Sow S *et al.* (2024)
Notulae Botanicae Horti Agrobotanici Cluj-Napoca
Volume 52, Issue 3, Article number 13934
DOI:10.15835/nbha52313934
Research Article

Soil test crop response based integrated nutrient management for enhancing agronomic performance of sugarcane with different planting materials

Sumit SOW[1], Navnit KUMAR[2*], Lalita RANA[2], Harendra SINGH[1], Vipin KUMAR[3], KAVITA[4], Shailesh KUMAR[5], Anil K. SINGH[2]

[1]*Dr. Rajendra Prasad Central Agricultural University, Department of Agronomy, Pusa 848 125, Bihar, India; sumitsow19@gmail.com (S.S); hsingh@rpcau.ac.in (H.S)*
[2]*Dr. Rajendra Prasad Central Agricultural University, Sugarcane Research Institute, Pusa 848 125, Bihar, India; navnit.sri@rpcau.ac.in (*corresponding author) (N.K); lalita@rpcau.ac.in (L.R); shantanil@yahoo.com (A.K.S)*
[3]*Dr. Rajendra Prasad Central Agricultural University, Department of Soil Science, Pusa 848 125, Bihar, India; vipin@rpcau.ac.in (V.K)*
[4]*Dr. Rajendra Prasad Central Agricultural University, Tirhut College of Agriculture, Dholi 843121, Bihar, India; kavita@rpcau.ac.in (K)*
[5]*Dr. Rajendra Prasad Central Agricultural University, Department of Plant Physiology, Pusa 848 125, Bihar, India; shaileshk@rpcau.ac.in (S.K)*

Abstract

The decline in performance of sugarcane either due to non-availability of suitable planting material or negligence in nutrient management is increasing at an alarming rate. Therefore, a field experiment was conducted for two consecutive years in Bihar, India to study the effect of different planting material and integrated nutrient management strategies on performance and yield of sugarcane. The experiment was conducted in a factorial randomized block design replicated thrice with four planting materials (single budded sett, double budded sett, three budded sett and tissue culture plantlets) and seven integrated nutrient management strategies [control, recommended dose of fertilizer (RDF), soil test-based RDF, RDF + 25% N through pressmud + $ZnSO_4$, soil test-based RDF+ 25% N through pressmud + $ZnSO_4$, RDF + 25% N through FYM + $ZnSO_4$ and soil test-based RDF+ 25% N through FYM + $ZnSO_4$]. Crop growth attributes viz. leaf area index, plant height, tillers, total chlorophyll content was found maximum with tissue culture plantlets followed by three budded setts while the minimum in single budded sett. During both the years of the study, three budded setts increased the cane yield by 33.9 and 34.5% over single budded sett respectively. Application of soil test-based RDF + 25% N through pressmud + $ZnSO_4$ significantly enhanced physio-agronomic performance and further, the sugar yield by 39.1, 13.3 and 38.7, 11.6 % as compared to RDF and soil test-based RDF in first and second year of the study respectively. Hence, it was concluded that three budded setts along with soil test-based RDF + 25% N through pressmud + $ZnSO_4$ of 25 kg/ha can increase overall growth and productivity of sugarcane.

Keywords: integrated nutrient management; planting materials; soil test-based RDF; sugarcane; yield

Received: 31 May 2024. Received in revised form: 03 Jul 2024. Accepted: 11 Sep 2024. Published online: 23 Sep 2024.
From Volume 49, Issue 1, 2021, Notulae Botanicae Horti Agrobotanici Cluj-Napoca journal uses article numbers in place of the traditional method of continuous pagination through the volume. The journal will continue to appear quarterly, as before, with four annual numbers.

Introduction

In India, Sugarcane (*Saccharum* hybrids L.) remains a key commercial crop, which is cultivated on 51.2 lakh hectares of land (ICAR, 2022). The main products of sugarcane are sugar, alcohol, and energy which is generated by burning sugarcane bagasse (Wani *et al.,* 2023). Sugarcane is heavy feeder crop and a long-duration biomass producer, which removes a considerable amount of nutrients from the soil (Boschiero *et al*., 2023). In general, farmers adopt planting of sugarcane using three budded setts while two budded and single budded sets are popular in limited research area under sugar factories. About 5-6 tonnes of seed cane are required per hectare when establishing the crop with three bud setts in subtropical conditions. The major issue arising in using three budded sett is its high requirement of seed rate that results in lower seed multiplication ratio 1:10 and problems in transportation (Otto *et al.,* 2022). Furthermore, as sugarcane favours accumulation of pathogens given that it is propagated vegetatively (Viswanathan, 2016). It is affected by various epidemics such as red rot, grassy shoot, wilt, smut, yellow leaf, ratoon stunting, and leaf scald, which plays a major role in reducing the productivity of sugarcane. Nonetheless it has been proven that such challenges can be controlled by establishing the crop using tissue culture plantlets (Salokhe, 2021). Use of single or double bud practice can be a potential solution to achieving sugarcane seed of healthy and superior quality (Kumar and Kumar, 2020). Thus, the use of proper and good quality planting materials increases the multiplication rate, uniformity and help to boost up the productivity of sugarcane.

Nowadays, minimum use of organics due to their meagre unavailability, high cropping intensity, and over reliance on chemical fertilizers under intensive agriculture results in imbalanced nutrients exploitation. Subsequently this results in deficiencies of some macro and micronutrients (Mugo *et al*., 2021; Shukla *et al*., 2023; Nungula *et al*., 2024). Therefore, the crop requires a large quantity of nutrients, so a proper ratio of nitrogen (N), phosphorus (P), and potassium (K) in inorganic and organic fertilizers is essential to increase sugarcane productivity on a sustainable basis. Besides the collaborative benefits of integrating inorganic and organic sources of nutrients, the current fertilizer production capacity in India is inadequate to meet the overall plant nutrient requirement. This creates a gap between demand and supply of fertilizer, which is further anticipated to amplify in future. Such a lacuna can be bridged using organic fertilizers supplied at a tune of 6-million tonnes of plant nutrients (Faridvand *et al*., 2021; Kumar *et al.,* 2023). Besides, there is substantial loss of nutrients through pathways such as leaching, volatilization denitrification, and surface erosion (Nyawade *et al*., 2019). To refill these nutrients, coupled use of organic and inorganic nutrient sources at optimum doses and suitable time is vital. Hence, efforts are needed to harness the potentiality of sugar industry wastes effectively. Indian sugar mills and distilleries generate huge amount of pressmud and distillery effluent, which can be utilized as a source of organic matter and plant nutrients (Chattha *et al.,* 2019). Furthermore, another organic source farm yard manure (FYM) also possesses immense potential in maintaining soil fertility status by improving soil properties (Mwadalu *et al*., 2022; Ranjan *et al*., 2023).

The application of fertilizers by farmers without knowledge of the status of soil fertility and nutrient requirements by crops can have adverse effects on the crop and soil in terms of nutrient deficiency or toxicity. A directed yield methodology, however, which makes fertilizer recommendations based on yield targets, is unique as it indicates not only the appropriate fertilizer dose based on soil testing, but also the level of yield which can be achieved if suitable practices are adhered to in growing the crop (Tayade *et al*., 2020). Moreover, farmers regularly use chemical fertilizers, which are sturdily associated with climate change, environmental degradation, and deteriorating soil health (Kumar *et al*., 2024a). Therefore, to make sugarcane production more rewarding there is a need to improve the NPK recommendation up to the preferred levels in the lower Indo-Gangetic plains with enormous calcareous soils.

The scientific knowledge regarding the impact of integrated nutrient management on cane productivity as well as juice quality in sugarcane fields remain essentially unstudied. Furthermore, there are few literatures available on the impact of different planting materials along with various integrated nutrient management strategies and soil test-based crop response-based fertilizer application on the growth and yield of the sugarcane. Based on the highlighted facts and research gap, this study was designed to determine best planting material with the most effective integrated nutrient management practice for achieving better growth attributes, yield and juice quality of sugarcane.

Materials and Methods

Study site description

A field experiment was conducted during the year 2022-24 at the Sugarcane Research Institute of Dr. Rajendra Prasad Central Agricultural University, Pusa, Bihar, India (85° 40' E longitude, 25° 59' N latitude, and 52.1 meter above mean sea level). The area receives an annual rainfall of 1234.7 mm (Kumar *et al*., 2024a). The average maximum temperature varies from 19 to 40 °C and minimum temperature between 7 to 27 °C. Between July and September, 75-80% of the rain occurs. There were significant patterns of rainfall variability during the two years of study. As illustrated in Figure 1, the total rainfall was 801.2 mm (2022-23) and 1525.8 mm (2023-24). The soil of experimental field was classified as sandy loam having 237.1 kg/ha of available nitrogen (Subbiah and Asija, 1956), 20.5 kg/ha of available phosphorus (Olsen *et al*., 1954) and 144.2 kg/ha of available potassium (Jackson, 1973).

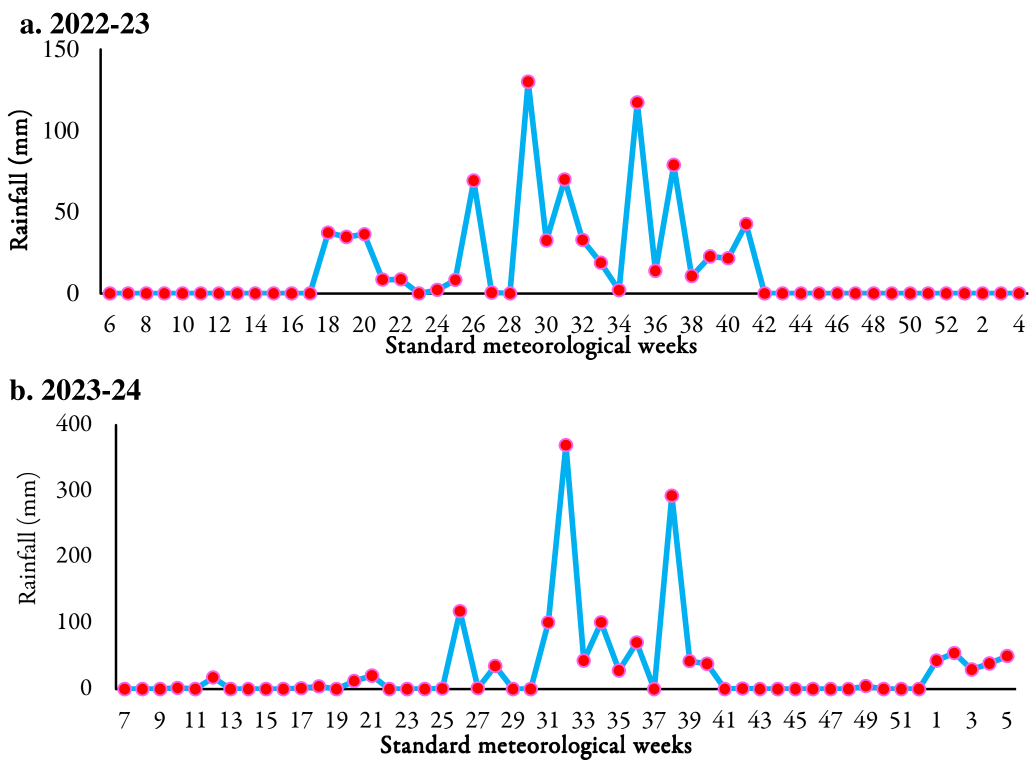

Figure 1. Rainfall (mm) during the study period (a) 2022–23 and (b) 2023–24

Experimental treatments and design

The experiment was conducted in a factorial randomized block design, consisting twenty-eight distinct treatment combinations replicated thrice. Factor A consists of four planting materials viz. single budded sett (P_1), double budded sett (P_2), three budded sett (P_3) and tissue culture plantlets (P_4). On the other hand, fertility levels in factor B viz. F_0: control (no NPK), F_1: recommended dose of fertilizer (RDF) (150 kg N, 85 kg P_2O_5 and 60 kg/ha K_2O), F_2: soil test-based RDF (175.8 kg N, 82.2 kg P_2O_5 and 66.6 kg/ha K_2O), F_3: RDF + 25% N through pressmud + $ZnSO_4$ (25 kg/ha), F_4: soil test-based RDF + 25% N through pressmud + $ZnSO_4$ (25 kg/ha), F_5: RDF + 25 % N through FYM + $ZnSO_4$ (25 kg/ha) and F_6: soil test-based RDF+ 25% N through FYM + $ZnSO_4$ (25 kg/ha). Soil test-based RDF was calculated on the basis of equations given below for sugarcane in Bihar for calcareous soil:

FN: 0.236 T – 0.275 SN

FP_2O_5: 0.113 T – 1.59 SP

FK_2O: 0.101 T – 0.25 SK

where, FN, FP_2O_5 and FK_2O are fertilizers N, P_2O_5 and K_2O in kg/ha, respectively; T is the yield target in t/ha which was 101.6 t/ha; SN (soil nitrogen), SP (soil phosphorus) and SK (soil potassium), respectively, are alkaline $KMnO_4$–N, Olsen–P and NH_4OAc–K in kg/ha.

The nutrient content of FYM was 0.41: 0.20: 0.38 % whereas in pressmud it was 1.27: 0.24: 0.52% N: P: K (Jackson, 1973) respectively. The gross size of each plot was 10.0 m × 5.4 m. A mouldboard plough was used to prepare the experimental field for planting, followed by two ploughings using a tractor operated disc harrow/cultivator. After planking, the area was levelled, and the layout was done. Deep furrows (15-20 cm) were opened for planting of setts or plantlets of sugarcane (Rajendra Ganna-1 (CoP 16437)) were used for planting as per the treatments. A basal dose of 1/3rd N and full P_2O_5 and K_2O were applied as per treatments through urea, diammonium phosphate, and muriate of potash. The full dose of pressmud, FYM and $ZnSO_4$ was applied in basal as per the treatments accordingly. After manually placing, setts were covered through soil not more than 2-3 inches on setts. Top dressing of the remaining 2/3rd N was done in two equal splits; first one before first irrigation and second one before earthing up. Planting was done on 11th February 2022, and on 14th February 2023 during the first and second cropping seasons. All other package of practices which are recommended for raising sugarcane crop in the region were followed. The crop was harvested on 28th January 2023 and 31st January 2024 during the first and second year respectively.

Sampling measurement and analysis

The cane growth and yield were recorded biometrically over two years, including plant height, number of tillers, total chlorophyll content, leaf area index, dry matter accumulation, and cane yield. At 120 days after planting (DAP), tillers were counted similarly for each plot and presented in thousands per hectare. At 240 DAP, ten randomly selected plants from each plot were measured from ground level to the last fully expanded leaf. Then, their average was calculated for the estimation of plant height. From the net plot area, two plants were pulled up from each treatment and plants were then broken up, and 100 grams of the total (homogeneous samples) were air-dried first, and then oven dried at 65.5 °C. Dry weight for each plant and treatment was thus measured at 240 DAP. Total chlorophyll content at 240 DAP were estimated with the help of acetone method (Arnon, 1949).

Leaf area from 1 m^2 area from each treatment plot at 240 DAP was measured as mentioned earlier. After that leaf area index (LAI) was determined by using the formula given below:

$$LAI = \frac{\text{Leaf area per plant } (cm^2)}{\text{Land area covered } (cm^2)}$$

At harvest, cane yield estimation was done and to avoid border effects, crop was harvested manually from net plots. After topping the plants and removing the trash from the stems, the cane yield was determined and then was expressed in t/ha. To extract cane juice, 10 randomly selected canes were crushed in an electric roller cane crusher. Then, for estimating the values of brix, pol, reducing sugar, purity, commercial cane sugar (CCS) and juice recovery percentage, five canes were randomly selected from each treatment. Brix, pol and reducing sugar % parameters were recorded from the extracted juice as per standard methods given by Meade and Chen (1977). The purity % was calculated by dividing pol % over corrected brix and multiplied by 100. CCS % was worked out using the formula (Parthasarthy, 1979):

CCS % = [Sucrose % - 0.4 (Brix % - Sucrose %)] × 0.73

The juice recovery % was calculated by dividing weight of the juice of 10 canes over weight of 10 canes and multiplied by 100. Sugar yield was determined by using the formula given below:

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

Statistical analysis

For the analysis of variance (ANOVA), the Statistical Package for Social Sciences (SPSS v. 23.0) software was used for all the parameters. In order to determine the significance of the treatment effect, F-tests were conducted at a level of significance of 5%. Using the least significant difference (LSD) approach, differences between treatments means were assessed (Gomez and Gomez, 1984). The box plots and correlation panel were drawn using the ggplot 2 package of R-software version 4.3.1.

Results

Plant height

Planting material and integrated nutrient management strategies have significantly influenced plant height of sugarcane. The maximum (288.5, 292.1 cm) and minimum (251.5, 253.6 cm) plant height at 240 DAP was recorded under tissue culture plantlets (P_4) and single budded sett (F_1) during the two years of study respectively (Table 1). Among integrated nutrient management practices, soil test-based RDF + 25% N through pressmud + $ZnSO_4$ (25 kg/ha) resulted in maximum plant height at 240 DAP which was 63.4 and 69.8 % higher as compared to control in first and second year respectively.

Leaf Area Index

LAI at 240 DAP during both the years, was observed maximum with tissue culture plantlets and minimum under single budded sett. Single budded sett (P_1) showed a reduction of 18.7 % in LAI at 240 DAP as compared to tissue culture plantlets in the first year. During second year of the study, an enhancement of 22.2 and 19.0 % was found with tissue culture plantlets and three budded setts respectively in comparison to single budded sett (Table 1). In both the years of the study, soil test-based RDF + 25% N through pressmud + $ZnSO_4$ (F_4) recorded signicantly maximum LAI over all the nutrient management treatments except soil test-based RDF + 25 % N through FYM + $ZnSO_4$ (F_6) and RDF + 25% N through pressmud + $ZnSO_4$ (F_3) (Table 1). A decline of 22.8 and 17.9 % in RDF (F_1) in comparison to F_4 was found in 2022-23 and 2023-24 respectively.

Total chlorophyll content

Total chlorophyll content did not vary significantly with planting materials but was found maximum with tissue culture plantlets follwed by three buded set in both the years at 240 DAP. However, different integrated nutrient management practices affected total chlorophyll content and maximum was under soil test-based RDF + 25% N through pressmud + $ZnSO_4$ which was 23.2, 28.8% and 11.4, 10.6% as compared to control and RDF respectively but was on par with RDF + 25% N through pressmud + $ZnSO_4$ and soil test-based RDF + 25% N through FYM + $ZnSO_4$ in both the years (Table 1).

Table 1. Impact of integrated nutrient management and different planting material on growth attributes of sugarcane at 240 days after planting (DAP)

Treatments	Plant height (cm)		Leaf Area Index		Total chlorophyll (mg/g)		Dry matter accumulation (t/ha)	
	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24
Planting material								
P_1: Single budded sett	251.5^{d}	253.6^{d}	3.30^{d}	3.42^{d}	1.66^{a}	1.68^{a}	25.7^{d}	26.6^{d}
P_2: Double budded sett	263.2^{c}	265.0^{c}	3.55^{c}	3.67^{c}	1.68^{a}	1.71^{a}	28.6^{c}	29.5^{c}
P_3: Three budded sett/ conventional method	284.3^{ab}	287.3^{ab}	3.95^{ab}	4.07^{ab}	1.72^{a}	1.76^{a}	31.5^{a}	32.7^{a}
P_4: Tissue culture plantlets	288.5^{a}	292.1^{a}	4.06^{a}	4.18^{a}	1.76^{a}	1.78^{a}	30.7^{ab}	31.5^{ab}
LSD (p≤0.05)	14.2	14.9	0.21	0.19	NS	NS	1.7	1.8
Fertility level								
F_0: Control	185.4^{f}	180.2^{f}	3.08^{f}	2.96^{f}	1.51^{g}	1.46^{g}	13.2^{g}	12.6^{g}
F_1: Recommended dose of fertilizer (RDF)	265.1^{de}	269.9d^{e}	3.38^{e}	3.62^{e}	1.67^{def}	1.68^{def}	25.0^{f}	26.0^{f}
F_2: Soil test-based RDF	276.3^{cde}	280.2^{cde}	3.56^{de}	3.76^{de}	1.68^{bcde}	1.70^{cde}	30.7^{de}	31.8^{de}
F_3: RDF + 25% N through pressmud + $ZnSO_4$	298.4^{ab}	299.3^{abc}	4.08^{ab}	4.11^{abc}	1.81^{ab}	1.82^{abc}	34.3^{ab}	35.0^{abc}
F_4: Soil test-based RDF+ 25% N through pressmud + $ZnSO_4$	303.0^{a}	305.9^{a}	4.15^{a}	4.27^{a}	1.86^{a}	1.88^{a}	35.1^{a}	36.6^{a}
F_5: RDF + 25% N through FYM + $ZnSO_4$	282.4^{bcd}	285.5^{bcd}	3.78^{cd}	3.95^{bcd}	1.71^{bcd}	1.74^{bcd}	31.8^{cd}	32.9^{cd}
F_6: Soil test-based RDF + 25% N through FYM + $ZnSO_4$	292.6^{abc}	300.7^{ab}	3.97^{abc}	4.18^{ab}	1.72^{abc}	1.85^{ab}	33.8^{abc}	35.5^{ab}
LSD (p≤0.05)	18.8	19.7	0.28	0.26	0.13	0.12	2.3	2.3
Planting material × Fertility level	NS	NS	NS	NS	NS	NS	NS	NS

Different letters indicate significant differences at the 0.05 level; NS: non-significant difference

Dry matter accumulation

Among different planting materials, dry matter accumulation at 240 DAP was maximum under three budded setts followed by tissue culture plantlets in both the years (Table 1). In the first year of the experimentation, a decline in dry matter accumulation of 18.4 % was found in single budded set over three budded sett while it was 18.7% in the succeeding year. Nutrient management strategies also affected dry matter accumulation and at 240 DAP and it was found maximum with application of soil test-based RDF + 25% N through pressmud + $ZnSO_4$ (F_4) (35.1, 36.6 t/ha respectively) and minimum under control (F_0) (13.2, 12.6 t/ha respectively). Moreover, F_4 showed 28.7, 29.0% and 12.5, 13.1% increase in dry matter as compared to RDF (F_1) and soil-test based RDF (F_2) during 2022-23 and 2023-24 respectively (Table 1).

Number of tillers

During both the years of the experiment, significantly highest number of tillers ('000/ ha) at 120 DAP was observed under tissue culture plantlets which was statistically at par with three budded sett and showing an increase of 18.5 and 19.8% as compared to single budded sett respectively (Figure 2). The number of tillers in soil test-based RDF+ 25% N through pressmud + $ZnSO_4$ (F_4) was statistically on par with RDF + 25% N through pressmud + $ZnSO_4$ (F_3) and soil test-based RDF + 25% N through FYM + $ZnSO_4$ (F_6). Furthermore, F_0 recorded a decrease of 24.8 and 27% in number of tillers ('000/ ha) as compared to F_4 in both the years respectively (Figure 2).

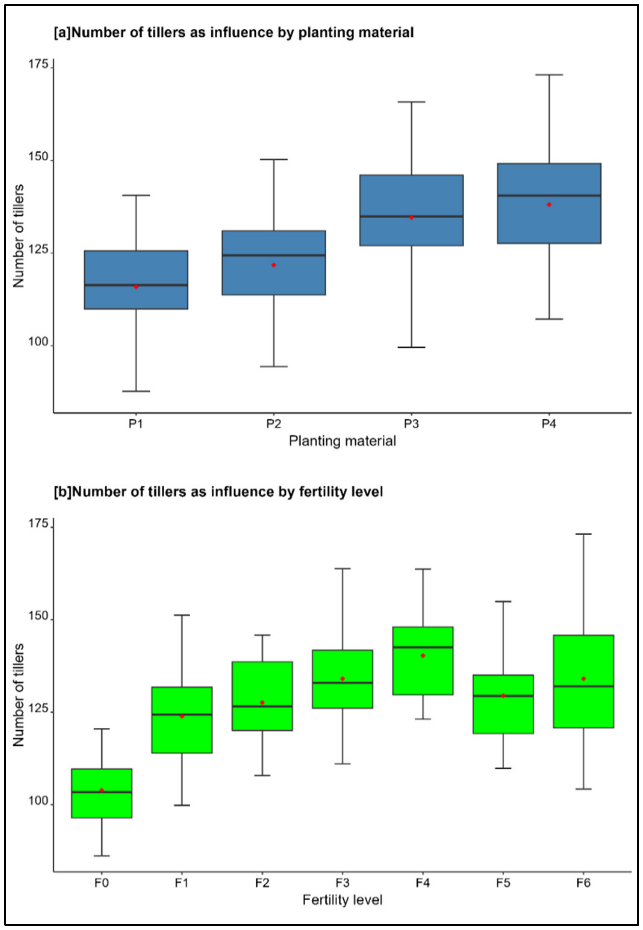

Figure 2. Number of tillers ('000/ ha) at 120 DAP (mean value of two years) in sugarcane as influenced by [a] planting material and [b] fertility level

*Treatment details given in materials and methods

Juice quality parameters

Different juice quality parameters viz. brix, pol, purity, CCS, reducing sugar, juice recovery % were estimated at 240 DAP (Table 2) and 300 DAP (Table 3). However, all these parameters were not affected significantly by various planting materials and integrated nutrient management practices. On the other hand, during both the years of experimentation, all the juice quality parameters were found highest in three budded sett and minimum was with single budded set at 300 DAP. In case of nutrient management strategies, brix, pol and reducing sugar percentage was highest in soil test-based RDF (F_2) while integrated nutrient management practices (F_3 to F_6) showed highest purity, CCS and juice recovery percentage (Table 3).

Table 2. Impact of integrated nutrient management and different planting material on juice quality of sugarcane at 240 days after planting (DAP)

Treatments	Brix (%)		Pol (%)		Purity (%)		Commercial cane sugar (CCS) (%)		Reducing sugar (%)		Juice recovery (%)	
	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24
Planting material												
P_1: Single budded sett	19.0	18.9	16.64	16.29	87.5	86.4	11.44	11.14	2.97	2.83	57.5	57.2
P_2: Double budded sett	19.2	19.0	16.77	16.52	87.1	87.0	11.52	11.33	3.01	2.88	58.3	58.0
P_3: Three budded sett/ conventional method	19.7	19.4	17.13	16.84	87.0	86.8	11.75	11.54	3.05	2.92	59.7	59.3
P_4: Tissue culture plantlets	19.4	19.2	16.94	16.58	87.3	86.5	11.65	11.34	3.04	2.90	59.1	58.6
LSD (p≤0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Fertility level												
F_0: Control	19.1	18.7	16.40	16.13	86.1	86.5	11.19	11.02	2.94	2.78	57.4	57.0
F_1: Recommended dose of fertilizer (RDF)	19.6	19.3	17.09	16.77	87.4	86.9	11.74	11.51	3.06	2.91	57.9	57.5
F_2: Soil test-based RDF	19.9	19.5	17.25	16.91	86.7	86.8	11.81	11.59	3.08	2.93	58.1	57.9
F_3: RDF + 25% N through pressmud + $ZnSO_4$	19.3	19.0	16.88	16.48	87.5	86.8	11.62	11.30	3.02	2.89	59.5	58.7
F_4: Soil test-based RDF+ 25% N through pressmud + $ZnSO_4$	19.4	19.3	17.01	16.67	87.7	86.4	11.71	11.39	3.03	2.90	60.0	59.6
F_5: RDF + 25% N through FYM + $ZnSO_4$	19.0	18.9	16.67	16.35	87.7	86.5	11.49	11.19	2.98	2.87	58.7	58.5
F_6: Soil test-based RDF + 25% N through FYM + $ZnSO_4$	19.2	19.1	16.79	16.59	87.7	86.9	11.56	11.38	3.01	2.89	59.0	58.7
LSD (p≤0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Planting material × Fertility level	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

"NS" represents non significant

Table 3. Impact of integrated nutrient management and different planting material on juice quality of sugarcane at 300 days after planting (DAP)

Treatments	Brix (%)		Pol (%)		Purity (%)		Commercial cane sugar (CCS) (%)		Reducing sugar (%)		Juice recovery (%)	
	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24
Planting material												
P_1: Single budded sett	19.8	19.7	17.46	17.31	88.0	88.3	12.05	11.94	2.67	2.60	60.5	60.2
P_2: Double budded sett	20.0	19.8	17.79	17.69	89.0	89.3	12.32	12.25	2.71	2.65	61.3	60.7
P_3: Three budded sett/ conventional method	20.4	20.2	17.96	17.80	88.1	88.1	12.38	12.27	2.75	2.69	62.7	61.9
P_4: Tissue culture plantlets	20.3	20.0	17.82	17.70	88.1	88.4	12.28	12.21	2.74	2.67	62.1	61.1
LSD ($p \leq 0.05$)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Fertility level												
F_0: Control	19.7	19.5	17.26	17.10	87.7	87.6	11.86	11.72	2.64	2.56	60.0	59.6
F_1: Recommended dose of fertilizer (RDF)	20.5	20.3	17.90	17.82	87.3	87.8	12.29	12.21	2.75	2.68	60.9	60.1
F_2: Soil test-based RDF	20.6	20.4	17.98	17.90	87.3	88.1	12.36	12.35	2.77	2.69	61.1	60.8
F_3: RDF + 25% N through pressmud + $ZnSO_4$	20.1	19.8	17.81	17.60	88.7	88.9	12.34	12.21	2.72	2.65	62.6	61.3
F_4: Soil test-based RDF+ 25% N through pressmud + $ZnSO_4$	20.3	20.1	17.87	17.77	88.4	88.5	12.36	12.30	2.73	2.67	63.1	62.3
F_5: RDF + 25% N through FYM + $ZnSO_4$	19.8	19.6	17.71	17.55	89.5	89.7	12.28	12.18	2.69	2.64	61.8	61.2
F_6: Soil test-based RDF + 25% N through FYM + $ZnSO_4$	20.0	19.9	17.75	17.64	89.3	89.0	12.31	12.22	2.71	2.66	62.1	61.6
LSD ($p \leq 0.05$)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Planting material × Fertility level	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

"NS" represents non significant

Cane yield

Three budded setts showed highest cane yield which was 33.9 and 34.5% more as compared to single budded set in both the years respectively (Table 4). During first year of the study, a decrease in cane yield of 14.6 and 13.0% was observed under two budded setts as compared to three budded sett and tissue culture plantlets respectively. In case of nutrient management strategies, soil test-based RDF + 25% N through pressmud + $ZnSO_4$ (F_4) enhanced cane yield by 38.2 and 13% in comparison to RDF and soil test-based RDF in the first year of study. Furthermore, in the second year, cane yield was reduced by 61.4% in F_0 as compared F_4. Moreover, during second year of the experimentation, application of RDF + 25% N through FYM + $ZnSO_4$ (F_5) reduced the cane yield by 7.7 and RDF by 27.2% over soil test-based RDF+ 25% N through pressmud + $ZnSO_4$. A significant interaction for cane yield was obtained for planting material × fertility level during the second year of study and three budded setts (P_3) with soil test-based RDF+ 25% N through pressmud + $ZnSO_4$ (F_4) had the highest cane yield (Figure 3a).

Table 4. Impact of integrated nutrient management and different planting material on yield (t/ha) of sugarcane

Treatments	Cane yield (t/ha)		Sugar yield (t/ha)	
	2022-23	2023-24	2022-23	2023-24
Planting material				
P_1: Single budded sett	72.5^{d}	73.3^{d}	8.7^{d}	8.8^{d}
P_2: Double budded sett	82.9^{c}	84.1^{c}	10.2^{c}	10.3^{c}
P_3: Three budded sett/ conventional method	97.1^{a}	98.6^{a}	12.1^{a}	12.2^{a}
P_4: Tissue culture plantlets	93.7^{ab}	95.5^{ab}	11.5^{ab}	11.7^{ab}
LSD ($p \leq 0.05$)	5.9	5.8	0.8	0.8
Fertility level				
F_0: Control	41.8^{f}	40.5^{f}	5.0^{f}	4.8^{f}
F_1: Recommended dose of fertilizer (RDF)	74.7^{e}	76.4^{e}	9.2^{e}	9.3^{e}
F_2: Soil test-based RDF	91.4^{cd}	92.3^{d}	11.3^{cd}	11.4^{cd}
F_3: RDF + 25% N through pressmud + $ZnSO_4$	101.1^{ab}	101.7^{abc}	12.5^{ab}	12.4^{abc}
F_4: Soil test-based RDF+ 25% N through pressmud + $ZnSO_4$	103.3^{a}	105.0^{a}	12.8^{a}	12.9^{a}
F_5: RDF + 25% N through FYM + $ZnSO_4$	95.3^{bcd}	96.8^{bcd}	11.7^{bcd}	11.8^{bcd}
F_6: Soil test-based RDF + 25% N through FYM + $ZnSO_4$	98.1^{abc}	102.5^{ab}	12.1^{abc}	12.5^{ab}
LSD ($p \leq 0.05$)	7.8	7.6	1.0	1.0
Planting material × Fertility level	NS	15.3	NS	2.0

Different letters indicate significant differences at the 0.05 level; NS: non-significant difference

Sugar yield

During first year of the study, three budded sett showed highest sugar yield which was 39.0 and 18.6% more as compared to single budded sett and two budded setts respectively (Table 4). During second year of the study, similar trend was followed among the planting materials. In case of fertility levels, F_4 increased sugar yield by 38.7 and 13.1% as compared to RDF and soil test-based RDF in the second year of study. Furthermore, in the second year, sugar yield was reduced by 62.8 and 61.6% in F_0 as compared F_4 and F_6. A significant interaction for cane yield was obtained for planting material × fertility level during the second year of study (Figure 3b).

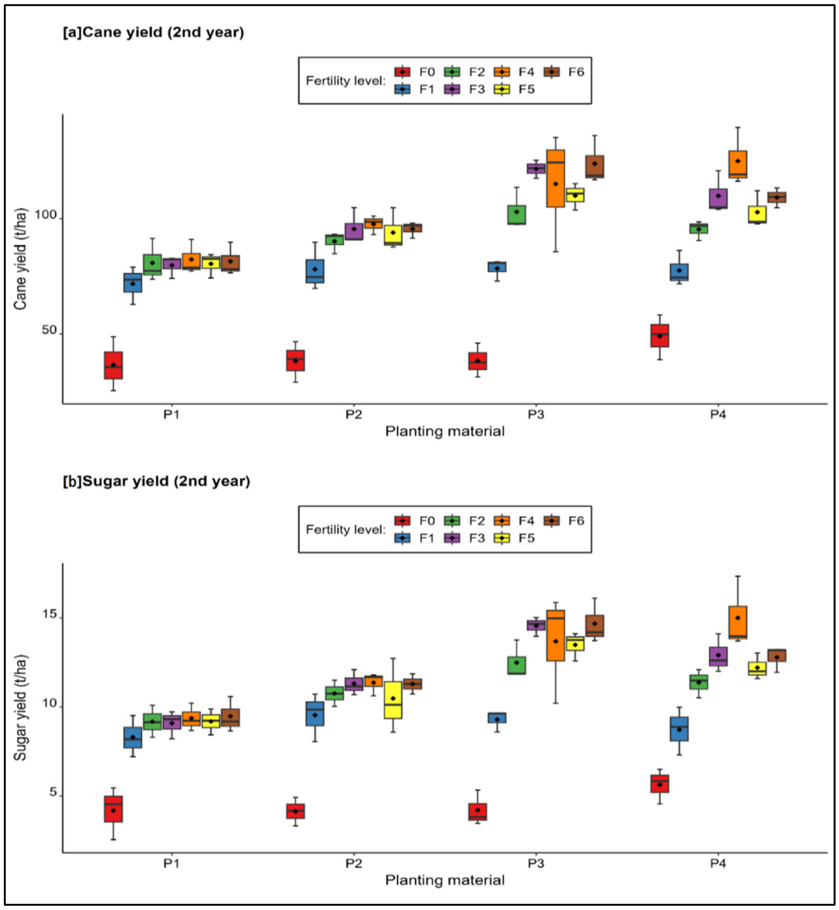

Figure 3. Interaction effect of planting material and fertility level on the cane yield (a) and sugar yield (b) of sugarcane in the second year of experimentation
*Treatment details given in materials and methods

Discussion

Growth attributes

Sugarcane raised through tissue culture plantlets showed higher growth attributes followed by three budded setts as compared to single budded setts and two budded setts. It was happened due to fast growth and early vigour in tissue culture plantlets and three bud setts. There is a possibility that this enhanced growth attributes in tissue culture plantlets and three budded setts may be due to better soil microclimates that allow for root growth, optimal sugarcane metabolism, and other favorable conditions for germination in comparison with single or double budded sett plantings. Moreover, a better root system contributes to a better swelling and sprouting of cane buds (Otto *et al*., 2022). Due to well-established root system the effective uptake of moisture and nutrients in the tissue culture plantlets might have increased the plant height, higher number of tillers. The reason behind this could be abundant light interception, aeration and lesser plant competition prevailed with interplant spacing would have offer congenial environment for each seedling for effective utilization of above resources for metabolic activities of sugarcane compared to conventional double or three bud method. In contrast, the sugarcane crop derived from tissue culture plants was characterized with higher number of thin canes with significantly lesser cane diameter in comparison to three budded cane setts propagated crops. The high tillering might have resulted in thinner canes since cane thickness is inversely related to the number of tillers per clump, resulting in lower dry matter accumulation than with three budded sets (Sugeerthi *et al*., 2018).

Application of nutrient through soil test based inorganic fertilizers along with FYM or pressmud significantly increased different growth attributes compared to the application of soil test-based RDF or RDF alone. The increase in growth attributes may be attributed to the fact that optimum inorganic fertilizers based on soil nutrient status applied in combination with organic sources and micronutrient are better utilized than inorganic source alone. This might be due to beneficial effect of pressmud or FYM which improves the soil aeration, permeability, aggregation, water-holding capacity and biological properties, thereby enhancing the nutrient use efficiency and ultimately leading to better plant growth (Bairwa *et al*., 2023). These results are also in line with the findings of Kumar *et al*. (2024b) who reported considerable increase in plant population and dry matter production with 150% of RDF + 5 t vermicompost/ha + $ZnSO_4$ + phosphate solubilizing bacteria as compared to RDF alone. The increased absorption of nutrients in soil test based integrated nutrient management treatments might have helped to improve the growth which led to higher LAI. The results of this study are in close agreement with those of Banerjee *et al*. (2018), who reported that the application of organic manure in conjunction with chemical fertilizer increased the LAI. Furthermore, Bokhtiar and Sakurai (2005) revealed that with increase in LAI leads to a considerable increase in cane and sugar yield of sugarcane. The increase in the rate of biosynthesis of various plant metabolites and physiological process in the plant system due to combined application of organic and inorganic application of fertilizers leading to increased rate of tiller formation. The better nutritional environment for plant growth at active vegetative stages as a result of improvement in root growth, cell multiplication and elongation in the plant body, which ultimately increased the plant height. The higher dry matter accumulation in soil test RDF + pressmud or FYM + Zn added plots was primarily responsible for higher sugar yield. The positive effect of pressmud and FYM on sugar yield has also been reported by Tayade *et al*. (2020) and Shukla *et al*. (2023).

As Mg and N are the soil nutrients that constitute chlorophyll, effects of inorganic fertilizer in combination with pressmud or FYM on total chlorophyll content in cane leaf was observed. During the both year of the study, an increasing trend of total chlorophyll was noticed in the soil test based inorganic fertilizer and pressmud or FYM and $ZnSO_4$ treated plot (Figure 4). Since, N plays major role in the growth of sugarcane and in the synthesis of sugar, N management in conjunction with these soil test-based RDF along with organic amendments will be critical in future experiments to optimize sugarcane biomass and sugar yield (Orndorff *et al*., 2018). Overall, a balanced supply of micro-and macro-nutrients is indispensable for high-quality, long-term cane production. As Zn plays a vital role in the enhancement of plant growth, the increase in plant height could be attributed to more vegetative development due to the availability of balanced Zn nutrition (Majeed *et al*., 2022). Furthermore, organic manures enhance soil organic matter and improves soil structure along with its buffering capacity, whereas inorganic fertilizer-based soil test crop response approach provide nutrients. Enhanced nutrient availability in the root zone, in conjunction with greater metabolic activity at the cellular level, may have ensued in an increased vegetative part (Isha *et al*., 2024).

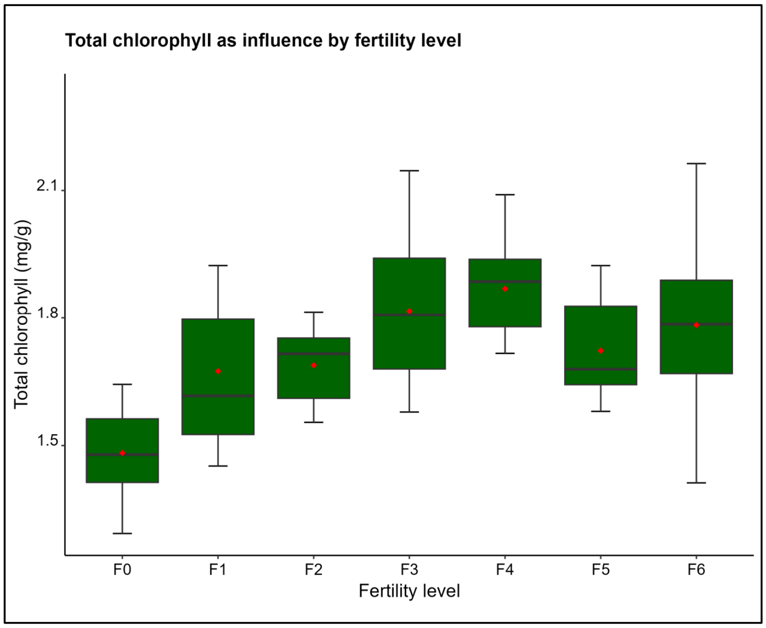

Figure 4. Total chlorophyll content of sugarcane leaves after 240 DAP (mean value of two years) in sugarcane as influenced by different fertility levels

Juice quality and yield

The juice quality parameters were lower in tissue culture derived crop as compared to conventional three budded sett leading to lower value of CCS%. Flynn *et al.* (2005) also observed that yield advantage of tissue culture lower than conventional three bud system and also reduced the sucrose% in cane. Enough storage and steady supply of nutrients due to mineralization of organic sources and release of readily available forms of nutrients from the inorganic fertilizers into the soil solution might have provided favourable condition for the absorption of required nutrients for physiological process which is a pre-requisite for adequate cane production with better juice quality. In the present study, treatments with RDF alone substantially improved juice quality like brix, pol and reducing sugar %. Whereas, The CCS, purity and juice recovery % was higher in three budded setts and integrated nutrient management treatments. Similar results were recorded by Tayade *et al*. (2021), varying fertilizer doses did not affect sucrose, purity, or CCS %. Several experiments conducted so far have demonstrated deterioration in juice quality parameters when the N levels were increased (Chattha *et al*., 2019). The value of all quality parameters of cane juice at 240 DAP and 300 DAP was lower in second year of study as compared to the first year due to the heavy rainfall of 216.7 mm (Figure 1) during the cane ripening period.

Kumar and Kumar (2020) found that the conventional method of three budded sett gave the highest cane yield and turned out to be the most economical. The productivity of sugarcane crop is determined by the tillering phase, and the number of tillers has a strong positive correlation with millable cane production. The development of uniform stalk diameter and stalk weight in tissue culture crops has been well documented by Sandhu *et al*. (2009). As a consequence, the low initial crop vigour in the main field, inadequate rooting biomass, and the competition among seed cane buds for inputs might have resulted in a lower level of sugarcane growth attributes, juice quality, and yield when compared with two budded and single budded setts (Patnaik *et al*., 2016).

Calculated amount of nutrients required for targeted yield of sugarcane indicated that there was need to apply fertilizer as per the soil nutrient status. Therefore, the common recommendation for the crop does not hold significance. Thus, as per RDF, farmers were not applying balanced or adequate dose of fertilizers. The fertilizers being applied by the farmers were much lower than crop requirements. As nitrogen (N), a constituent of amino acids, plays an important role in the partitioning of photosynthates, and protoplasts directly impact plant growth and development by improving the utilization of photosynthesis, which results in a higher yield of cane when all essential nutrients, including nitrogen (N), are adequately supplied (Nawaz *et al*., 2017; Bhilala *et al*., 2023). In contrast higher doses of N through organic and inorganic sources recorded numerically less sucrose content when compared with lower doses. Moreover, Zhao *et al*. (2015) showed that pressmud application significantly increased cane yield by 125% in the first ratoon cane and 21% in the second ratoon cane. Sugar yield is analogous to healthy sugarcane crop; balanced fertilized sugarcanes are thick, long and always giving maximum juice recovery as compared to unbalanced fertilized ones. Lamba *et al.* (2016) reported that application of micronutrients such as Fe and Zn in addition to NPK fertilizers was essential to attain maximum benefits from sugarcane crop, as integration of different type of fertilizers and micronutrients can improve soil fertility and hence increase cane yield. The increase in sugarcane biomass yield and sugar yield in the various amendment treatments compared to the control shows positive results for their use as organic amendments along with inorganic fertilizers. The correlation results indicated that cane yield was positively associated with the different growth, sugar and cane yield (Figure 5). Cane yield revealed significantly positive correlation with dry matter (R^2=0.936), plant height (R^2= 0.842) and number of tillers (R^2=0.751).

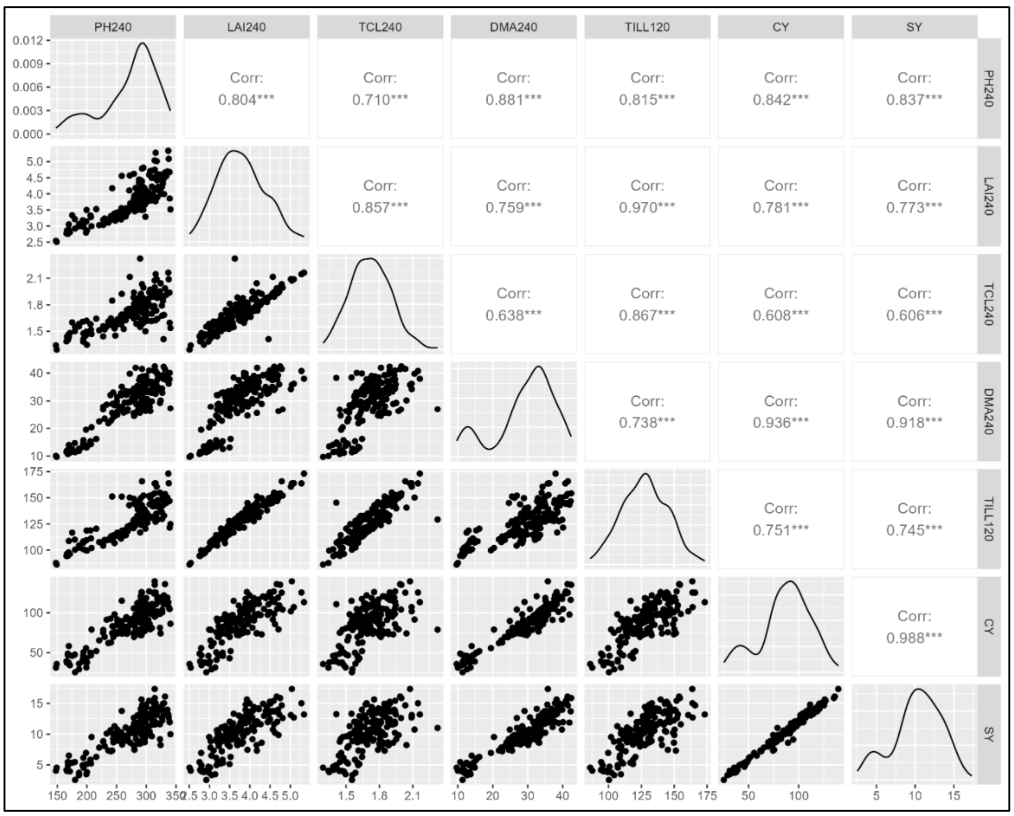

Figure 5. Correlation panel graph of sugarcane parameters (PH240: plant height 240 days after planting (DAP), TILL120: number of tillers 120DAP, LAI240: leaf area index at 240 DAP, TCL240: total chlorophyll content at 240 DAP, DMA240: dry matter accumulation at 240DAP, CY: cane yield, SY: sugar yield)

Conclusions

This study provided an opportunity for the assessment of the impact of different planting materials and various assimilated nutrient management practices on the performance and productivity of sugarcane. Planting sugarcane using tissue culture plantlets has enhanced the agronomic performance in terms of plant height, LAI and total chlorophyll content but three budded sett showed higher dry matter accumulation, juice quality parameters and yield of sugarcane. Among nutrient management practices, soil test-based RDF + 25% N through pressmud or FYM + $ZnSO_4$ of 25 kg/ha has resulted in higher growth and yield of sugarcane. There is a lack of literature on sugarcane cultivation using tissue culture plantlets and its interaction with nutrient management strategies. Therefore, in order to enhance the productivity of sugarcane, future research should be focused on this area for recommendation of best organic amendment along with soil test-based RDF and micronutrient combination for different planting materials.

Authors' Contributions

Conceptualization: SS, NK; Data curation: SS, NK and LR; Formal analysis: SS, NK; Investigation: SS, NK and LR; Methodology: SS, NK, HS and VK; Resources: SS, NK and AKS; Software: SS, NK; Supervision: NK, HS, VK, K, SK; Writing - original draft: SS; Writing - review and editing: SS, NK and LR. All authors read and approved the final manuscript.

Ethical approval (for researches involving animals or humans)

Not applicable.

Acknowledgements

The authors would like to thank Dr. Rajendra Prasad Central Agricultural University, Pusa, Bihar for providing all the necessary facilities for conducting this research work.

Conflict of Interests

The authors declare that there are no conflicts of interest related to this article.

References

Arnon D (1949). Copper enzymes isolated chloroplasts, polyphenoloxidase in *Beta vulgaris.* Plant Physiology 24:1-15. *https://doi.org/10.1104%2Fpp.24.1.1*

Bairwa R, Jha CK, Thakur SK, Mamta, Roy DK, Brajendra (2023). Carbon pools and indices under activated trash treatments in sugarcane plant–ratoon system grown in calcareous soil of subtropics. Sugar Tech 25(6):1433-1444. *http://doi.org/10.1007/s12355-023-01280-1*

Banerjee K, Puste AM, Gunri SK, Jana K, Barman M (2018). Effect of integrated nutrient management on growth, yield, quality and soil health of spring planted sugarcane (*Saccharum officinarum*) in West Bengal. Indian Journal of Agronomy 63(4):499-505. *http://doi.org/10.59797/ija.v63i4.5688*

Bhilala S, Rana L, Kumar N, Kumar A, Meena SK, Singh AK (2023). Yield and juice quality in sugarcane influenced by split application of nitrogen and potassium under subtropical climates. Environment and Ecology 41(1B):492-495.

Bokhtiar SM, Sakurai K (2005). Effect of application of inorganic and organic fertilizers on growth, yield and quality of sugarcane. Sugar Tech 7(1):33-37. *https://doi.org/10.1007/BF02942415*

Boschiero BN, de Castro SGQ, da Cruz LP, Carvalho JLN, Silva SR, Bressiani JA, Köll OT (2023). Biomass yield, nutrient removal, and chemical composition of energy cane genotypes in southeast Brazil. Industrial Crops and Products 191:115993. *https://doi.org/10.1016/j.indcrop.2022.115993*

Chattha MU, Hassan MU, Barbanti L, Chattha MB, Khan I, Usman M, ... Nawaz M (2019). Composted sugarcane by-product press mud cake supports wheat growth and improves soil properties. International Journal of Plant Production 13:241-249. *http://doi.org/10.1007/s42106-019-00051-x*

Faridvand S, Rezaei-Chiyaneh E, Battaglia M, Gitari H, Raza MA, Siddique KHM (2021). Application of bio and chemical fertilizers improves yield, and essential oil quantity and quality of Moldavian balm (*Dracocephalum moldavica* L.) intercropped with mung bean (*Vigna radiata* L.). Food and Energy Security 11:e319. *http://doi.org/10.1002/fes3.319*

Flynn J, Powell G, Perdomo R, Montes G, Quebedeaux K, Comstock JC (2005). Comparison of yield parameters and disease incidence of traditional seed cane sources and kleentek, a commercial tissue culture-based seed cane. Journal of American Society of Sugarcane Technologists 25:88-100.

Gomez KA, Gomez AA (1984). Statistical Procedures for Agricultural Research; John Wiley & Sons: Hoboken, NJ, USA.

ICAR (2022). ICAR Annual Report 2021-22. *https://icar.org.in/sites/default/files/2024-03/ICAR-AR-21-22%E2%80%93E.pdf*

Isha, Gautam P, Chandra R (2024). Soil test crop response-based site-specific integrated nutrient management in mungbean. Journal of Plant Nutrition 47(5):690-704. *http://doi.org/10.1080/01904167.2023.2280158*

Jackson ML (1973). Soil Chemical Analysis. Prentice-Hall of India Pvt. Ltd., New Delhi, pp 498.

Kumar N, Kumar V (2020). Production potential and nitrogen fractionation of sugarcane-based cropping system as influenced by planting materials and nitrogen nutrition. Sugar Tech 22(4):622-629. *https://doi.org/10.1007/s12355-020-00809-y*

Kumar N, Kumar V, Kishor K, Singh AK (2024b). Optimizing nutrient application and nitrogen transformation to maximize the growth and productivity of bud chip transplanted sugarcane. Journal of Plant Nutrition 1-14. *http://doi.org/10.1080/01904167.2024.2354201*

Kumar N, Rana L, Singh AK, Pramanick B, Gaber A, Alsuhaibani AM, ... Hossain A (2023). Precise macronutrient application can improve cane yield and nutrient uptake in widely spaced plant-ratoon cycles in the Indo-Gangetic plains of India. Frontiers in Sustainable Food Systems 7:1223881. *https://doi.org/10.3389/fsufs.2023.1223881*

Kumar N, Sow S, Rana L, Kumar V, Kumar J, Pramanick B, ... Hossain A (2024a). Productivity, water use efficiency and soil properties of sugarcane as influenced by trash mulching and irrigation regimes under different planting systems in sandy loam soils. Frontiers in Sustainable Food Systems 8:1340551. *https://doi.org/10.3389/fsufs.2024.1340551*

Lamba S, Kumar V, Grewal KS (2016). Analysis of sugarcane (*Saccharum officinarum*) yield and quality in response to fertilizer application. Indian Journal of Agronomy 61(3):404-406. *https://doi.org/10.59797/ija.v61i3.4385*

Majeed A, Rashid I, Niaz A, Ditta A, Sameen A, Al-Huqail AA, Siddiqui MH (2022). Balanced use of zn, Cu, fe, and b improves the yield and sucrose contents of sugarcane juice cultivated in sandy clay loam soil. Agronomy 12(3):696. *https://doi.org/10.3390/agronomy12030696*

Meade GP, Chen JCP (1977). Cane sugar handbook. 10th ed. New York: Wiley, pp 515-545.

Mugo NJ, Karanja NN, Gachene CK, Dittert K, Gitari HI, Schulte-Geldermann E (2021). Response of potato crop to selected nutrients in Central and Eastern highlands of Kenya. Cogent Food & Agriculture 7:1898762. *https://doi.org/10.1080/23311932.2021.1898762*

Nawaz M, Chattha MU, Chattha MB, Ahmad R, Munir H, Usman M, ... Kharal M (2017). Assessment of compost as nutrient supplement for spring planted sugarcane (*Saccharum officinarum* L.). The Journal of Animal and Plant Sciences 27:283-293.

Nungula EZ, Mugwe J, Massawe BHJ, Seleiman MF, Ali N, Gitari HI (2024). GIS-AHP based approach in land evaluation and suitability assessment for sunflower (*Helianthus annus*) production. Cogent Food & Agriculture 10(1):2309831. *https://doi.org/10.1080/23311932.2024.2309831*

Nyawade SO, Gachene CKK, Karanja NN, Gitari HI, Schulte-Geldermann E, Parker M (2019). Controlling soil erosion in smallholder potato farming systems using legume intercrops. Geoderma Regional 17:e00225. *https://doi.org/10.1016/j.geodrs.2019.e00225*

Olsen BC, Cole CV, Watenabe FS, Dean LA (1954). Estimation of available phosphorus by extraction with sodium carbonate. Circular No. 939. USDA, Washington, DC.

Orndorff SG, Lang TA, Bhadha JH., McCray JM, Daroub SH (2018). Sugarcane by-products used as soil amendments on a sandy soil: Effects on sugarcane crop nutrition and yield. Journal of Plant Nutrition 41(7):928-942. *http://doi.org/10.1080/01904167.2018.1428750*

Otto R, Machado BA, da Silva ACM, de Castro SGQ, Lisboa IP (2022). Sugarcane pre-sprouted seedlings: A novel method for sugarcane establishment. Field Crops Research 275:108336. *http://doi.org/10.1016/j.fcr.2021.108336*

Parthasarthy SV (1979). Sugarcane in India. K.C.P. Ltd., Madras, pp 634-653.

Patnaik J, Singh S, Sarangi D, Nayak P (2016). Assessing potentiality of bud chip technology on sugarcane productivity, profitability and sustainability in real farming situations under south east coastal plain zone of Odisha, India. Sugar Tech 19(4):373-377. *http://doi.org/10.1007/s12355-016-0481-7*

Ranjan S, Kumar S, Dutta SK, Sow S, Kumar S, Sushant (2023). Long-term organic amendment application improves soil fertility status, nutrient accumulation and crop productivity under rice-wheat cropping system. Communications in Soil Science and Plant Analysis 54(18):2579-2589. *http://doi.org/10.1080/00103624.2023.2227240*

Salokhe S (2021). Development of an efficient protocol for production of healthy sugarcane seed cane through meristem culture. Journal of Agriculture and Food Research 4:100126. *https://doi.org/10.1016/j.jafr.2021.100126*

Sandhu SK, Gosal SS, Thind KS, Uppal SK, Sharma B, Meeta M, ... Cheema GS (2009). Field performance of micropropagated plants and potential of seed cane for stalk yield and quality in sugarcane. Sugar Tech 11:34-38. *https://doi.org/10.1007/s12355-009-0006-8*

Shukla SK, Jaiswal VP, Sharma L, Dwivedi AP, Nagargade M (2023). Integration of bio-products and NPK fertilizers for increasing productivity and sustainability of sugarcane-based system in subtropical India. Sugar Tech 25(2):320-330. *http://doi.org/10.1007/s12355-022-01182-8*

Subbiah BV, Asija GL (1956). A rapid procedure for the determination of available nitrogen in soils. Current Science 25:259-260.

Sugeerthi S, Jayachandran M, Chinnusamy C (2018). Effect of planting materials and integrated nutrient management on yield of sugarcane seed crop. Madras Agricultural Journal 105(4-6):141-146. *http://doi.org/10.29321/MAJ.2018.000118*

Tayade AS, Bhaskaran A, Anusha S (2020). IPNS–STCR-based nutrient management modules for enhancing soil health, fertilizer-use efficiency, productivity and profitability of tropical Indian sugarcane plant–ratoon agro-ecosystem. Sugar Tech 22(1):32-41. *http://doi.org/10.1007/s12355-019-00737-6*

Tayade AS, Geetha P, Anusha S (2021). Standardizing planting agro-techniques for sugarcane tissue culture plantlets and bud chip settlings. Sugar Tech 23(5):1097-1104. *http://doi.org/10.1007/s12355-021-01003-4*

Viswanathan R (2016). Varietal degeneration in sugarcane and its management in India. Sugar Tech 18(1):1-7. *http://doi.org/10.1007/s12355-015-0369-y*

Wani AK, Rahayu F, Fauziah L, Suhara C (2023). Advances in safe processing of sugarcane and bagasse for the generation of biofuels and bioactive compounds. Journal of Agriculture and Food Research 12:100549. *https://doi.org/10.1016/j.jafr.2023.100549*

Zhao D, Glaz B, Irey M, Hu C. (2015). Sugarcane genotype variation in leaf photosynthesis properties and yield as affected by mill mud application. Agronomy Journal 107:506-14. *http://doi.org/10.2134/agronj14.0401*

The journal offers free, immediate, and unrestricted access to peer-reviewed research and scholarly work. Users are allowed to read, download, copy, distribute, print, search, or link to the full texts of the articles, or use them for any other lawful purpose, without asking prior permission from the publisher or the author.

License - Articles published in ***Notulae Botanicae Horti Agrobotanici Cluj-Napoca*** are Open-Access, distributed under the terms and conditions of the Creative Commons Attribution (CC BY 4.0) License.

© Articles by the authors; Licensee UASVM and SHST, Cluj-Napoca, Romania. The journal allows the author(s) to hold the copyright/to retain publishing rights without restriction.

Notes:

- Material disclaimer: The authors are fully responsible for their work and they hold sole responsibility for the articles published in the journal.
- Maps and affiliations: The publisher stay neutral with regard to jurisdictional claims in published maps and institutional affiliations.
- Responsibilities: The editors, editorial board and publisher do not assume any responsibility for the article's contents and for the authors' views expressed in their contributions. The statements and opinions published represent the views of the authors or persons to whom they are credited. Publication of research information does not constitute a recommendation or endorsement of products involved.