Exploring the Impact of Organic-Inorganic Coupling on Nutrient Use Efficiency and Cane Yield in Calcareous Soils of the Indo-Gangetic Plains of India

Abstract

Improving nutrient use efficiency beyond its typical ceiling of 50% is imperative for enhancing sugarcane production and juice quality, while concurrently reducing reliance on synthetic fertilizers and mitigating environmental impact. To address this challenge, a field experiment was conducted during the year 2021–2022 at the Kalyanpur research farm of Dr. Rajendra Prasad Central Agricultural University, Pusa, Bihar. The study aimed to evaluate the effects of integrated nutrient management on sugarcane yield and nutrient utilization efficiency in spring-planted crops like sugarcane. Employing the randomized block design with three replications, the experiment utilized the sugarcane variety CoP-112. Although various treatments exhibited no significant influence on parameters such as germination percentage, plant height, cane length, diameter and individual cane weight, the combination of the recommended dose of fertilizers (RDF) with vermicompost and biofertilizer (*Azotobacter* + PSB) at a rate of 4 kg/ha resulted in the highest millable cane (125.4×10^3/ha) and cane yield (94.0 t/ha). This combination led to an increase of 78% and 24% over the sole prescribed dose of fertilizer and the absolute control, respectively. No substantial differences were observed in juice quality among treatments. The maximum agronomic use efficiency was achieved in plots treated with RDF + vermicompost + *Azotobacter* + PSB, exhibiting a 75% improvement over plots receiving only the recommended dose of fertilizer. The findings underscore the efficacy of integrated nutrient management as the optimal approach for fostering sustainable sugarcane production.

Keywords Sugarcane, Bio fertilizer, Vermicompost, Nutrient use efficiency, Juice quality

Introduction

In India's tropical and subtropical regions, sugarcane (*Saccharum* spp. hybrid complex) is a significant cash crop that is planted extensively. It is crucial to both our nation's agricultural and industrial sectors. Because of its many uses and exceptional capacity to satisfy the demands of an expanding population, it is frequently referred to as "wonder cane". Sugarcane is a C_4 plant with high productivity that is used to produce ethanol, a renewable transportation fuel, as well as sugar (Kumar, et. al., 2024a). According to Shankaraiah and Murthy (2005), it is far more advantageous to employ both chemical and organic fertilisers together for sustainable sugarcane production. To meet the high crop nutrient requirement, it is not viable to completely replace inorganic fertilisers with organic fertilisers. Therefore, it is crucial to employ organic manure along with inorganic fertilizer or integrated nutrient management to stop the loss of soil fertility (Sinha, et. al., 2024). Utilising organic manures, crop residues, and biofertilizers in conjunction with other plant nutrients prevents soil fertility from declining. In addition to improving soil fertility, it will maintain the physical, chemical, and biological health of the soil. This justifies the development of methods for the carefully blending of various nutrition sources, which will both increase the potency of both sources and minimize the negative effects of excessive chemical use (Chatterjee et al. 2014; Kumar,

UNDER PEER REVIEW

et. al., 2023). In order to maintain high yields, increase fertiliser use efficiency including NUE, and restore soil health, integrated nutrient management (INM), which incorporates the cooperative use of several nutrient sources, appears to be a promising technique (Singh et al. 2012; Das et al. 2015).

The Sugarcane crop uses up a lot of nutrients and severely deplete the soil's nutrients. In addition to other micronutrients, it removes 208 kilogram of N, 53 kg of P, 280 kg of K, 30 kg of S, 3.4 kg of Fe, 1.2 kg of Mn, 0.6 kg of Zn and 0.2 kg of Cu from the soil in order to produce 100 tonnes per hectare yield (Pal et al. 2021). Although mineral fertilisers are a rapid and reliable approach to increase crop productivity but their continued usage in sugarcane farming has led to the loss of essential nutrients as well. Due to the higher cost and other constraints of mineral fertilizers, farmers often use recommended quantities in a balanced proportion. Nutrient use efficiency (NUE) measures how well plants can absorb and use nutrients to produce their highest possible yields. Thus, the NUE idea encompasses three crucial processes in plants: nutrient absorption, assimilation, and utilisation. Under integrated nutrient management, it is crucial to use both readily available renewable organic and biological plant and animal sources in addition to mineral fertiliser to preserve soil sustainability (Yadav et al. 2019).

In addition, to atmospheric nitrogen fixation by *Acetobacter* in sugarcane crop (Kumar, et.al., 2024b) and supplying the soil with organic matter, sugarcane can be intercropped with a short-term, a quick-growing intercrop such as a pulse or green manure crop. After the leguminous intercrops' grains were harvested, crop leftovers might be added to the soil. As a result, part of the fixed nitrogen may be released for the sugarcane crop through the breakdown of the root system, including root nodules and residues (Gopalsundram et al. 2012). For long-term maintenance of crops and soil, the use of chemical fertilizers in conjunction with the right proportion of vermicompost can be done. This creates favourable condition for stable high cane yield. Uninterrupted nutrient supply to the crop during the growth period is pivotal to releasing the full yield potential of the crop. Vermicompost has been shown to have several positive impacts on plant growth and soil health. *Azotobacter* (nitrogen-fixing biofertilizers) have a higher potential for use in non-leguminous crops, reducing soil fertility issues while increasing productivity. In light of this, the current study aims to evaluate integrated nutrient management on cane production and nutrient use efficiency of applied nitrogen, phosphorous, and potassium in sugarcane in terms of agronomic efficiency and physiological use efficiency.

Statement of problem

The cultivation of sugarcane holds significant importance in India's tropical and subtropical regions, contributing significantly to both agricultural and industrial sectors. Termed as the "wonder cane" due to its versatility and capacity to meet growing demands, sugarcane serves as a vital source for ethanol production and sugar. However, the intensive cultivation of sugarcane necessitates substantial nutrient inputs, leading to concerns regarding soil fertility depletion. Traditional approaches relying solely on chemical fertilizers have shown limitations, with continued usage exacerbating nutrient loss and environmental impact. Integrated nutrient management emerges as a promising solution, advocating for the synergistic utilization of organic manures, biofertilizers, and mineral fertilizers to sustain soil fertility and enhance crop productivity. The inefficiency of solely relying on mineral

UNDER PEER REVIEW

fertilizers, coupled with their higher costs, underscores the urgency of implementing INM practices. Addressing the complex nutritional requirements of sugarcane while maintaining soil health necessitates a balanced approach, incorporating various nutrient sources to optimize nutrient utilization efficiency (NUE). Moreover, exploring additional strategies such as intercropping with nitrogen-fixing crops and integrating vermicompost further enhances the sustainability and productivity of sugarcane cultivation. Therefore, the present study aims to assess the efficacy of INM in enhancing sugarcane production and NUE, focusing on agronomic and physiological efficiency of applied nutrients, including nitrogen, phosphorus, and potassium, to provide insights for sustainable sugarcane cultivation practices

Materials and Methods

Experimental Site

During the sugarcane crop season of 2021–2022, the field experiment was conducted at the Research farm in Kalyanpur at the Dr. Rajendra Prasad Central Agricultural University in Pusa, Bihar. The farm is situated at 52.0 m above mean sea level and 25°95' N latitude, 85°77' E longitude. The experimental site had a subtropical climate. The experimental plot was well drained, medium upland and had uniform topography. The soil was sandy loam having *p*H 7.93, available nitrogen 230.6 kg/ha, available P_2O_5 23.5 kg/ha and available K_2O 130.3 kg/ha.

Treatment details

The trial was laid out in a randomized block design with three replications. Altogether eight treatments, viz., $T_{1:}$ Absolute control, T_2: RDF (Recommended dose of fertilisers), T_3: RDF+VC (Vermicompost), T_4: RDF+ VC+ *Azotobacter*, T_5: RDF + VC + *Azotobacter* + PSB (Phosphorus Solubilizing Bacteria), T_6: RDF + GM (Green gram), T_7: RDF + GM + *Azotobacter*, T_8: RDF + GM+ *Azotobacter* + PSB were tested.

Methods of Planting and input applications

Using a Bihar senior ridger, furrows were made in each plot according to the spacing between the treatments. Fertilisers, vermicompost, green manure, and biofertilizers were used in accordance with the treatments. Applying urea, di-ammonium phosphate (DAP) and muriate of potash (MOP) as sources of N, P_2O_5, and K_2O. The full doses of P and K, together with half of the amount of N, were administered as basal. After the first irrigation and during the earthing up process, the remaining N was top dressed in the form of urea in two equal splits. The biofertilizer was mixed in compost and applied in the furrow planting. Green gram was sown in the interspace of sugarcane (between rows), and it was incorporated into the soil 60 days after planting.

Climatic condition during growth period

The maximum and minimum temperatures were 37.1^0C and 7.2^0C respectively, and the maximum rainfall was 268.4 mm between the growing periods. The weather data of the experimentation period is presented in the Fig. 1.

Cane juice Analysis

The method described by Spencer and Meade (1964) was used to determine the cane juice quality, including brix, pol, and purity percent, and commercial cane sugar (CCS) was

UNDER PEER REVIEW

calculated. Brix was measured by brix hydrometer. Commercial cane sugar was calculated by formula, CCS (%) ={S-(B-S) × 0.4} × 0.73; where B is corrected brix reading and S is the sucrose percent in juice.

Nutrient use efficiency (NUE)

Nutrient use efficiency is expressed in terms of the partial factor productivity (PFP), agronomic use efficiency (AUE), physiological use efficiency (PUE) and crop recovery efficiency (CRE) of N, P and K. The different efficiencies like PFP, AUE, PUE and CRE were calculated as, **PFP** = Y_N / F_N; **AUE** = $(Y_N - Y_0) / F_N$; **PUE** = $(Y_N - Y_0) / (U_N - U_0)$; **CRE** = $(U_N - U_0) / F_N$; where, Y_N is crop yield in treated plot (kg ha^{-1}), Y_0 is crop yield (kg ha^{-1}) in untreated plot, F_N is amount of fertilizer applied (kg ha^{-1}), U_N is total nutrient uptake in above ground biomass at maturity (kg ha^{-1}) in a plot that received fertiliser and U_0 is the total nutrient uptake in above ground biomass at maturity (kg ha^{-1}) in a plot that received no fertiliser.

Statistical Analysis

The data was statistically analysed using the analysis of variance (ANOVA); utilising the statistical programmes OPSTAT and Microsoft Excel. The Duncan Multiple Range Test (DMRT) was used to determine whether there was a significant difference between the treatments at $p \leq 0.05$.

Result and Discussion

Growth Attributes

According to the findings, the combined application of inorganic and organic sources as well as biofertilizers caused a significant fluctuation in the sugarcane germination percentage at 45 days after planting (DAP) (Table 1). The combined use of RDF + vermicompost + *Azotobacter* + PSB recorded the highest germination percentage (43.4%) and its range varied from 43.4 to 36.5 percent but there was no significant difference between the treatments (Banerjee et al. 2018). The tiller population of sugarcane had significant differences among the treatments at 120, 150 and 180 DAP by the combined application of inorganic, organic and biofertilizers as shown in Fig 2. Regardless of treatment differences maximum tillers was recorded at 120 DAP and gradually declined thereafter at 150 and 180 DAP. The maximum number of tiller population (170.7, 168.2 and 165.3×10^3/ha) was recorded at 120, 150 and 180 DAP in treatment which received RDF + vermicompost + *Azotobacter* + PSB which is 89, 90 and 92% higher over untreated plot respectively. This can be possible due to better availability of nutrients in soil because of addition of inorganic fertilizers in combination with organic manures (vermicompost, green manure) and biofertilizers which resulted in more uptakes of nutrients. The improved tiller populations may have resulted from the increased nutrient absorption caused by integrated nutrient management (Bokhtiar et al. 2005). The data on plant height of sugarcane was recorded at 180 days after planting and it varies from 205.9-240.3cm (Table 1). It was found that the integrated application of nutrients showed no significant difference among the treatments. The work is in accordance with the work of Karmakar et al. 2020; Bhardwaj et al. 2023. However, taller plants were observed in treatment which constitute RDF + vermicompost +

UNDER PEER REVIEW

Azotobacter + PSB which is 16% higher over the treatment which constitute no fertilisers. Significant differences were observed in dry matter production which was very slow during early growth stages (90 DAP and 120 DAP). However, it increases sharply up to 150 DAP followed by a gradual increment till harvest stage. While at harvest stage it was found non-significant. The plots receiving no fertilizer and the recommended dose of fertilizer accumulated the least dry matter and it was decreased by 33, 19%, 43, 33%, 55, 45%, and 25, 5% at 90, 120, 150 and at harvest stage, respectively, in comparison to the treatment which comprise RDF + vermicompost + *Azotobacter* + PSB (Fig 2). Application of only recommended dose of fertilizers had less dry matter accumulation as compared to integrated nutrient management might be due to loss of nutrients through various ways.

Yield Attributes and Yield

The analysis of the data showed that in comparison to the absolute control and the recommended dose of fertiliser (RDF), the combined application of nutrients utilising inorganic, organic, and biofertilizers produced significantly more millable cane (Table 1). The treatment receiving RDF + vermicompost together with *Azotobacter* and Phosphorus Solubilising Bacteria (PSB) recorded significantly higher millable canes (125.4 $\times 10^3$/ha) which was 78 % higher than the unfertilised plot. This may be due to the fact that organic sources enhance the physical, chemical and biological environment of the soil creating the ideal conditions for nutrient release, whereas chemical fertilizer applications immediately supply the NPK levels through the recommended dose. Similar finding was recorded by Umesh et al. (2013). Furthermore, when nutrients from both organic and inorganic sources were supplied along with biofertilizers, a considerable increase in the quantity of millable canes was produced (Patel, 2006; Sinha et, al., 2024). The sugarcane's cane length, cane diameter, and single cane weight did not significantly differ across the treatments. The cane length, cane diameter and single cane weight were increased by 11%, 9% and 20% respectively, in the RDF + Vermicompost + *Azotobacter* + PSB treated plot as compared to the unfertilized plot. The integrated use of organic and inorganic fertiliser combinations with biofertilizers also had an impact on the variation in cane output (Table 1). The maximum cane yield of 94.0 t/ha of sugarcane was recorded in RDF + vermicompost along with *Azotobacter* and PSB treated plot which was 124% higher than the 41.8 t/ha of an untreated plot. Throughout the sugarcane plant's growth phase, both the steady supply of plant nutrients from organic sources and the quick and easy availability of plant nutrients from inorganic sources. The combined use of organic and inorganic fertilizers along with biofertilizers also provides a favourable soil environment for plant growth, which might have improved the cane yield. Balanced chemical fertiliser use alone will not be able to sustain cane productivity since one or more secondary and micronutrient deficiencies are becoming more prevalent. When chemical fertilisers and organic manures were used together, productivity increased noticeably and overall soil fertility improved compared to when chemical fertilisers were used alone. Similar finding was recorded by Shukla et al. (2015). According to Singh et al. (2014), the integrated usage of inorganic + organic fertiliser combined with biofertilizers (*Azotobacter* + PSB) considerably boosted cane production. Lakshmi et al. (2011) explained that FYM + RDF recorded a higher cane yield than RDF alone. Higher cane and sugar yield

UNDER PEER REVIEW

was reported by Durai and Devaraj (2003) with the application of FYM + 100% NPK + Azospirillum.

Juice Quality

Data on juice quality are presented in table 2. Regarding juice quality, including brix, pol, purity, and CCS%, none of the treatments had any significant impact. The genetic makeup of the cultivar has the greatest impact on juice quality (brix, pol, purity and CCS%). In the current study, the application of organic, inorganic, and biofertilizers could have created a favourable soil environment and increased the supply of nutrients due to various treatments, which could have proportionately improved the growth and maintained the juice quality under various treatments. The results of research confirmed the non-significant impact of applying biocompost on juice quality by Rakkiyappan et al. (2001). According to Thakur et al. (2012), cane juice quality, including brix, sucrose, and purity content, is unchanged by the use of organic and conventional farming methods. According to research by Sinha et al. (2014) and Kumar (2012), both organic and inorganic nutrients had no impact on the juice's quality indicators of brix, pol, and purity.

Nutrient Use Efficiency (NUE)

The results on NUE for the nutrients N, P, and K assessed in terms of PFP, AUE, PUE, and CRE are shown in Fig. 3. The variation in sugarcane production may be responsible for variations in partial factor productivity, physiological use efficiency, agronomic use efficiency, and crop recovery efficiency of plant crops. Further, it was noticed that the application of RDF + vermicompost + *Azotobacter* + PSB gave higher AUEn (348.1 kg kg^{-1}), AUEp (614.2 kg kg^{-1}) and AUEk (870.1 kg kg^{-1}) than the rest of the treatment. Partial factor productivity and crop recovery efficiency was also found higher value in treatments which constitute RDF + vermicompost + *Azotobacter* + PSB which was PFPn (626.9 kg kg^{-1}), PFPp (1106.5 kg kg^{-1}), PFPk (1567.5 kg kg^{-1}), CREn (1.13 kg kg^{-1}), CREp (0.15 kg kg^{-1}), and CREk (2.59 kg kg^{-1}) respectively than the rest of the treatment. Physiological use efficiency of sugarcane plant crop was varied according to uptake of nutrient by the plants as well as cane yield was obtained. The data variation of PUEn (301.1-319.7 kg kg^{-1}), PUEp (2983.8-3236.1 kg kg^{-1}), PUEk (332.0-353.7 kg kg^{-1}) respectively. The present investigation's findings showed that using inorganic, organic, and biofertilizers in combination can boost sugarcane's N, P, and K of PFP, PUE, crop recovery efficiency, and agronomic use efficiency in sugarcane. Increases in NUE may be the result of optimal nutrient availability in response to crop demand, which results in effective uptake. Similar finding was recorded by Tayade et al. (2020).

Correlation Studies

Correlation studies (Table 3), revealed that cane yield was highly correlated with the number of tillers at 180 DAP (r=0.85), dry matter production at the harvest stage (r=0.64), number of millable cane (r=0.91), and single cane weight (r=0.66) respectively. However, plant height at 210 DAP was significantly correlated with cane yield. Dry matter production at harvest stage, millable canes and single cane weight was highly correlated with number of tillers at 180 DAP. Kumar (2020) also reported similar results. However, there was no statistically significant correlation between tiller and quality indicators like brix, pol, purity,

UNDER PEER REVIEW

and CCS% at 180 DAP. Plant height was significantly correlated with brix percentage and non-significantly correlated with dry matter production (DMP), millable cane, single cane weight, pol and CCS%. Dry matter production (DMP) was highly correlated with millable cane (r=0.63) and significantly correlated with single cane weight (r=0.45). Millable cane was highly correlated with single cane weight (r=0.54). Pol percent was highly correlated with purity and commercial cane sugar (CCS) percent (r=0.57 and r=0.75) respectively and CCS percent was also highly correlated with purity percent (r=0.54). Non-significant correlations were found between cane yield and brix, pol, purity, and CCS percentage.

Conclusion

Based on the study, it may be concluded that the application of different treatments resulted significant differences between tiller populations, dry matter production, millable canes and cane yield, while having a non-significant effect on germination percentage, plant height, cane length, cane diameter and single cane weight. A significantly higher value was recorded by combining organic, inorganic and biofertilizer nutrient sources over an absolute control and fertilized (RDF) plot. In terms of tillers, dry matter accumulation, number of millable cane and cane yield treatment which received RDF +Vermicompost + *Azotobacter* + PSB was significantly superior over others. While impact of various treatments on brix, pol, purity and CCS was found non-significant effect. This may be because the genetic makeup of the variety mostly determines the juice's quality.

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UNDER PEER REVIEW

Key findings for recommendation

Based on the findings presented, we strongly recommend the adoption of integrated nutrient management practices to improve sugarcane production and quality while reducing reliance on synthetic fertilizers and mitigating environmental impact. The study demonstrated the effectiveness of integrating vermicompost and biofertilizer (*Azotobacter* + PSB) with the recommended dose of fertilizers for enhancing sugarcane yield and nutrient utilization efficiency.

Key findings include:

1. The combination of RDF with vermicompost and biofertilizer resulted in the highest millable cane and cane yield, with increases of 78% and 24% respectively over the sole prescribed dose of fertilizer and the absolute control.
2. Plots treated with RDF + vermicompost + *Azotobacter* + PSB exhibited a 75% improvement in agronomic use efficiency compared to plots receiving only the recommended dose of fertilizer.

These results underscore the efficacy of integrated nutrient management as the optimal approach for sustainable sugarcane production. Further research and policy initiatives should prioritize the widespread adoption of such practices to enhance productivity, improve nutrient use efficiency, and reduce environmental impact in sugarcane cultivation.

References

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): 41-47.

Bhardwaj AK, Malik K, Rani M, Mandal UK, Basak N, Singh A, Yadav RK, Chaudhari SK, Sharma DK. (2023) Residue recycling options and their implications for sustainable nitrogen management in rice–wheat agroecosystems. Ecological Processes. Nov 10;12(1):53.

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

Chatterjee R, Bandyopadhyay S, Jana JC (2014) Impact of organic amendments and inorganic fertilizers on production potential, nitrogen use efficiency and nitrogen balance in tomato *(Lycopersicon esculentum* Mill.). International Journal of Scientific Research in Knowledge 2(5): 233-240. https://doi.org/10.12983/ijsrk-2014-p0233-0240

Das D, Dwivedi BS, Meena MC, Singh VK, Tiwari KN (2015) Integrated nutrient management for improving soil health and crop productivity. Indian Journal of Fertilisers 11(4): 64-83.

Durai R, Devaraj G (2003) Organic farming in sugarcane. Cooperative Sugar 34(6): 491-492.

Gopalasundaram P, Bhaskaran A, Rakkiyappan P (2012) Integrated nutrient management in sugarcane. Sugar Tech 14(1): 3-20. https://doi.org/10.1007/s12355-011-0097-x

Karmakar S, Bhattacharyya A, Ghosh B, Roy R, Kumar S, Kar B, Saha G. (2020) Suitability of coupling application of organic and inorganic fertilizers for crop cultivation. Ecological and Practical Applications for Sustainable Agriculture.149-77.

Kumar N (2012) Productivity, quality and nutrient balance in spring sugarcane (*Saccharum* spp. hybrid complex) under organic and inorganic nutrition. Indian Journal of Agronomy 57(1): 68-73.

Kumar N (2020) Enhancing sugarcane plant–ratoon Productivity through bud chip transplanting geometry. Sugar Tech 22(2): 208-215. https://doi.org/10.1007/s12355-019-00772-3.

Kumar, A., Chattopadhyay, S. and Meena, S.K. (2023) Soil Fertility Assessment of Sugarcane Growing Villages in Samastipur District of Bihar. *Environment and Ecology*. 41 (2): 759-764, April-June 2023. ISSN 0970-0420. Link:https://doc.article-environmentandecology.com/external/file/15vy05a767e7a4e17435695f722fc209e2248

Kumar, A., Meena, S. K., Singh, S. K., Sinha, S.K. and Singh, A.K. (2024a) Carbon sequestration in sugarcane plant - soil system as influenced by nutrient integration practices under Indo-Gangetic plains of India. *Journal of Advances in Biology & Biotechnology*. *27*(5), 116–125. DOI: https://doi.org/10.9734/jabb/2024/v27i5769.

Kumar, A., Meena, SK., Sinha, SK., Singh, AK., Minnatullah, and Singh, S.K. (2024b) Isolation and biochemical characterization of endophytic bacterium

UNDER PEER REVIEW

Gluconacetobacter diazotrophocus from native sugarcane cultivar of middle gangetic plains of India. *Indian Journal of ecology*, 51(1): 104-112. DOI: https://doi.org/10.55362/IJE/2024/4202.

Lakshmi CSR, Sreelatha T, Rani TU, Rao SRK, Naidu NV (2011) Effect of organic manures on soil fertility and productivity of sugarcane in north-coastal zone of Andhra Pradesh. Indian Journal of Agricultural Research 45(4): 307-313.

Pal R, Singh O, Sanghera GS, Gupta RK (2021) Influence of INM on sugarcane productivity and soil fertility under Indo-Gangetic plain. The Indian Journal of Agricultural Sciences 91(5):703-7. https://doi.org/10.56093/ijas.v91i5.112987

Pandey DK, Kumar S, Singh PK, Singh J (2012) Interpreting phenotypic stability in sugarcane using different parametric models. Indian Journal of Sugarcane Technology 27(1): 48–53.

Patel GG (2006) Sustenance of soil health and productivity of sugarcane through integrated nutrient management in inceptisols of South Gujarat. Ph.D. thesis submitted to NAU., Navsari (Gujarat).

Rakkiyappan P, Thangavelu S, Malathi R, Radhamani R (2001) Effect of biocompost and enriched pressmud on sugarcane yield and quality. Sugar Tech 3(3): 92-96. https://doi.org/10.1007/BF03014569

Shankaraiah C, Murthy KNK (2005) Effect of enriched pressmud cake on growth, yield and quality of sugarcane. Sugar Tech 7 (2&3):1-4. https://doi.org/10.1007/BF02942519

Shukla SK, Singh PN, Chauhan RS, Solomon S (2015) Soil physical, chemical and biological changes and long-term sustainability in subtropical India through integration of organic and inorganic nutrient sources in sugarcane. Sugar Tech 17(2): 138-149. https://doi.org/10.1007/s12355-013-0300-3

Singh A, Kumar R, Ram B (2014) Response of soil test based integrated nutrient management under sugarcane cultivation (CCP). In: Proc. of the National Seminar on Recent Advances and Challenges in Sugarcane Research, 23- 24 January, Mysore, India. p.71.

Singh M, Dwivedi BS, Datta SP (2012) Integrated nutrient management for enhancing productivity, nutrient use efficiency and environmental quality. In Soil Science in the Service of Nation, pp. 55- 67, ISSS, New Delhi.

Sinha SK, Jha CK, Kumar V, Kumari G, Alam M (2014) Integrated effect of bio-methanated distillery effluent and bio-compost on soil properties, juice quality and yield of sugarcane in Entisol. Sugar Tech 16(1): 75-79. https://doi.org/10.1007/s12355-013-0256-3

Sinha, S.K., Kumar, A., Kumari, A and Singh. A.K. (2024) The Integrated Effect of Organic Manure, Biofertilizer and Inorganic Fertilizer on Soil Properties, Yield and Quality in Sugarcane Plant-ratoon System under Calcareous Soil of Indo Gangetic Plains of India. Journal of Scientific Research and Reports (JSRR). 30(5): 193-206. https://doi.org/10.9734/jsrr/2024/v30i51934.; https://hal.science/hal-04507744;

Spencer EF, Meade GP (1964) Cane sugar hand book, 7th ed. New York: Wiley.

Tayade AS, Bhaskaran A, Anusha S (2020) IPNS–STCR-Based Nutrient Management Modules for Enhancing Soil Health, Fertilizer-Use Efficiency, Productivity and

UNDER PEER REVIEW

Profitability of Tropical Indian Sugarcane Plant–Ratoon Agro-Ecosystem. Sugar Tech 22(1): 32-41. https://doi.org/10.1007/s12355-019-00737-6

Thakur SK, Jha CK, Alam M, Singh VP (2012) Productivity, quality and soil fertility of sugarcane (*Saccharum* spp. complex hybrid) plant and ratoon grown under organic and conventional farming system. Indian Journal of Agricultural Sciences 82(10): 896-899.

Umesh UN, Kumar V, Alam M, Sinha SK, Verma K (2013) Integrated effect of organic and inorganic fertilizers on yield, quality parameter and nutrient availability of sugarcane in calcareous soil. Sugar Tech 15(4): 365- 369. https://doi.org/10.1007/s12355-013-0213-1

Yadav SP, Singh SC, Yadav S, Yadav SK, Tiwari AK, Sharma BL (2019) Integrated nutrient management approaches for enhancing production potential and sustainability of sugarcane (*Saccharum* spp. hybrid) plant–ratoon system in north region of India. Sugar Tech 21(1): 170-175. https://doi.org/10.1007/s12355-018-0641-z

UNDER PEER REVIEW

Table 1 Growth, yield and yield attributes of sugarcane as influenced by different treatments during spring season

Treatments	Germination percentage at 45 DAP	Plant height (cm) at 180 DAP	Millable canes at harvest ($\times 10^3$ ha^{-1})	Cane length at harvest (cm)	Cane diameter (cm)	Single cane weight (g)	Cane yield (t/ha)
T_1: Absolute control	41.6 ± 2.06a	205.9 ± 22.24a	70.5 ± 2.62c	275.3 ± 24.55a	2.0 ± 0.13a	605 ± 0.08a	41.8 ± 0.71 c
T_2: RDF	38.1 ± 0.30a	223.9 ± 8.55a	100.6 ± 8.44b	296.7 ± 18.78a	2.1 ± 0.15a	722 ± 0.04a	71.6 ± 10.02b
T_3: RDF + vermicompost	36.5 ± 5.19a	227.8 ± 15.04a	122.3 ± 4.56a	299.4 ± 18.36a	2.2 ± 0.15a	748 ± 0.03a	90.2 ± 7.29a
T_4: RDF + vermicompost + *Azotobacter*	42.1 ± 0.30a	233.3 ± 13.07a	124.1 ± 5.72a	311.7 ± 15.89a	2.2 ± 0.11a	751 ± 0.07a	92.1 ± 2.11a
T_5:RDF + vermicompost + *Azotobacter* + PSB	43.4 ± 2.96a	240.3 ± 8.73a	125.4 ± 2.18a	312.8 ± 14.44a	2.2 ± 0.07a	757 ± 0.05a	94.0 ± 5.32a
T_6: RDF + GM	39.2 ± 1.28a	227.8 ± 9.10a	117.7 ± 4.17a	301.7 ± 17.02a	2.2 ± 0.09a	742 ± 0.03a	86.1 ± 3.36ab
T_7: RDF + GM + *Azotobacter*	40.7 ± 0.54a	230.6 ± 7.34a	119.1 ± 9.76a	304.4 ± 19.27a	2.2 ± 0.08a	753 ± 0.00a	88.5 ± 4.25a
T_8: RDF + GM + *Azotobacter* + PSB	41.1 ± 2.01a	238.3 ± 16.41a	121.9 ± 0.47a	312.2 ± 15.93a	2.2 ± 0.05a	743 ±0.01a	89.6 ± 0.74a

Different letters in the same column indicates significant effect at 0.05 % level (Duncan multiple range test); RDF: Recommended dose of fertilizer (150 kg N, 85 kg P_2O_5, and 60 kg K_2O); GM: Green manure; PSB: Phosphate solubilising bacteria; Vermicompost was applied @ 5 t/ha, *Azotobacter* and PSB @4 kg/ha

UNDER PEER REVIEW

Table 2 Juice quality parameters as influenced by different treatments during spring season

Treatments	Juice quality (%)			CCS
	Brix	Pol	Purity coefficient	(%)
T_1 : Absolute control	17.8 ± 0.48a	15.7 ± 0.57a	88.3 ± 0.87a	10.9 ± 0.18 a
T_2 : RDF	18.3 ± 1.03a	16.1 ± 0.27a	88.4 ± 0.52a	11.1 ± 0.17a
T_3 : RDF + vermicompost	18.3 ± 0.25a	16.3 ± 0.44a	89.2 ± 1.38 a	11.3 ± 0.38a
T_4 : RDF + vermicompost + *Azotobacter*	18.6± 0.16a	16.5 ± 0.57a	88.6 ± 0.90a	11.4 ± 0.13a
T_5 : RDF + vermicompost +*Azotobacter* +PSB	18.2 ± 0.30a	16.1± 0.20a	88.6 ± 2.52a	11.1 ± 0.24a
T_6 : RDF + GM	18.9 ± 0.17a	16.6 ± 0.68a	87.9 ± 4.42a	11.5 ± 0.17a
T_7 : RDF + GM + *Azotobacter*	19.3 ± 0.15a	17.0 ± 0.40a	88.0 ± 2.70a	11.7 ± 0.44a
T_8 : RDF + GM + *Azotobacter* + PSB	19.2 ± 0.23a	16.8 ±0.35a	87.4 ± 1.96a	11.6 ± 0.35a

Similar letters in the same column indicates no significant differences at 0.05 % level (Duncan multiple range test); RDF: Recommended dose of fertilizer (150 kg N, 85 kg P_2O_5 , and 60 kg K_2O); GM: Green manure; PSB: Phosphate solubilising bacteria; Vermicompost was applied @ 5 t/ha, *Azotobacter* and PSB @4 kg/ha

UNDER PEER REVIEW

Table 3 Correlation coefficient of growth, cane yield and juice quality in sugarcane

	Tillers at 180 DAP	Plant height at 210 DAP	Dry matter accumulation (g/plant) at harvest	Millable canes (× 10^3/ha)	Single cane weight (kg)	Cane yield (t/ha)	Brix (%)	Pol (%)	Purity (%)	Commercial cane sugar (%)
Tillers at 180 DAP	1									
Plant height at 210 DAP	0.359^{NS}	1								
Dry matter accumulation (g/plant) at harvest	0.557^{**}	0.377^{NS}	1							
Millable canes (× 10^3/ha)	0.847^{**}	0.346^{NS}	0.629^{**}	1						
Single cane weight (kg)	0.530^{**}	0.211^{NS}	0.448^{*}	0.543^{**}	1					
Cane yield (t/ha)	0.854^{**}	0.440^{*}	0.638^{**}	0.913^{**}	0.657^{**}	1				
Brix (%)	0.327^{NS}	0.450^{*}	0.293^{NS}	0.365^{NS}	0.287^{NS}	0.267^{NS}	1			
Pol (%)	0.400^{NS}	0.086^{NS}	0.141^{NS}	0.264^{NS}	0.074^{NS}	0.265^{NS}	0.376^{NS}	1		
Purity (%)	0.004^{NS}	-0.124^{NS}	-0.178^{NS}	-0.050^{NS}	-0.187^{NS}	-0.032^{NS}	-0.283^{NS}	0.571^{**}	1	
Commercial cane sugar (%)	0.396^{NS}	0.133^{NS}	0.232^{NS}	0.232^{NS}	0.424^{*}	0.376^{NS}	0.243^{NS}	0.754^{**}	0.535^{**}	1

UNDER PEER REVIEW

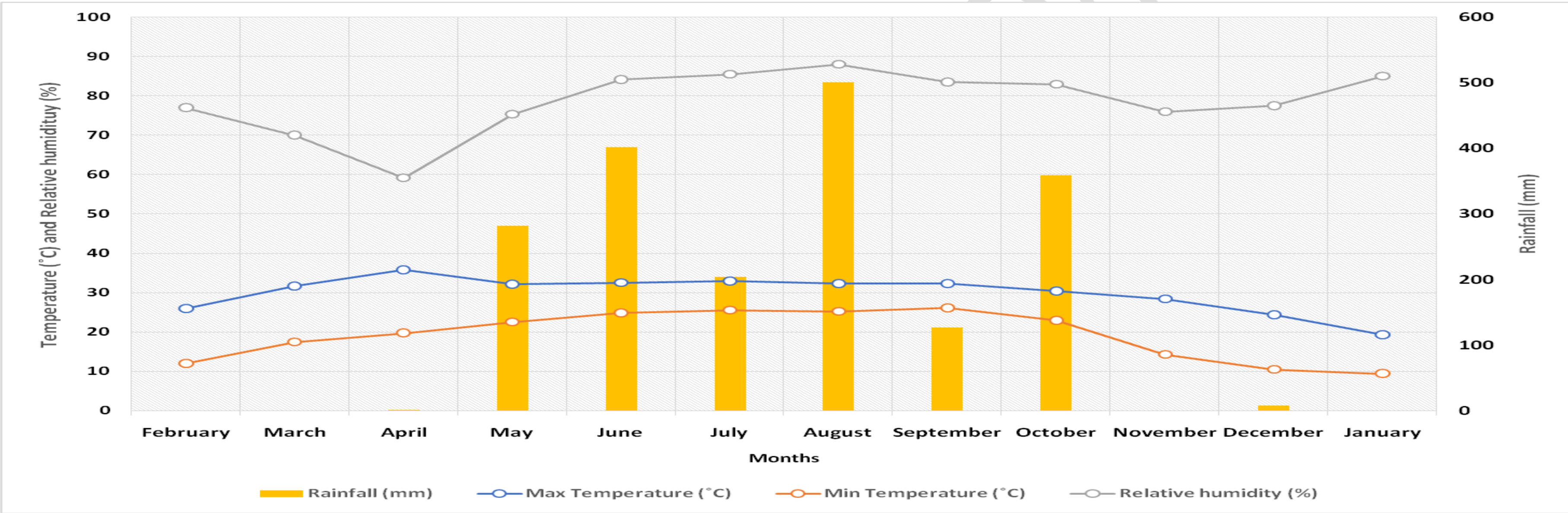

Fig 1 Weekly meteorological parameters during experimentation period

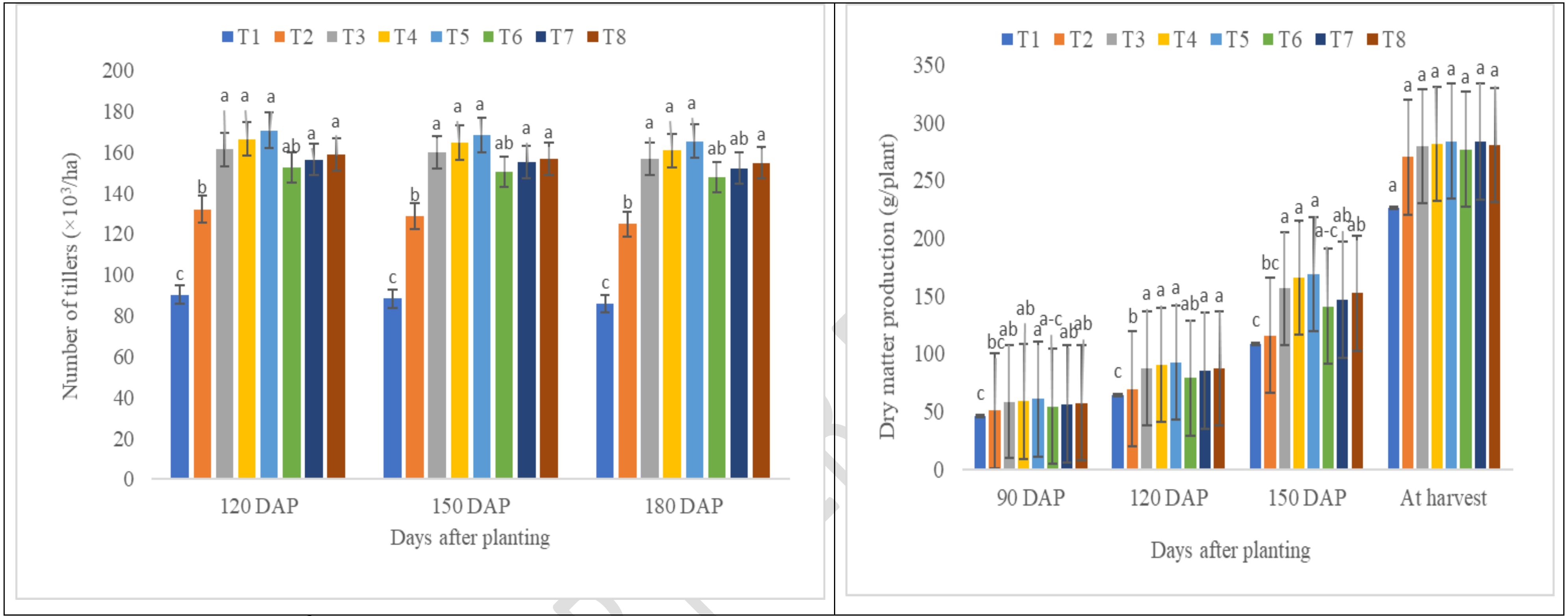

Fig. 2 Tiller population ($\times10^3$/ha) and dry matter production at different growth stages of sugarcane

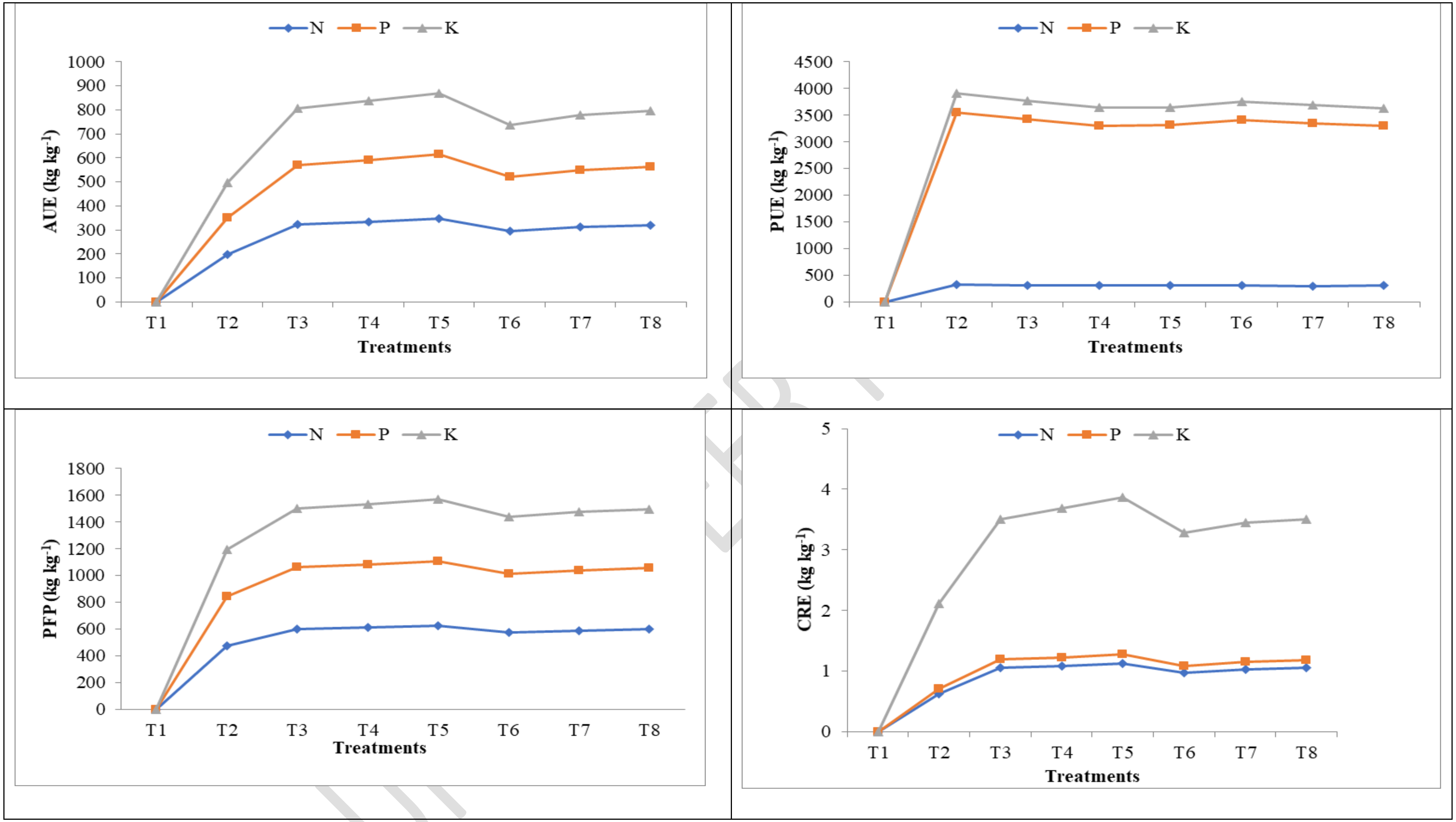

Fig. 3 Agronomic use efficiency (AUE), Physiological use efficiency (PUE), Partial factor productivity (PFP) and Crop recovery efficiency (CRE) as influenced by different treatments during spring season of sugarcane