters were observed throughout the crop cycle to assess their correlation with final yield. Qualitative observations were also made during harvest. Key observations are categorized as follows:

2.1 Plant Population

2.1.1 Germination percent

Germination counts were conducted three times at 15, 30, and 45 days after planting (DAP) from the net plot area. Germination percentage was calculated using the formula:

$$\text{Germination Percentage} = \frac{Number\ of\ germinated\ buds}{Numner\ of\ buds\ planted} \times 100$$

2.1.2 Plant population count

From 60 to 120 DAP, the total number of plants, including mother shoots and tillers, was counted on a monthly basis from the net plot area and expressed in thousands per hectare.

2.1.3 Number of millable canes (NMC)

At harvest, the number of millable canes was counted from the net plot area and expressed in thousands per hectare.

2.2 Growth and Development

2.2.1 Dry matter accumulation

Observations on dry matter accumulation were made at 120, 180, and 240 DAP. Two plants from each plot were uprooted, weighed, and then dried in a hot air oven at 70℃ until consistent weight was achieved. The dry weight was then recorded.

2.2.2 Cane yield and commercial cane sugar yield

Cane Yield (t/ha): At harvest, after detopping and detrailing, the total cane weight for each plot was measured using a spring balance. Cane yield was expressed in tonnes per hectare.

Commercial Cane Sugar Yield (t/ha): The CCS yield per hectare was calculated by multiplying the CCS percentage at harvest with the cane yield and dividing by 100:

$$\text{CCS (t/ha)} = \frac{\text{CCS\% at harvest} \times \text{cane yield (t/ha)}}{100}$$

2.3 Economics

2.3.1 Cost of Cultivation (₹/ha)

The total cost of cultivation was calculated by summing the cultivation costs and treatment-related expenses.

2.3.2 Gross returns (₹/ha)

Gross returns were calculated by multiplying the cane yield (t/ha) with the cane price (₹/t):
Gross returns (₹/ha) = Cane yield (t/ha) × Cane price (₹/t)

2.3.3 Net returns (₹/ha)

Net returns were computed by subtracting the cost of cultivation from the gross returns:
Net returns = Gross returns – cost of cultivation

2.3.4 Benefit: cost ratio

The benefit-to-cost ratio was calculated by dividing the net returns by the total cost of cultivation:

$$\text{Benefit: Cost Ratio} = \frac{Net\ Returns}{Cost\ of\ cultivation}$$

2.4 Statistical Analysis

Analysis of Data: Data recorded for various parameters were subjected to statistical analysis using Analysis of Variance (ANOVA) appropriate for a factorial randomized block design (FRBD) at a 5% significance level, following the procedure outlined by Gomez and Gomez (1984). Differences among treatment means were compared using the least significant difference (LSD) test where applicable.

3. RESULTS AND DISCUSSION

3.1 Germination Percentage

Sett soaking significantly influenced sugarcane germination at 15, 30, and 45 days after planting (DAP). The highest germination was observed with 50 ppm ethrel solution, recording 33.8% at 15 DAP, 68.2% at 30 DAP, and 79.1% at 45 DAP. The 100 ppm ethrel treatment showed slightly lower but comparable germination rates. Water soaking and untreated setts had the lowest germination rates, suggesting limited effectiveness. The superior performance of 50 ppm ethrel is attributed to increased in vivo nitrate reductase (NR) activity, bud moisture, acid invertase (AI), ATPase, superoxide dismutase (SOD), and indole acetic acid oxidase (IAAO). Enhanced AI and ATPase activities in ethrel-treated setts promoted higher reducing sugar content, aiding rapid sprouting. Integrated nutrient management (INM) showed no significant effect on germination; however, RDF + VC @ 10 t/ha yielded slightly higher germination rates. The interaction between sett soaking and INM practices was not statistically significant. The study's favorable germination rates, particularly under ethrel treatment, are attributed to the synergistic effects of enzyme activation and improved hormonal regulation, aligning with the findings of Rai et al. (2017).

3.2 Tiller Count (000/ha) at 60, 90 and 120 Days after Planting

Sett soaking and integrated nutrient management (INM) significantly influenced sugarcane tiller count at 60, 90, and 120 days after planting (DAP). Soaking in 50 ppm ethrel consistently showed the highest tiller counts (65.5×10^3/ha at 60 DAP, 80.5×10^3/ha at 90 DAP, and 85.4×10^3/ha at 120 DAP), followed by 100 ppm ethrel. Water soaking and untreated setts had lower tiller counts, suggesting limited effectiveness. The tiller enhancement from ethrel aligns with Rai et al. (2017) and Li & Solomon (2003). INM treatments combining RDF + VC @ 10 t/ha + PSB + Azotobacter achieved the highest tiller counts, likely due to enhanced nutrient availability and soil biological activity. The lowest counts occurred with sole RDF, indicating limitations of inorganic fertilizers alone. While both factors significantly influenced tillering, their interaction was not statistically significant. These findings emphasize ethrel and integrated nutrient strategies for maximizing tiller production, contributing to higher yields.

Table 1. Effect of sett soaking and integrated nutrient management on germination percent of sugarcane

Treatments	15 DAP	30 DAP	45 DAP
A. Sett soaking			
S_1: Without soaking	23.8	55.9	59.9
S_2: Overnight soaking in water	25.4	57.1	63.5
S_3: Overnight soaking in 50 ppm *ethrel* solution	33.8	68.2	79.1
S_4: Overnight soaking in 100 ppm *ethrel* solution	30.6	64.8	77.5
SEm±	0.76	1.60	1.83
CD (p=0.05)	2.1	4.4	5.1
B. Integrated nutrient management			
N_1: RDF	28.1	60.8	68.4
N_2: RDF +VC @ 5t/ha	27.5	59.6	70.6
N_3: RDF +VC @ 10t/ha	29.4	62	71.3
N_4: RDF +VC @ 5t/ha+ PSB+ *Azotobacter*	28.1	61.4	69.2
N_5: RDF +VC @ 10t/ha+ PSB+ *Azotobacter*	28.8	63.9	70.5
SEm±	0.85	1.79	2.05
CD (p=0.05)	NS	NS	NS
CV	10.3	10.1	10.1

Table 2. Effect of sett soaking and integrated nutrient management on tiller count (000/ha) of sugarcane at 60, 90 and 120 DAP

Treatment	60 DAP	90 DAP	120 DAP
A. Sett soaking			
S_1: Without soaking	56.2	62.3	65.9
S_2 : Overnight soaking in water	58.3	65.1	71.1
S_3: Overnight soaking in 50 ppm *ethrel* solution	65.5	80.5	85.4
S_4: Overnight soaking in 100 ppm *ethrel* solution	62.8	76.2	82.8
SEm±	1.47	1.72	2.16
CD (p=0.05)	4.1	4.8	6.0
B. Integrated nutrient management			
N_1: RDF	53.9	62.3	64.9
N_2: RDF + VC @ 5t/ha	59.9	69.8	74.1
N_3: RDF + VC @ 10t/ha	62.4	74.0	80.3
N_4: RDF + VC @ 5t/ha+ PSB+ *Azotobacter*	61.8	72.3	77.8
N_5: RDF +VC @10 t/ha+ PSB+ *Azotobacter*	65.5	76.8	84.4
SEm±	1.65	1.92	2.41
CD (p=0.05)	4.6	5.3	6.7
CV	9.4	9.4	11

3.3 Number of Millable Canes (000"/ha) at Harvest

Both sett soaking and integrated nutrient management (INM) significantly influenced the number of millable canes (NMC) in sugarcane. The highest NMC (63.9×10³/ha) was achieved with 50 ppm ethrel soaking, followed by 100 ppm ethrel (62.3×10³/ha), indicating ethrel's effectiveness in promoting tillering and shoot emergence, consistent with the findings of Abd El-Lattief and Bekheet (2012), Conventional planting without soaking had lower NMC (52.2×10³/ha), showing its limitations compared to ethrel treatments. INM treatments showed notable impacts, with RDF + VC @ 10 t/ha + PSB + Azotobacter achieving the highest NMC (65.4×10³/ha). This enhanced performance aligns with the studies of Sison et al. (2010), and Umesh et al. (2013), who reported improved nutrient uptake, soil health, and reduced mortality from combined organic and inorganic nutrient sources. No significant interaction between sett soaking and INM was observed, suggesting their independent effects. These findings highlight the value of ethrel soaking and comprehensive nutrient management in maximizing millable cane production and improving yield potential.

3.4 Dry Matter Accumulation at 120,180,240 Days after Planting and at Harvest

Dry matter accumulation, a key determinant of sugarcane yield, was significantly influenced by sett soaking and integrated nutrient management (INM). Soaking setts overnight in a 50 ppm ethrel solution resulted in the highest dry matter accumulation across all growth stages — 76.5 q/ha at 120 DAP, 164.7 q/ha at 180 DAP, 253.6 q/ha at 240 DAP, and 293.2 q/ha at harvest. These values were comparable to a 100 ppm ethrel solution but notably superior to water soaking and untreated controls. The increased dry matter can be attributed to enhanced leaf area, improved light interception, and greater photosynthetic efficiency, consistent with findings by and similar reports by Rai et al. (2017), Upadhaya and Kumar (2018), and Roberto et al. (2015).In terms of INM, the combination of RDF + VC @ 10 t/ha + PSB + Azotobacter yielded the maximum dry matter accumulation at all stages, with 75.8 q/ha, 164.5 q/ha, 251.1 q/ha, and 291.5 q/ha at 120, 180, 240 DAP, and harvest, respectively. These results were on par with RDF + VC @ 5 t/ha + PSB + Azotobacter and RDF + VC @ 10 t/ha but significantly outperformed sole RDF. The improved performance under INM is likely due to enhanced nutrient availability, balanced fertilization, and better soil health.

No significant interaction was found between sett soaking and INM, indicating their independent influence on dry matter accumulation. These results suggest that combining ethrel soaking with INM can optimize dry matter accumulation and enhance sugarcane productivity.

Table 3. Effect of sett soaking and integrated nutrient management on number of millable canes ('000/ha)

A. Sett soaking	Millable canes (000/ha)
S_1: Without soaking	52.2
S_2: Overnight soaking in water	56.0
S_3: Overnight soaking in 50 ppm *ethrel* solution	63.9
S_4: Overnight soaking in 100 ppm *ethrel* solution	62.3
SEm±	1.72
CD(p=0.05)	4.8
B. Integrated nutrient management	
N_1: RDF	48.7
N_2: RDF + VC @ 5 t/ha	57.1
N_3: RDF + VC @10 t/ha	61.7
N_4: RDF + VC @ 5 t/ha+ PSB+ *Azotobacter*	60.1
N_5: RDF+VC @10 t/ha+ PSB+ *Azotobacter*	65.4
SEm±	1.92
CD (p=0.05)	5.3
CV	11.4

Table 4. Effect of sett soaking and integrated nutrient management on dry matter accumulation (q/ha) of sugarcane at 120, 180 and 240 days after planting

Treatment	120 DAP	180 DAP	240 DAP	At harvest
A. Sett soaking				
S_1: Without soaking	64.3	146.8	221.5	242.1
S_2: Overnight soaking in water	66.8	148.3	224.7	258.3
S_3: Overnight soaking in 50 ppm *ethrel* solution	76.5	164.7	253.6	293.2
S_4: Overnight soaking in 100 ppm *ethrel* solution	75.2	163.4	251.4	288.4
SEm±	1.63	3.49	5.38	6.43
CD(p=0.05)	4.5	9.7	14.9	17.8
B. Integrated nutrient management				
N_1: RDF	61.3	139.9	214.7	232.3
N_2: RDF + VC @ 5 t/ha	69.4	154.3	235.9	266.0
N_3: RDF + VC @10 t/ha	73.7	162.5	247.4	284.9
N_4: RDF + VC @ 5 t/ha+ PSB+ *Azotobacter*	73.3	157.8	239.9	277.3
N_5: RDF+ VC @ 10 t/ha+ PSB+ *Azotobacter*	75.8	164.5	251.1	291.5
SEm±	1.82	3.90	6.02	7.18
CD(p=0.05)	5.0	10.8	16.7	19.9
CV	8.9	8.7	8.8	9.0

3.5 Cane Yield (t/ha) and Sugar Yield (t/ha) of Sugarcane

Both sett soaking and integrated nutrient management (INM) significantly influenced cane and sugar yield in sugarcane. Overnight soaking in a 50 ppm ethrel solution produced the highest cane yield (78.0 t/ha), comparable to 100 ppm ethrel (77.2 t/ha) and superior to water soaking (69.5 t/ha), likely due to improved germination and increased millable canes, as noted by Kumar et al. (2023) . For INM, the combination of RDF + VC @ 10 t/ha + PSB + Azotobacter achieved the highest cane yield (79.4 t/ha), comparable to RDF + VC @ 5 t/ha + PSB + Azotobacter (74.0 t/ha) and RDF + VC @ 10 t/ha (76.3 t/ha), all significantly outperforming sole RDF (62.1 t/ha). The enhanced performance under INM is attributed to improved nutrient availability, better soil health, and increased nutrient uptake, aligning with Virdia and Patel (2010) . In terms of sugar yield, the highest value (10.23 t/ha) was recorded with 50 ppm ethrel soaking, similar to 100 ppm (10.07 t/ha) and superior to no soaking (8.60 t/ha), mainly due to higher cane yield rather than changes in CCS percentage. INM also positively influenced sugar yield, with RDF + VC @ 10 t/ha + PSB + Azotobacter achieving the

Table 5. Effect of sett soaking and integrated nutrient management on cane yield (t/ha) and sugar yield (t/ha) of sugarcane

A. Sett soaking	Cane Yield (t/ha)	Sugar Yield(t/ha)
S_1: Without soaking	65.4	8.60
S_2: Overnight soaking in water	69.5	9.09
S_3: Overnight soaking in 50 ppm *ethrel* solution	78.0	10.23
S_4: Overnight soaking in 100 ppm *ethrel* solution	77.2	10.07
SEm±	1.90	0.231
CD(p=0.05)	5.3	0.64
B. Integrated nutrient management		
N_1: RDF	62.1	8.16
N_2: RDF +VC @ 5 t/ha	70.8	9.29
N_3: RDF +VC @10 t/ha	76.3	9.97
N_4: RDF +VC @5 t/ha+ PSB+ *Azotobacter*	74.0	9.59
N_5: RDF + VC @10 t/ha + PSB +*Azotobacter*	79.4	10.48
SEm±	2.13	0.258
CD(p=0.05)	5.9	0.71
CV	10.2	9.4

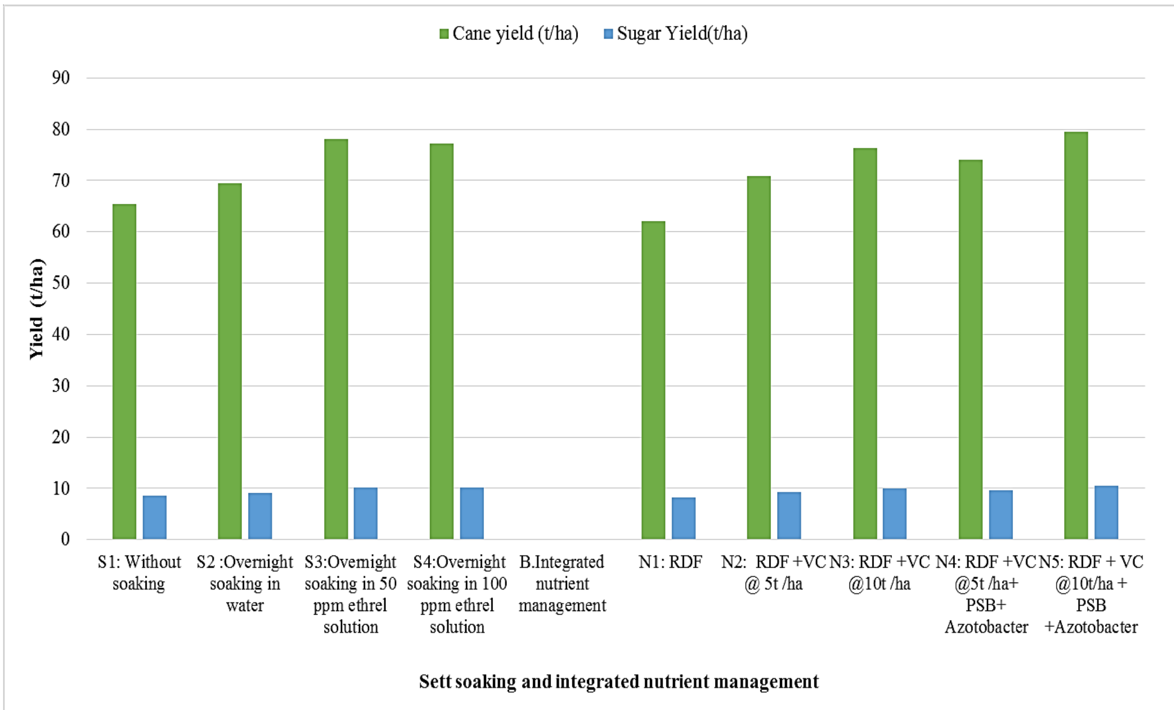

Fig. 1. Effect of sett soaking and integrated nutrient management on cane yield and sugar yield of sugarcane

maximum value (10.48 t/ha), surpassing sole RDF (8.16 t/ha), likely due to increased sucrose content and improved brix percentage. Notably, there was no significant interaction effect between sett soaking and INM, indicating their independent influence on yield components, suggesting that their combined application could be a viable strategy for maximizing sugarcane productivity.

4. ECONOMICS

Economic analysis revealed notable variations in costs, returns, and profitability across treatments. The highest cost of cultivation for sett soaking was observed with overnight soaking in a

Table 6. Effect of sett soaking and integrated nutrient management on economics of sugarcane

Treatments	Cost of cultivation (₹/ha)	Gross returns (₹/ha)	Net returns (₹/ha)	B:C ratio
A. Sett soaking				
S_1: Without soaking	126294.1	219090	92795.9	0.79
S_2: Overnight soaking in water	126706.3	232758	106051.7	0.90
S_3: Overnight soaking in 50 ppm *ethrel* solution	127254.7	261233	133978.3	1.12
S_4: Overnight soaking in 100 ppm *ethrel* solution	129121.8	258620	130707.2	1.09
SEm±		6575.7	2249.93	0.024
CD(p=0.05)		17672	7622.4	0.07
B. Integrated nutrient management				
N_1: RDF	83350.8	208035	124684.2	1.50
N_2: RDF + VC @ 5 t/ha	119119.1	237180	118060.9	0.99
N_3: RDF +VC @ 10 t/ha	154475.3	255605	101129.7	0.66
N_4: RDF + VC @ 5 t/ha + PSB + *Azotobacter*	121454.3	247900	126445.7	1.04
N_5: RDF + VC @ 10t/ha + PSB + *Azotobacter*	156810.5	265906.3	109095.76	0.70
SEm±		7128.2	3074.52	0.027
CD(p=0.05)		19758	8522.1	0.07
CV		10	9.2	9.48

100 ppm ethrel solution (₹129,121.8/ha), while no soaking had the lowest cost (₹126,294/ha). Among INM treatments, RDF + VC @ 10 t/ha + PSB + Azotobacter had the highest cost (₹156,810.5/ha), whereas sole RDF had the lowest (₹83,350.8/ha). Despite the higher costs, the highest gross returns (₹261,233/ha), net returns (₹133,978/ha), and B:C ratio (1.12) were achieved with overnight soaking in a 50 ppm ethrel solution, demonstrating its economic viability for farmers. The findings align with those of Praharaj et al. (2018). In INM, RDF + VC @ 10 t/ha + PSB + Azotobacter recorded the highest gross returns (₹265,906/ha), while sole RDF exhibited the most cost-effective B:C ratio (1.50). Although RDF + VC @ 10 t/ha + PSB + Azotobacter had higher initial costs due to vermicompost, its profitability could increase if farmers produce vermicompost on-site, reducing cultivation expenses. These insights emphasize the importance of balancing input costs with yield benefits for optimal profitability.

5. CONCLUSION

The study demonstrated that overnight soaking of sugarcane setts in 50 ppm ethephon (Ethrel) significantly improved germination, tiller development, and cane yield, making it the most effective sett treatment. Similarly, integrated nutrient management (INM) combining RDF with vermicompost and biofertilizers (PSB + *Azotobacter*) enhanced cane and sugar yield compared to RDF alone. Economic analysis indicated that 50 ppm ethrel soaking combined with appropriate nutrient management offers an optimal balance between productivity and profitability. Therefore, a synergistic approach of ethrel-treated setts and INM is recommended for maximizing sugarcane yield, quality, and economic returns under subtropical conditions.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

The author(s) hereby declare that generative AI technology was used during the preparation of this manuscript. ChatGPT (OpenAI; Large Language Model) was used exclusively for grammar checking and language refinement to improve clarity and readability of the text. No scientific content, data analysis, interpretation of results, or conclusions were generated or altered using AI tools. Full responsibility for the content of the manuscript remains with the author(s).

Details of AI usage:

1. Tool used: ChatGPT (OpenAI)
2. Purpose: Grammar correction and language improvement
3. Input prompts: Requests for grammatical correction and sentence restructuring without modification of scientific meaning

COMPETING INTERESTS

Authors have declared that they have no known competing financial interests or non-financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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