Evaluating Nitrogen Use Efficiency on Cane Yield, Yield Components and Quality of Two Sugarcane Genotypes under Agro-Ecological Conditions of Kenana Estate

[*]Abdelrahman Jeffon[1], A. A Gamar,[1]. Y. M Dagash [2]., and Y. O. Samia [2]
[1]White Nile University, White Nile Center for Scientific Research, [2]Sudan University of Science and Technology, College of Agricultural Studies.
[*]Corresponding author: jufun@wnu.edu.sd

doi: https://doi.org/10.37745/ijeats.13/vol14n41124 Published September 06, 2026

Citation: Jeffon A., Gamar A.A., Dagash Y.M., and Samia Y.O. (2026) Evaluating Nitrogen Use Efficiency on Cane Yield, Yield Components and Quality of Two Sugarcane Genotypes under Agro-Ecological Conditions of Kenana Estate, *International Journal of Engineering and Advanced Technology Studies*,14 (4),11-24

Abstract: *Sugarcane (*Saccharum officinarum *L.) productivity and sucrose accumulation are critically dependent on nitrogen (N) availability; however, optimal N management remains challenging, particularly for newly introduced genotypes under specific agro-ecological conditions. This study was conducted to evaluate the effects of five N application rates (0, 164, 219, 274, and 329 kg N ha⁻¹) in the form of urea on the yield, yield components, and quality attributes of two commercial sugarcane varieties (R 579 and TUC75-3) at the Kenana Sugar Company Estate, Sudan. Two field experiments were established over consecutive growing seasons using a split-plot design with a randomized complete block arrangement and four replications, wherein varieties were assigned to main plots and N levels to subplots. Measured traits included stalk height, number of internodes, stalk diameter, stalk population density, cane yield (t ha⁻¹), sugar yield (t ha⁻¹), Brix, Pol, fiber content, estimated recoverable sucrose (ERSC), purity, and moisture content. Analysis of variance revealed highly significant effects of N rate on stalk height, internode number, stalk diameter, cane yield, and sugar yield (*P *< 0.01). In contrast, varietal differences were statistically significant solely for moisture content (*P *< 0.05), whereas a significant variety × N interaction was detected for purity (*P *< 0.05). Cane and sugar yields exhibited a positive, linear response to increasing N supply, with maximum cane yield (123.97 t ha⁻¹) recorded at the highest N rate (329 kg ha⁻¹), compared with 73.33 t ha⁻¹ under the unfertilized control (0 kg N ha⁻¹). Although variety R 579 consistently yielded numerically higher mean cane (109.83 t ha⁻¹) and sugar (16.77 t ha⁻¹) yields than TUC75-3, these genotypic differences were not statistically significant. Collectively, these findings demonstrate that N fertilization exerts a predominant influence on agronomic productivity relative to genotype selection under these edaphic conditions; nevertheless, the cultivar-specific response in juice purity merits consideration for targeted sugar recovery optimization.*

Keywords*: Sugarcane; nitrogen rates; cane yield; sugar yield; juice purity; variety evaluation.*

INTRODUCTION

Sugarcane (*Saccharum* spp.) is a globally significant industrial crop, supplying approximately 80% of the world's sugar and serving as a leading feedstock for bioenergy production (Govindasamy et al. 2023) Nitrogen is the most critical macronutrient governing sugarcane growth, yield, and quality (Abhiram et al. 2025) Nitrogen fertilizer additions are an important contributor to productivity in farming systems. The nitrogen (N) requirement of sugarcane is very high because of the crop's extensive biomass production (Kumar et al. 2014). Global estimates indicate that only 30–50% of applied N is recovered by the crop ((Abhiram et al. 2025; Hajari et al. 2015), meaning up to20- 60% of applied nitrogen is lost, (Yang et al. 2024) to volatilization, leaching, and denitrification (Anas et al. 2020; Oliveira Junior et al. 2023). To support optimal growth, N fertilizers are often applied in large amounts. Optimizing NUE is critical to reduce fertilizer costs, minimize greenhouse gas emissions (Takeda et al. 2021), and prevent environmental pollution (Luo et al. 2025). Therefore, enhancing NUE has become a priority for both economic and environmental sustainability in the sugarcane industry (Yang et al. 2024).

In Sudan, sugarcane cultivation is predominantly confined to large-scale irrigation schemes, with the Kenana Sugar Company standing as one of the largest integrated sugar complexes in Africa. As a cornerstone of the Sudanese economy, the sugar crop has consistently attracted substantial state attention, reflected in comprehensive research agendas aimed at enhancing productivity. These research efforts have primarily focused on optimizing irrigation management (Elbasheir et al. 2023; Elbashier et al. 2023), improving soil fertility and fertilization practices (Alama et al. 2022), and refining various field operations (Alama et al. 2023; J. Abdelrahman & Abdelasmi 2026).

On the other hand, in Sudan, nitrogen fertilizer research has been conducted across major sugar estates. A study at the Guneid, Assalaya, and New Halfa Sugar Estates investigated urea application for plant cane, recommending a dose of 150 kg urea/feddan (approximately 0.42 ha) for optimal cane and sugar yields (Mukhtar et al. 2009). Additionally, micronutrient research has explored nitrogen application combined with zinc and copper to address deficiencies in central Sudan's Vertisols, indicating that integrated nutrient management is necessary for maximizing crop performance (Mukhtar et al. 2010).

Sugarcane requires large amounts of nitrogen for healthy growth and high yields, so breeders should prioritize nitrogen-use efficiency when developing new cultivars (Mălinas et al. 2022). More efficient use of nitrogen in cropping systems can be achieved through a combination of improved management practices and advances in crop genetics (Govindasamy et al. 2023).The present study was therefore designed to quantify the responses of two promising important sugarcane varieties –R 579 and TUC75-3- to wide range of nitrogen fertilization levels (0- 329 kg

Print ISSN: 2053-5783(Print)

Online ISSN: 2053-5791(online)

Website: https://www.eajournals.org/

Publication of the European Centre for Research Training and Development -UK

N/ hec) under field conditions at Kenana R&D farm. The specific objectives were: (i) to assess variety differences in growth, yield, and quality traits; (ii) to determine the effect of nitrogen rates on these traits; and (iii) to identify any significant variety-by-nitrogen interactions that might guide variety-specific fertilizer recommendations.

MATERIALS AND METHODS

Experimental Site:

The experiments were conducted at the Research and Development Farm of Kenana Sugar Company, Sudan, during two consecutive seasons. Kenana located between white Nile and blue Nile at the intersection is longitude 33˚E, Latitude 13˚N and 410 M above sea level, distance about 330 km south of capital Khartoum, and 30 km southeast of Rabak Town (Hamid & Dagash 2014; Elzaki 2003). The climate is tropical with a rainy summer season of four months from June to September, with peak in August. The soil is brown heavy clay and classified as true vertisols, the upper 60 cm of the soil profile is cracking clay with 40– 60% clay content; the dominant clay mineral is montmorillonite. Bulk density 1.60 -1.70 gm cm-3, ninety percent of the upper horizon has an electric conductivity less than 2 mmhos/cm, the organic carbon ranges between 0.30 – 0.40%, available P ranges between 0.03 –11.50 ppm, available K 170 –350 ppm, CEC 58–61, exchangeable sodium percent (ESP) is less than 15, and the soil pH ranges between 7.0 – 8.50 (Ali 1986; Hamid & Dagash 2014).

Experimental Design:

The trial employed a split-plot arrangement within a Randomized Complete Block Design (RCBD) with four replications (r= 4). Main plots were assigned to two commercial sugarcane (Saccharum officinarum L.) varieties

Two sugarcane varieties namely (R 579 early-maturing, high-sucrose commercial variety and TUC75-3 medium-late maturing commercial) were allocated to the main plots, and five nitrogen fertilization levels (0.0, 164.0, 219.0, 274.0, and 329 kg N/ hec) were assigned as subplots, yielding a total of 40 experimental units. Each plot has (4 row× 1.5 width× 10 meter length) = (60 m2).

Agronomic Data Collection & Industrial Juice Quality Assessment

At harvest, the following data were taken from the inner two rows: (i) stalk height (cm); (ii) internodes number; (iii) stalk diameter (cm); (iv) stalk population (stalk per two inter rows); (v) yield “tons cane per hectare” (TCH); (vi) yield “tons sugar per hectare” (TSH); (vii) Brix% cane; (viii) Pol% cane; (ix) fiber content (%) cane (x) estimated recoverable of sucrose (ERSC%); (xi) purity% cane; and (xii) moisture content (%). Juice quality parameters were determined according to standard laboratory procedures using a polarimeter and refractometer.

- **Stalk Height (cm):** Measured from soil surface to the top visible dewlap.

- **Stalk Population (1000 stalk per ha^{-1})** Total millable stalk counts extrapolated per hectare.
- **Tons Cane per Hectare {TCH}:** Total stalk biomass harvested and weighed directly in the field.

Industrial sucrose parameters were evaluated on fresh juice samples extracted via a three-roller hydraulic laboratory mill:

- **Brix (%) & Pol (%):** Determined using a temperature-compensated digital refractometer and automatic polarimeter, respectively, following standard ICUMSA methods.
- **Estimated Recoverable Sucrose (ERSC %):** Calculated using the standard estate recovery formula: ERSC% = [Pol% - 0.4 × (Brix% - Pol%)] × (1 - 0.01 × Fiber%)
- **Tons Sugar per Hectare (TSH, t ha^{-1}):** Calculated as: TSH = TCH × (ERSC% / 100)

Nitrogen Use Efficiency (NUE) Metrics

Agronomic and partial factor efficiencies were calculated according to standard frameworks (Hoang 2013; Olk et al. 1998):

- **Agronomic Efficiency of Applied Nitrogen (AE_N, kg cane biomass kg^{-1} N):** AE_N = (Y_N - Y_0) / F_N
  Where Y_N is the cane yield (kg ha^{-1}) at a given N rate, Y_0 is the unfertilized control yield (kg ha^{-1}), and F_N is the rate of N applied (kg ha^{-1}).
- **Partial Factor Productivity of Applied Nitrogen (PFP_N, kg cane kg^{-1} N):** PFP_N = Y_N / F_N
- **Internal Efficiency of Nitrogen (IE_N, kg sugar kg^{-1} N):** IE_N = (TSH × 1000) / F_N

Statistical Analysis:

Data were subjected to analysis of variance (ANOVA) appropriate for split-plot arrangement using Statistix (v8.0) and R (v4.3.2). Main plot effects (variety) were tested against Error (a) (Replication × Variety), while subplot effects (N level) and the Variety× Nitrogen interaction were tested against Error (b). Mean separation was performed using Tukey's Honestly Significant Difference (HSD) test or Fisher's protected LSD at $P \leq 0.05$.

To determine the economic and agronomic optimal nitrogen rate (AONR), quadratic response functions and linear-plateau regression models were fitted to the yield data: $Y = a + bN + cN^2$
Where Y is the cane yield (t ha^{-1}), N is the fertilizer rate (kg ha^{-1}), and a, b, c are fitted model parameters.

Artificial Intelligence Integration& Transparency Statement:

During the preparation of this manuscript, the authors utilized Gemini (an advanced Artificial Intelligence platform) as an interactive research assistant to support scientific synthesis, statistical workflow design, computational script development (R and Python data transformation pipelines), and structural refinement of the text. Specifically, AI tools assisted in:

- Translating field trial datasets into standardized agronomic and nitrogen-use efficiency mathematical models.
- Formulating response-surface quadratic equations to calculate optimal N rates
- Language refinement and formatting adjustments to conform to manuscript standards

All primary field trial data collection, laboratory analyses, interpretation of statistical outputs, and final agronomic conclusions were performed independently by the human authors, who assume full responsibility for the integrity and accuracy of the published work.

RESULTS

Analysis of variance (Table.1) revealed that varietal effects were largely non-significant across the majority of traits assessed, with the sole exception of nitrogen content, for which a significant difference between varieties was detected ($P \leq 0.05$). For all other growth, yield, and juice quality parameters, the two sugarcane varieties (R 579 and TUC75-3) performed comparably. In contrast, nitrogen level exerted a highly significant influence ($P \leq 0.01$) on stalk height, internode number, stalk diameter, total cane yield (TCH), and total sugar yield (TSH). These findings indicate that nitrogen supply profoundly modulates both vegetative growth and cane productivity. Stalk population, however, remained unaffected by nitrogen application.

Regarding juice quality attributes—including Brix, Pol, Fiber, ERSC, and purity—no significant main effects of nitrogen were observed. Nevertheless, the variety × nitrogen interaction term was significant for juice purity ($P \leq 0.05$), suggesting that the two varieties differed in their purity response to varying nitrogen regimes. A marginally non-significant trend toward nitrogen effect was noted for fiber content ($P = 0.053$), while all other quality traits exhibited no interactive or main effects. The coefficients of variation (CV) ranged from 1.06% (purity) to 14.64% (population), indicating generally acceptable experimental precision across traits, with population showing the greatest relative variability.

Print ISSN: 2053-5783(Print)

Online ISSN: 2053-5791(online)

Website: https://www.eajournals.org/

Publication of the European Centre for Research Training and Development -UK

Table 1: Analysis of Variance for Growth, Yield, and Quality Traits of two Sugarcane Varieties (R 579 and TUC75-3) under Five Nitrogen Levels

Traits	F (v)	P (v)	F (N)	P (N)	F (V×N)	P (V×N)	CV%
Height	1.03	0.38^{ns}	12.46	<0.0001**	0.75	0.57^{ns}	5.62
Internodes No.	0.12	0.75^{ns}	48.17	<0.0001**	0.20	0.93^{ns}	2.45
Stalk Diameter	1.11	0.37^{ns}	5.00	<0.005**	0.72	0.59^{ns}	4.75
Population	1.14	0.36^{ns}	1.14	<0.36^{ns}	0.66	0.62^{ns}	14.64
TCH	0.79	0.44^{ns}	56.24	<0.0001**	0.22	0.92^{ns}	7.14
TSH	3.19	0.17^{ns}	41.23	<0.0001**	0.36	0.84^{ns}	8.40
Brix%	4.37	0.13^{ns}	1.19	0.34^{ns}	0.52	0.72^{ns}	2.93
Pol%	3.66	0.15^{ns}	1.72	0.179^{ns}	1.43	0.25ns	3.17
Fiber%	5.81	0.1^{ns}	2.72	0.053^{ns}	0.38	0.82^{ns}	8.46
ERSC%	1.55	0.30^{ns}	2.24	0.10^{ns}	1.90	0.14^{ns}	3.71
Purity%	0.07	081^{ns}	1.60	0.206^{ns}	3.88	0.014*	1.06
Moisture%	30.90	0.012*	2.32	0.09^{ns}	0.59	0.67^{ns}	1.71

*V= variety; N= nitrogen level; V×N = variety by nitrogen interaction; ns = not significant; * P ≤0.05; ** P ≤0.01; CV = coefficient of variation.*

Effect of Variety:

(Table 2) presents the mean values of all traits for R 579 and TUC75-3, along with LSD values and significance levels. Among the 12 measured traits, only moisture content differed significantly between varieties. R 579 recorded significantly lower moisture content (66.38%) compared to TUC75-3 (68.21%), indicating superior ripening and juice concentration in R 579 under the experimental conditions.

For yield related traits, R 579 consistently showed numerically higher means than TUC75-3 recording 259.81 versus 238.33 cm for stalk height, 3.04 versus 2.79 cm for stalk diameter, 109.83 versus 105.29 t/ hec for TCH and 16.77 versus 15.69 t/ hec TSH- although none of these differences reached statistical significance at $P \leq 0.05$. Similarly, Brix (18.92 vs. 18.43%), Pol (17.19 vs. 16.76%), fiber (14.70 vs. 13.36%), and ERSC (15.24 vs. 14.93) were numerically higher in R 579 but statistically equivalent to TUC75-3. The absence of significant variety effects for most traits. Combined with relatively high CV values for stalk population (14.64), suggests that within-field variability and management uniformity may have partially masked genetic differences.

Print ISSN: 2053-5783(Print)

Online ISSN: 2053-5791(online)

Website: https://www.eajournals.org/

Publication of the European Centre for Research Training and Development -UK

Table 2: Mean values of growth, yield, and quality traits for varieties R 579 and TUC75-3, with LSD at 5% probability

trait	R 579	TUC75-3	LSD (5%)
stalk Height (cm)	259.81	238.33	67.36^{ns}
internodes Number (cm)	22.87	22.61	2.38^{ns}
stalk Diameter (cm)	3.04	2.79	0.75^{ns}
Population (1000/ hec)	82.30.	88.72	19.17^{ns}
TCH (Ton cane/ hectare)	109.83	105.29	16.27^{ns}
TSH (Ton Sugar/ hectare)	16.77	15.69	1.93^{ns}
Brix (%)	18.92	18.43	0.76^{ns}
Pol (%)	17.19	16.76	0.71^{ns}
Fiber (%)	14.70	13.36	1.76^{ns}
ERSC (%)	15.24	14.93	0.79^{ns}
Juice Purity (%)	90.82	90.95	1.63^{ns}
Moisture (%)	66.38	68.38	1.05*

Ns = not significant; * $P \leq 0.05$; LSD = Least Significant Different

Effect of Nitrogen Fertilization

Table 3 summarizes the mean values of all traits across the five nitrogen levels. A clear and consistent positive trend in growth and yield parameters was observed with increasing nitrogen supply.

Stalk height increased progressively from 221.20 at N0 (0.0 kg/ hec.) to 267.88 cm at N4 (329.0 kg/ hec), representing a 21.1% increase due to nitrogen fertilization (LSD = 14.49 cm). Similarly, internodes no increased significantly from 20.62 (NO) to 24.05 (N4), a gain of 16.6% (LSD = 0.58). stalk diameter showed a significant response, peaking at N3 (274.0 kg N/ hec.) with 3.06 cm versus 2.76 cm at N0 (LSD = 0.14 cm).

The most pronounced nitrogen responses were recorded for yield traits. TCH increased dramatically from 73.33 ton/ hec. Without nitrogen application to 105.84 113.94, 120.74 and 123.97 ton/ hec at N1 through N4, respectively, the gain from N0 to N1 (164 kg N/ hec) alone was 32.51 t/hec. Representing a 44.3% improvement –the largest marginal increment across the N range tested (LSD = 7.93). TSH followed a similar pattern, rising from 10.88 t/hec (N0) to 18.51 t/ hec (N4), yielding a 70.1% improvement with full nitrogen supply (LSD = 1.41).

In contrast, juice quality parameters (Brix, Pol, ERSC, Purity, fiber and Moisture) were not significantly influenced by nitrogen supply, though numerically the highest Brix (18.95%) and Pol 17.35 %) were recorded at N1 (164 kg N/ hec) with slight declines at higher nitrogen rates, consistent with a dilution effect from enhanced vegetative growth.

Table 3: Mean values of growth, yield and quality traits at five nitrogen fertilization levels, with LSD at 5% probability

Traits	Nitrogen Levels (kg/ hec)					LSD
	N0 (0)	N1 (164.0)	N2 (219)	N3 (274)	N4 (329)	(5%)
Stalk Height (cm)	221.20	245.30	254.65	256.32	267.88	14.49
Internodes Number	20.62	22.30	22.95	23.78	24.05	0.58
Stalk Diameter (cm)	2.76	2.96	2.89	3.06	2.92	0.14
Population (1000 stalk/hec)	80.81	90.11	89.61	80.25	86.79	12.92
TCH (ton cane/ hectare)	73.33	105.84	113.94	120.74	123.97	7.93
TSH (ton sugar/ hectare)	10.88	16.48	17.25	18.05	18.51	1.41
Brix %	18.48	18.95	18.82	18.66	18.46	0.56
Pol %	16.75	17.35	17.09	16.89	16.78	0.56
Fiber%	14.06	13.05	14.3	15.01	13.99	1.23
ERSC%	14.86	15.56	15.18	14.92	14.90	0.58
Purity%	90.66	91.62	90.79	90.50	90.87	0.99
Moisture%	67.45	68.00	67.15	66.33	67.55	1.19

NO- N4 = nitrogen levels 0, 164, 219, 274, and 329 kg/ hec, respectively. LSD = Least Significant Different at 5% probability.

Variety ×Nitrogen Interaction:
The V× N Interaction was statistically significant for juice purity (P = 0.0143) and non-significant for all other traits (table 1). (Table 4) presents interaction means for key traits. For TCH and TSH, both varieties responded similarly to nitrogen -increasing cane and sugar yields with each successive nitrogen increment- with R 579 maintaining a numerical advantage across all levels that did not rise to statistical significance.

The interaction in juice purity revealed contrasting patterns: TUC75-3 recorded higher purity at No (91.76%) and N1 (91.80%) compared to R 579 (90.66% and 91.14% respectively), while at N3 (274 kg N/ hec.) and N4 (329 kg N/ hec), R 579 was slightly superior (90.66% and 91.14% vs. 90.08 and 90.25%) this suggests that TUC75-3 juice purity is more adversely affected by higher nitrogen inputs compared to R 579, a finding of practical relevance for tailoring fertilizer programs to specific varieties.

DISCUSSION

Variety Performance:
The absence of significant varietal differences for most growth and yield traits in the present study may reflect the adaptive equivalence of both R 579 and TUC75-3 under the specific agro-climatic conditions prevailing at the Kenana R&D Farm. Both varieties belong to elite germplasm

developed and tested under tropical irrigated conditions, and their broad adaptability likely minimizes the expression of genetic differences when management conditions are optimized (Allier et al. 2020; Pérez-Contreras et al. 2025). The numerically superior TCH and TSH values consistently recorded for R 579 across all nitrogen level are consistent with its reputation as a high-yielding variety in African sugarcane systems (Gu et al. 2023; Vasconcelos et al. 2026), but the current trial did not generate sufficient statistical power to confirm this advantage –possibly due to the moderate number of replications (r = 4) and environmental heterogeneity reflected in the high stalk population (CV 14.64%).

The significant variety effect on moisture content – with TUC75-3 recording higher moisture (68.21%) than R 579 (66.38%) - is consistent with differences in ripening behavior between the two varieties.

Lower moisture content in R 579 indicates earlier maturation and more efficient water utilization during juice concentration, properties that are agronomically advantageous for harvest scheduling and sugar recovery in mechanical harvesting systems (Inman-Bamber & Smith 2005).

Table 4: Variety × Nitrogen interaction means for selected traits (TCH, TSH, Stalk Height, and Juice Purity:

varieties	TCH (Ton Cane per Hectare) nitrogen Levels (kg/ hectare) N0 (0)	N1 (164)	N2 (219)	N3 (274)	N4 (329)
R 579	76.35	106.60	117.90	123.00	125.32
TUC75-3	70.30	105.08	109.97	118.47	122.62
	TSH (Ton Sugar per Hectare)				
R 579	11.20	16.65	17.85	18.80	19.38
TUC75-3	10.55	16.30	16.65	17.30	17.65
	Stalk Height (cm)				
R 579	224.95	254.80	267.20	270.40	281.70
TUC75-3	217.45	235.80	242.10	242.25	254.05
	Juice Purity (%)				
R 579	90.66	9.43	90.45	90.86	91.14
TUC75-3	91.76	91.80	91.11	90.08	90.25

No-N4 = nitrogen levels 0, 164, 219, 274, and 329 kg/ hec respectively. Nitrogen units: kg/ per hectare.

Nitrogen Fertilization Effects on Growth and Yield

The highly significant positive responses of stalk height, internodes number, stalk diameter, TCH and TSH to increasing nitrogen levels confirm the fundamental role of nitrogen nutrition in driving sugarcane productivity. These findings are consistent with an extensive body of literature from diverse sugarcane-growing regions (Abhiram et al. 2025; Bokhtiar & Sakurai 2005; Wiedenfeld 2000; Yuan et al. 2025).

The progressive increase in stalk height (221.20 cm at N0 to 267.88 cm at N4; 21.1%) is attributable to the role of nitrogen in promoting meristematic activity and cell elongation, mediated through Auxin synthesis and enhanced photosynthetic rates. Internode number – a key determinant of individual stalk biomass – increased by 16.6% across the nitrogen range, consistent with observations by (Wiedenfeld 2000) in Texas and (Singh et al. 2006) in India. These responses reflect the optimization of source-sink relationships when adequate nitrogen is available for chlorophyll synthesis and carbon fixation.

The dramatic improvement in TCH – from 73.33 t/ hec without fertilization to 123.97 t/ hec at 329 kg N/ hec (+69.1%) – underscores the severely nitrogen-limited baseline productivity of the experimental soil. The steepest response occurred between N0 and N1 (0.0 to 164.0 kg/ hec), where TCH increased by 44.3%, suggesting that even a modest nitrogen application provides large yield benefits in this system. The rate of marginal return diminished at higher nitrogen levels (N3 to N4 increment = 3.23 t/ hec), indicating an approaching yield plateau that is agronomically and economically important for determining the optimal application rate. A quadratic or plateau model would likely provide the best fit to the TCH-N response curve in this dataset.

Similarly, TSH increased from 10.88 to 18.51 t/hec (+70.1%), reflecting the compound benefit of higher cane biomass production. The TSH response to closely tracked TCH, suggesting that nitrogen primarily stimulated cane tonnage rather than sucrose concentration percent, a common observation in the literature (Chen et al. 2017). It is noteworthy that the highest TSH (18.51 t/hec) was recorded at N4 (329 kg/ hec), with no evidence of a yield decline at this rate, indicating that the optimal nitrogen application for TSH may exceed the maximum level tested.

Nitrogen Effects on Juice Quality

The non-significant effects of nitrogen on Brix, Pol, Fiber, ERSC, and juice purity contrast with some reports in the literature that describe nitrogen-induced dilution of sucrose at high application rates (Lakshmanan et al. 2005). In the present study, Brix values ranged narrowly from 18.46 to 18.95% across nitrogen levels, and Pol ranged from 16.75 to 17.35%, with maxima at N1 (164.0 kg N/ hec). While these differences did not achieve statistical significance, the numerical pattern is consistent with a mild sucrose dilution effect at nitrogen rates above 164.0 kg N/ hec, where rapid vegetative growth may slightly increase in the proportion of non-sucrose solids and water in the juice. The trends have practical implications: the highest TCH and TSH occur at 329 kg N/ hec, where the highest juice quality indices appear at 164 kg N/ hec, suggesting a trade-off between yield and quality that should be considered in optimization models for the specific market context.

Print ISSN: 2053-5783(Print)

Online ISSN: 2053-5791(online)

Website: https://www.eajournals.org/

Publication of the European Centre for Research Training and Development -UK

The overall stability of juice quality across nitrogen treatments is positive from an industrial standpoint, as it indicates that increasing nitrogen to maximize cane sugar yields does not compromise factory processing efficiency at the rates tested.

Variety × Nitrogen Interaction for Juice Purity

The significant V × N interaction for juice purity (P = 0.0143 represents an important agronomic finding. Juice purity is a key determinant of sugar crystallization efficiency and factory recovery; even small reductions in purity can substantially reduce extractable sugar yield. The data reveal that TUC75-3 achieves superior purity under low nitrogen conditions (N0-N1), while R 579 maintains more stable purity levels across the nitrogen range. At high nitrogen rates (N3-N4), R 579 recorded numerically higher purity than TUC75-3. This interaction suggests that TUC75-3 may be more sensitive to nitrogen-induced accumulation of non-sucrose impurities – possibly through elevated amino acid and organic acid concentrations in the juice at higher nitrogen supply (Wiedenfeld 2000). From a practical perspective, this finding supports variety-specific nitrogen management: TUC75-3 many benefit from moderate nitrogen inputs (up to 219 kg N/ hec) that optimize the balance of yield and juice purity, while R 579 can sustain higher nitrogen rates without a significant purity penalty.

Experimental Precision and Agronomic Implications

The CV values obtained for most traits (2.45-8.46%) reflect good to excellent experimental precision, confirming the reliability of the statistical inferences drawn. The higher CV for stalk population (14.64%) is consistent with the inherent special variability in emergence and tillering, which is commonly observed in sugarcane field trials. The coefficient of variation for moisture (1.71%) and juice purity (1.06%) indicates higher precise measurements, lending confidence to the significant interaction detected for purity.

From an agronomic perspective, the results recommend nitrogen rates between 274 and 329 kg N/ hec for maximizing TCH and TSH under Kenana conditions, though the diminishing marginal returns at 329 kg N/ hec suggest that the 274 274 kg N/ hec may offer a more economically optimal rate when nitrogen cost is considered. Further trials incorporating economic analysis, soil nitrogen dynamic, and ratoon cycle responses would strengthen these recommendations.

CONCLUSIONS

This study demonstrated that nitrogen fertilization significantly influenced the growth and yield characteristics of sugarcane at Kenana R&D Farm, with highly significant effects on stalk height, internode number, stalk diameter, TCH, and TSH. Juice quality traits were largely unaffected by nitrogen level. R 579 and TUC75-3 did not differ significantly in most measured traits, except for moisture content, where R 579 exhibited superior ripening characteristics. The significant V × N interaction for juice purity highlights the importance of variety-specific nitrogen management to optimize both yield and quality simultaneously. The following key conclusions are drawn:

1. Nitrogen fertilization at 274-329 kg N/ hec maximized TCH and TSH for both varieties, with the highest recorded means of 123.97 and 18.51 t/ hec, respectively, at 329 kg N/ hec.
2. The largest marginal TCH gain (+32.51 t/ hec) occurred between 0 and 164 kg N/ hec, underscoring the critical of basal nitrogen application in this system.
3. R 579 consistently exhibited numerically higher yield and Brix values and significantly lower moisture content than TUC75-3, suggesting agronomic advantages under the prevailing conditions.
4. TUC75-3 showed greater sensitivity to nitrogen-induced purity reduction at high N rates, recommending its management at moderate nitrogen inputs (up to 219-274 kg N/ hec) to balance yield and juice quality.
5. Overall experimental precision was high (CV 1.06- 8.46% for most traits), supporting the validity of the statistical conditions.

REFERENCES

Abhiram, G., Gopalasingam, T. and Inthujan, J., 2025. Enhancing sustainability in sugarcane production through effective nitrogen management: A comprehensive review. *Nitrogen*, 6(3), p.69.

Alama, I.A. , 2023. Herbicide Management for Sustainable Sugar Cane (Saccharum officinarum l.) Production in Sudan. *J. Exp. Agric. Int*, 45(6), pp.42–48.

Alama, I.E.M.A., 2022. Effect of potassium sulphate fertilizer doses on sugarcane growth yield and quality grown in Sudan. *Yuzuncu Yıl University Journal of Agricultural Sciences*, 32(3), pp.635–640.

Ali, O.A., 1986. *Sugarcane Response to to Applied Potassium at Different Potassium Levels at Kenana Sugar Company*. University of Khartoum.

Allier, A., 2020. Optimized breeding strategies to harness genetic resources with different performance levels. *BMC genomics*, 21(1), p.349.

Anas, M., 2020. Fate of nitrogen in agriculture and environment: agronomic, eco-physiological and molecular approaches to improve nitrogen use efficiency. *Biological research*, 53(1), p.47.

Bokhtiar, S. and Sakurai, K., 2005. Effects of organic manure and chemical fertilizer on soil fertility and productivity of plant and ratoon crops of sugarcane. *Archives of Agronomy and Soil science*, 51(3), pp.325–334.

Chen, D., 2017. Research progress on potassium nutrition in sugarcane. *Journal of Agricultural Sciences*, 7(6), pp.443–450.

Elbasheir, H.A. 2023. Effect of Deficit Irrigation at Different Growth Periods on Yield and Quality of Sugarcane (Saccharum officinarum l.) First Ratoon. *Asian J. Res. Crop Sci*, 8(3), pp.62–78.

Elbashier, H., 2023. Effect of water deficit at different growth periods on yield, quality and water productivity of sugarcane (Saccharum officinarum L.) under Central Sudan agro-climatic zone. *Yuzuncu Yıl University Journal of Agricultural Sciences*, 33(2), pp.313–326.

Elzaki, M.A.M.I., 2003. *The effect of Spacing and Plant Density on the Performance and Yield of Guar (Cyamposis tatragonoloba(L.) Taub) Under Suplementary irrigation in Sudan*. University of Gazera.

Govindasamy, P., 2023. Nitrogen use efficiency—a key to enhance crop productivity under a changing climate. *Frontiers in Plant Science*, 14, p.1121073.

Gu, Q., 2023. Effects of sugarcane variety and nitrogen application level on the quality and aerobic stability of sugarcane tops silage. *Frontiers in Plant Science*, 14, p.1148884.

Hajari, E., Snyman, S.J. and Watt, M.P., 2015. Nitrogen use efficiency of sugarcane (Saccharum spp.) varieties under in vitro conditions with varied N supply. *Plant Cell, Tissue and Organ Culture (PCTOC)*, 122(1), pp.21–29.

Hamid, A. and Dagash, Y., 2014. Effects of sulfur on sugarcane yield and quality at the heavy clay soil vertisols of Sudan. *Universal Journal of Applied Science*, 2(3), pp.68–71.

Hoang, V.-N., 2013. Analysis of productive performance of crop production systems: An integrated analytical framework. *Agricultural Systems*, 116, pp.16–24.

Inman-Bamber, N. and Smith, D.M., 2005. Water relations in sugarcane and response to water deficits. *Field crops research*, 92(2-3), pp.185–202.

J. Abdelrahman, A.F.G. E. A. Gamar Y. Dagash O. Y. Samia and Abdelasmi, M.I., 2026. Roles of Biostimulant (Agrispon) on Sugarcane (PC) at the Heavy Clay Soils "Vertisols", Kenana Sugar Company, Sudan. *European Journal of Agriculture and Forestry Research*, 14(2), pp.1–11.

Kumar, V., Singh, S. and Chand, M., 2014. NUTRIENT AND WATER MANAGEMENT FOR HIGHER SUGARCANE PRODUCTION, BETTER JUICE QUALITY AND MAINTENANCE OF SOIL FERTILITY-A REVIEW. *Agricultural Reviews*, 35(3), p.184.

Lakshmanan, P., 2005. Sugarcane biotechnology: the challenges and opportunities. *In Vitro Cellular & Developmental Biology-Plant*, 41(4), pp.345–363.

Luo, L., Luo, B. and Tai, A.P., 2025. Reactive nitrogen from agriculture: A review of emissions, air quality, and climate impacts. *Current Pollution Reports*, 11(1), p.41.

Mălinas, A., 2022. Current status and future prospective for nitrogen use efficiency in wheat (Triticum aestivum L.). *Plants*, 11(2), p.217.

Mukhtar, S., 2010. Effect of nitrogen and zinc plus copper on sugarcane (Saccharum spp) plant crop in Guneid and Assalaya Sugar Estates, in central Sudan. *Gezira Journal of Agricultural Science*, 8(1).

Mukhtar, S.A., 2009. Response of Sugarcane (Saccharum spp.) to Urea and Methods of Application in some Soils in the Central Clay Plain of Sudan. *University of Khartoum Journal of Agricultural Sciences*, 17(2).

Oliveira Junior, A.C., 2023. Effect of mineral and organic nitrogen sources on vegetative development, nutrition, and yield of sugarcane. *Agronomy*, 13(6), p.1627.

Olk, D., 1998. Interpreting fertilizer-use efficiency in relation to soil nutrient-supplying capacity, factor productivity, and agronomic efficiency. *Nutrient Cycling in Agroecosystems*, 53(1), pp.35–41.

Pérez-Contreras, S., 2025. Sugarcane Industry By-Products: A Decade of Research Using Biotechnological Approaches. *Recycling*, 10(4), p.154.

Singh, I., 2006. Crop sensors for efficient nitrogen management in sugarcane: Potential and constraints. *Sugar Tech*, 8(4), pp.299–302.

Takeda, N., 2021. Exponential response of nitrous oxide (N2O) emissions to increasing nitrogen fertiliser rates in a tropical sugarcane cropping system. *Agriculture, Ecosystems & Environment*, 313, p.107376.

Vasconcelos, J.C.S., 2026. Estimating sugar yield in sugarcane using green normalized difference vegetation index derived from imagery obtained by remotely piloted aircrafts.

Wiedenfeld, R.P., 2000. Water stress during different sugarcane growth periods on yield and response to N fertilization. *Agricultural Water Management*, 43(2), pp.173–182.

Yang, L, 2024. High sugarcane yield and large reduction in reactive nitrogen loss can be achieved by lowering nitrogen input. *Agriculture, Ecosystems & Environment*, 369, p.109032.

Yuan, X., 2025. Global synthesis of nitrogen management in sugarcane systems: Decoding climate-soil-management drivers of Brazil-China contrasts. *Field Crops Research*, 333, p.110075.