

Effect of Compost and Urea Fertilizers on Sugarcane Quality at the Kenana Sugar Scheme, Sudan

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Abstract— Sugarcane (*Saccharum officinarum* L.) is recognized as one of the world's most important cash crops. The climatic conditions and soil types in Sudan, particularly within the central clay plains, are highly suitable for its cultivation. Organic fertilizer (compost) is a vital resource for improving soil fertility by increasing organic matter content, enhancing soil structure, and stimulating microbial activity, which collectively improve nutrient uptake and crop productivity. In contrast, urea is a synthetic nitrogen fertilizer that provides a highly concentrated and readily available source of nitrogen, a macronutrient essential for vigorous vegetative growth, tillering, and the synthesis of proteins and chlorophyll in plants. This study aimed to evaluate the effects of compost and urea fertilizer on quality of sugarcane (var. Co6806). A field experiment was conducted over two consecutive seasons (2023/24 and 2024/25) at the Research and Development Farm of the Kenana Sugar Scheme, Sudan. The treatments were arranged in a 4×4 factorial in split-plot design with four replications. Urea was assigned to the main plots at four levels (0, 119, 238, and 357 kg/ha), while compost was applied to the sub-plots at four rates (0, 12, 24, and 36 ton/ha). Data were collected on juice quality parameters (Pol%, Brix%, Fiber%, Purity%, Moisture%, and Estimated Recoverable Sucrose Content (ERSC%). The results showed that the main effects of compost and urea, both individually and in combination, on sugarcane quality parameters were non-significant across both seasons. Seasonal variation was the dominant factor influencing juice quality, indicating that environmental conditions played a greater role than fertilization in determining sucrose accumulation. Based on the results of this study, it could be recommended that to obtain high cane yield with maintained quality under similar soil and climatic conditions, the crop should be fertilized with compost at the rate of 36 tons/ha in combination with urea at the rate of 357 kg/ha.

Keywords— Sugarcane, Compost, Urea, Juice quality, Pol%, Brix%, Purity%, ERSC%, Kenana Sugar Scheme, Sudan.

I. INTRODUCTION

Sugarcane (*Saccharum officinarum* L.) is a globally vital crop, primarily cultivated for sugar production (accounting for ~80% of world sugar) and increasingly as a renewable source for bioethanol (40% of global bioethanol) (Nair & Sachan, 2022; Voora et al., 2023). As a C4 plant, it possesses high photosynthetic efficiency, enabling rapid growth and substantial biomass accumulation (Tew & Cobill, 2008). Originating in New Guinea, it is now grown extensively in tropical and subtropical regions, including Sudan, and adapts to various soil types from sandy loams to heavy clays (Moore et al., 2013; Mwasinga, 2018). The crop's economic value lies in its ability to store high concentrations of sucrose in its stalk internodes (James, 2008).

Intensive monoculture and continuous ratooning deplete soil nutrients, necessitating regular inorganic fertilizer application (Kusumawati & Noviyanto, 2025). However, soil degradation under sugarcane monoculture is severe, with documented losses of 30-40% of original soil organic carbon after 20 years of continuous cultivation (Bottinelli et al., 2020). This degradation directly reduces yield potential by up to 35% in degraded soils (Obour et al., 2017) and negatively impacts sucrose accumulation, with reductions of 2-4% absolute sucrose content (Verma et al., 2024). Additionally, heavy machinery use causes soil compaction, restricting root penetration, water movement, and ultimately reducing yields (Shaheb et al., 2021).

Sugarcane has a high nitrogen demand (200–300 kg N/ha), but nitrogen use efficiency in current systems is only 30–50% (Otto et al., 2016; Thorburn et al., 2017). This inefficiency results in significant nitrogen losses through leaching, volatilization, and denitrification, causing environmental and economic consequences, including groundwater nitrate contamination often exceeding WHO limits (Canton, 2021; Chen et al., 2022), significant N₂O emissions estimated at 1.5–5.0 kg N₂O-N/ha/year—a potent greenhouse gas (Van Beneden et al., 2010)—and annual economic losses of approximately \$1.2 billion in wasted fertilizer globally (De Luca & Müller, 2023).

Sugarcane cultivation and processing generate substantial organic wastes, including bagasse, filter mud, molasses, trash, and vinasse (Singh et al., 2021; Salman et al., 2023). For each ton of sugarcane processed, approximately 250 kg of bagasse, 36 kg of filter mud, and 100 kg of tops are generated (Mena et al., 1985). Recycling these by-products into compost offers a sustainable strategy to enhance soil fertility, improve soil physical properties, and reduce reliance on chemical fertilizers (Iqbal, 2018). Compost application has been shown to improve soil organic carbon, total nitrogen, available phosphorus, and potassium (Teshome et al., 2014), increase soil water holding capacity by 15–25% (Diacono & Montemurro, 2011), enhance microbial biomass carbon by 30–50% (Sá et al., 2001), and improve cane growth parameters such as height and stalk weight, as well as sugar quality traits including Brix and sucrose content, particularly when combined with nitrogen fertilizer (Bekheet et al., 2018; Zeng et al., 2020).

In Sudan, sugarcane yields are considerably lower (about 60 t/ha) compared to other irrigated cane production areas worldwide (Ibrahim, 2020). The Kenana Sugar Scheme, located on the eastern bank of the White Nile, is characterized by Vertisol soils with high clay content, low nitrogen, and low organic matter (Emam & Musa, 2011; Ganawa & Kheiralla, 2011). Currently, the scheme relies exclusively on chemical fertilizers such as urea, ammonium sulphate, and di-ammonium phosphate (Hamid & Dagash, 2014). However, in response to sustainability challenges, the Kenana Scheme has begun recycling sugarcane by-products and animal waste into compost for field application.

Despite advances, most research has evaluated compost or urea fertilizer in isolation, with limited studies on their combined, synergistic effects (Aouass & Kenny, 2024). There is currently no consensus on the extent to which compost can replace urea fertilizer without compromising yield and quality, nor on the optimal compost-to-nitrogen fertilizer ratios (Reimer et al., 2023). With the increasing need to conserve natural resources and reduce pollution, recycling sugar industry wastes as compost offers a promising strategy to lower fertilizer costs and mitigate environmental and health risks. Accordingly, a research project was initiated over two consecutive seasons (2023/24 and 2024/25) at the Kenana Sugarcane Estate with the following objectives:

Main Objective:

- To evaluate the effects of compost and urea fertilizer applications on the quality of sugarcane at the Kenana Sugar Scheme.

Specific Objectives:

- To study the effects of compost and urea fertilizers on sugarcane quality.
- To determine the optimum application rates of compost and urea fertilizer to achieve the highest yield of sugarcane without compromising quality.

II. LITERATURE REVIEW

2.1 Sugarcane: Origins, Biology, and Agronomic Requirements:

Sugarcane is a tropical C₄ plant domesticated in New Guinea approximately 10,000 years ago (Grivet et al., 2004; Sánchez-Ken, 2019; Zhang et al., 2023). It is characterized by high photosynthetic efficiency under intense solar radiation (Mehdi et al., 2024; Sage et al., 2013). Optimal growth requires warm temperatures (18–33°C), adequate water (300–2,500 mm annual rainfall or irrigation), and well-structured soil (Bonnett et al., 2006; Devi et al., 2022). In Sudan, sugarcane is predominantly cultivated on heavy clay soils, which, despite their challenges, support high yields with proper management (Bakker, 2012). The crop is vegetatively propagated via setts, and its productivity is determined by critical growth stages including tillering, stalk elongation, and sucrose accumulation (Terefe et al., 2017; Impollonia et al., 2024).

2.2 Economic and Industrial Importance:

Globally, sugarcane is a major commercial crop for sugar and bioethanol production, with expanding applications in bioplastics and organic fertilizers (Huang et al., 2020; Lee et al., 2023). The industry contributes significantly to agricultural GDP and rural livelihoods, particularly in developing economies (Solomon, 2016; Mohan, 2017).

2.3 Compost: Production, Composition, and Soil Benefits

Composting is a biological process that stabilizes organic wastes (e.g., bagasse, filter mud, press mud) into a humus-rich amendment (Haug, 2018). The process requires controlled moisture and aeration to achieve thermophilic temperatures that eliminate pathogens (Raviv, 2013). Compost derived from sugarcane residues is rich in organic carbon (~28.6%), macronutrients (N: 0.35–0.65%, P: 0.04–0.15%, K: 0.40–0.50%), and micronutrients (Fe, Zn, Mn) (Fortes et al., 2013; Tajmirriahi et al., 2021). Its application improves soil physical properties (structure, water-holding capacity, aeration), chemical properties (organic matter, CEC, nutrient availability), and biological activity (microbial biomass and diversity) (Dotaniya et al., 2016; Khan et al., 2023; Miháliková et al., 2025).

2.4 Effect of Compost on Sugarcane Quality:

Compost application can positively influence sugarcane juice quality parameters, particularly Brix (total soluble solids), Pol (sucrose percentage), and juice purity. However, these effects are highly variable and depend on several interacting factors, including the type of organic manure used, prevailing soil conditions, and the specific sugarcane variety being cultivated (Teama et al., 2017; Ghallab et al., 2024). A critical factor in maintaining or improving quality is the implementation of balanced nutrition. Specifically, avoiding excessive nitrogen application is essential, as an over-supply of nitrogen, even from organic sources, can delay crop maturity and reduce sucrose accumulation in the stalks (Zeng et al., 2020).

2.5 Effect of Urea (Nitrogen) on Sugarcane Yield:

Nitrogen is essential for sugarcane, promoting tillering, biomass accumulation, and photosynthesis (Gopalasundaram et al., 2012; Aslam et al., 2024). Urea (46% N) is the most widely used nitrogen fertilizer (Poultney et al., 2024). Moderate nitrogen rates (e.g., 46–220 kg N/ha) increase cane yield, but excessive application can delay maturity, reduce sucrose concentration (Pol% and Brix), lower juice purity, and increase impurities (Muchow et al., 1996; Skocaj et al., 2013; Yang et al., 2019). The optimal nitrogen rate for balancing yield and quality is typically around 220 kg N/ha, beyond which sugar recovery declines (Ahmed et al., 2008; Yahaya et al., 2010).

2.6 Integrated Nutrient Management: Compost and Urea:

Integrating compost with urea produces synergistic effects, often outperforming either amendment alone. This combination enhances nutrient use efficiency, sustains soil health, and reduces environmental impacts such as nitrate leaching and N₂O emissions (Bokhtiar et al., 2015; Tang et al., 2022). Studies in Ethiopia and elsewhere confirm that applying compost (15 t/ha) with reduced nitrogen rates (46 kg N/ha) maximizes cane and sugar yields while improving economic returns (Teshome et al., 2014; Xu et al., 2021). The slow-release nature of compost complements the readily available nitrogen from urea, ensuring balanced nutrition throughout the crop cycle (Priya et al., 2024).

2.7 Long-Term and Environmental Benefits:

Long-term compost use builds soil organic matter, enhances carbon sequestration, and improves soil resilience to drought and climate variability (Diacono & Montemurro, 2011; Wright et al., 2022). Recycling sugarcane industry by-products (bagasse, filter mud, vinasse) as compost aligns with circular economy principles, reducing waste and chemical fertilizer dependency (Raza et al., 2021; Sathiyapriya et al., 2024). Economically, compost reduces input costs and increases profitability over multiple seasons (Noor et al., 2023; Stephen et al., 2024).

III. MATERIALS AND METHODS

3.1 Experimental Site Description:

The experiment was conducted at the Research and Development Farm of Kenana Sugar Scheme, Sudan, over two consecutive seasons (2023/24 and 2024/25). Kenana is geographically situated between the White Nile and Blue Nile rivers, at approximately 33° E longitude and 13° N latitude, with an elevation of 410 meters above sea level (Ibrahim & Workneh, 2023). The site is located about 330 km south of Khartoum, the capital city of Sudan, and 30 km southeast of Rabak Town (Ahmed & others, 2016). The climate of the area is characterized as tropical aridic, with a distinct summer rainy season lasting approximately five months, from June to October, peaking in August. The average annual rainfall for the two seasons under study was 379 mm, although rainfall varies considerably from year to year. Temperature extremes range from a mean maximum of 42 °C in May to a minimum of 13.7 °C in January. Relative humidity fluctuates between 20.5% and 79.8%. The soil at the experimental site is classified as a brown, heavy clay Vertisol. The top 60 cm soil profile consists of cracking clay with a clay content ranging from 40% to 60% (Mohamed, 2018). Soil pH values range from 7.50 to 8.50 (Antille et al., 2016). More than

90% of the upper soil horizon exhibits electrical conductivity values below 3 mS/cm³. Extractable sodium percentage (ESP) ranges between 510 and 770 ppm (Mohammed, 2006).

3.2 Experimental Layout Design and Treatments:

This study examined the individual and interactive effects of compost and urea fertilization on quality parameters of sugarcane. The experimental material consisted of four urea levels (0, 119, 238, and 357 kg/ha) and four compost levels (0, 12, 24, and 36 tons/ha). The experiment design was a 4×4 factorial in split-plot design with four replications. Urea levels were assigned to the main plots, and compost levels to the subplots. The total plot area was 60 m² (plot size: 4 furrows, each 10 meters long and 1.5 meters wide). The test variety used was Co6806. Data were collected on key agronomic and quality parameters and subjected to analysis of variance (ANOVA), with means separated using Duncan's Multiple Range Test (DMRT).

3.3 Cultural Practices:

3.3.1 Fertilizer and Compost Application:

Compost was applied as a single dose and uniformly spread along the ridges at the time of planting. Urea fertilizer was also applied as a single dose at planting. All agronomic practices including irrigation, weeding, and other management operations were carried out uniformly across all experimental plots, following the standard protocols of the Sugar Estate.

The compost used in this study was produced by the Kenana Sugar Company using the windrow composting method. Windrow composting involves piling organic materials, such as agricultural and industrial by-products, into long rows (windrows) that are regularly turned to ensure adequate aeration, moisture distribution, and temperature control. This aerobic process accelerates the decomposition of organic matter, reduces odor, and minimizes the risk of soil and water pollution. The temperature of the windrows is monitored to ensure the process passes through the necessary mesophilic and thermophilic phases, which are critical for pathogen reduction and compost stabilization.

Before field application, the maturity of the compost was assessed by evaluating its odor and colour, which are reliable indicators of stability and readiness for use. Additional parameters, such as the C/N ratio and cation exchange capacity, may also be used to confirm compost maturity and biological stability.

The compost formula consisted of organic raw materials with balanced nutrient content, specifically tailored for agricultural use by the Kenana Sugar Company. The composition was as follows: filter mud (45–50%), green cane trash (25–30%), cow manure (8–10%), poultry manure (4–5%), and vinasse sludge (3–5%). This blend provides a rich source of macro- and micronutrients, improves soil structure, and enhances water-holding capacity, contributing to long-term soil fertility and sustainability.

3.3.2 Land Preparation:

Land under continuous sugarcane cultivation in two locations was used. The stubble of the previous crop was uprooted using a disc plow, and the land was then left fallow during the summer months and rainy period. When it was dry, it was deeply plowed using the same disc plow, disk harrowed by a wide level disc, levelled using a planer, and ridged at 1.5 meters spacing using a ridger.

3.3.3 Planting Date and Method:

Planting was carried out using the continuous double-set furrow method. Seed cane was obtained from ten-month-old stalks of the plant crop, which were cut into short setts, each containing three buds. Following fertilizer application, these setts were uniformly placed in the furrows at a rate of 264 setts per plot. To protect the setts from termite damage, the insecticide Regent was applied directly by spraying at a rate of 2.38 L/ha. After treatment, the setts were manually covered with soil and irrigated immediately to ensure proper establishment. Planting was done in the first season on 2nd December 2023, and the second season on 1st December 2024.

3.3.4 Weed Control:

A combination of the herbicides Stomp (pendimethalin) and Gezaprim (Atrazine) was applied as a pre-emergence treatment, following commercial recommendations, just prior to the second irrigation. The application rates were 1.43 L/ha for Stomp and 1.79 kg/ha for Gezaprim. To ensure effective weed control, plots were maintained weed-free by supplementary hand weeding whenever necessary throughout the growing seasons.

3.3.5 Hilling-Up Practice:

Hilling up of the plant rows was performed three months after planting. This involved raising the soil around the cane plants by employing the split ridging technique to cover the furrows in which the cane was planted. This practice helps improve soil aeration, moisture retention, and supports healthy crop growth.

3.3.6 Irrigation Management:

During the germination phase, setts were irrigated at 12-day intervals to ensure optimal moisture for sprouting. After the completion of germination, subsequent irrigations were applied as needed based on crop requirements and prevailing environmental conditions.

3.3.7 Pre-Harvest Drying Off:

Prior to each harvest, irrigation was withheld from the plots scheduled for harvesting for a period of one month to allow the fields to dry adequately. This pre-harvest drying off facilitates easier harvesting and improves cane quality.

3.3.8 Harvesting Procedure:

The harvested area for each plot was 30 m², consisting of two rows, each 10 meters in length and 1.5 meters in width. Harvesting was conducted manually. Stalks were cut precisely at the soil surface to maximize yield and ensure uniformity. After cutting, all stalks were thoroughly cleaned by removing leaves and tops, ensuring that only the cane stalks were retained for subsequent analysis determination. This standardized harvesting method ensures accurate assessment of quality parameters across all experimental plots.

3.3.9 Collection of Data for Cane Quality Parameters:

Cane quality data were collected one day prior to harvest. Cane analysis was conducted in the Sucrose Laboratory of the Kenana Sugarcane Research Department, following the procedures outlined by the International Commission for Uniform Methods of Sugar Analysis (ICUMSA, 1994). For each plot, a random sample of 10 stalks (5 stalks per row) was collected from the effective harvested area at harvest time. The sampled stalks were immediately stripped of leaves, topped, and prepared for laboratory analysis. The stalks were chopped and ground using a Jeffco Cutter Grinder to obtain crushed cane. From the crushed material, a 50 g subsample was randomly selected to determine cane moisture content by oven drying at 105°C for 5 hours. The remaining quality parameters were assessed using the Jeffco Wet Disintegrator method. A 100 g sample of crushed cane was disintegrated in two liters of distilled water for 20 minutes using the Jeffco Wet Disintegrator Machine. From the disintegrated material, 100 ml was filtered through Whatman No. 42 filter paper and used to determine Brix% extract with an RFM 340 refractometer (B+S Ltd). Another 150 ml aliquot, mixed with three teaspoons of Octapol, was filtered and the filtrate was analyzed for Pol% extract using an AA-10 Polarimeter (Optical Activity Ltd). The following cane quality components were determined according to standard ICUMSA calculation procedures:

- Pol% cane
- Brix% cane
- Fiber% cane
- Moisture% cane
- Purity% cane
- ERSC% (Estimated Recoverable Sucrose Content)

3.4 Data Statistical Analysis:

The data were analyzed using standard analysis of variance (ANOVA) appropriate for the split-plot design, utilizing the MSTATC statistical software package. Means found to be significant were separated using Duncan's Multiple Range Test (DMRT) as described by Gomez and Gomez (1976). This approach ensured robust evaluation of treatment effects and reliable comparison among means.

IV. RESULTS AND DISCUSSION

4.1 Effect of Compost and Urea Fertilizers on Pol% Cane:

Table 1 presents the effect of compost and urea fertilizer levels, as well as their interaction, on Pol% (sucrose content) in sugarcane. The results showed that neither compost nor urea fertilizer, nor their interaction, had a significant effect on Pol% in both seasons. In the first year (2023/24), all mean values for compost (ranging from 14.6 to 15.1) and urea (from 14.6 to 14.9) were statistically similar. Similarly, in the second year, all treatment combinations were statistically equivalent, confirming the absence of a significant treatment response. These findings are consistent with those of Teshome et al. (2014), who reported that compost application did not significantly affect sucrose content (Pol%), although it significantly enhanced sugar yield by increasing cane biomass. This suggests that the primary contribution of compost to sugar production is through increased biomass rather than direct improvements in juice quality. Similarly, Nawaz et al. (2017) found that moderate rates of compost and urea fertilizer do not significantly influence sucrose content, which is more strongly affected by varietal characteristics, crop maturity, and climatic conditions. It is noteworthy that Yousif et al. (2021) observed that high urea rates can reduce Pol% by promoting vegetative growth at the expense of sucrose accumulation. However, the stability of Pol% observed in the present study suggests that the fertilizer rates applied were within safe and optimal limits, avoiding any detrimental effects on sucrose content.

Although compost and urea significantly improved physical growth parameters and overall yield, they had little effect on the sugar concentration (Pol%) of the cane. The only major factor influencing Pol% was season, which was highly significant ($P < 0.01$). This suggests that climatic conditions between the two years played a much larger role in sucrose accumulation than the nutrient treatments. The lack of a significant change in Pol% despite the increased yields is positive, as it shows that the higher biomass produced by the compost and urea did not 'dilute' the sugar content of the stalks.

TABLE 1
EFFECT OF COMPOST AND UREA FERTILIZERS ON POL% CANE

Seasons	First year (2023/2024)					Second year (2024/2025)				
Treatments	Urea (kg/ha)									
Compost (t/ha)	0	119	238	357	Means	0	119	238	357	Means
0	15.4	15.6	14.5	15	15.1 A	14.4	14.1	14.4	14.7	14.4 A
12	14.8	14.5	14.7	14.5	14.6 A	14.4	13.7	14.5	14.6	14.3 A
24	15.2	14.6	14.6	14.2	14.7 A	14.7	13.6	13.7	13.5	13.9 A
36	14	14.9	14.9	15	14.7 A	14.6	14.6	13.6	14.7	14.4 A
Means	14.9 A	14.9 A	14.6 A	14.7 A		14.5 A	14.0 A	14.0 A	14.4 A	
<i>Statistical Parameters</i>										
	Compost	Urea	Interaction			Compost	Urea	Interaction		
SE±	0.24	0.26	0.53			0.28	0.2	0.4		
CV%	7.2					5.69				

Note: Values are means of four replications. Means followed by the same letter (A) within each main effect (urea or compost) are not significantly different at $P \leq 0.05$ according to Duncan's Multiple Range Test (DMRT).

4.2 Effect of Compost and Urea Fertilizers on Brix% Cane:

Table 2 presents the effects of compost and urea fertilizer rates, and their interaction, on sugarcane juice quality measured as Brix% (total soluble solids). The results indicate that the main effects of the treatments were largely non-significant, with their interaction also showing no consistent influence across the two seasons. In the first season, neither compost nor urea application had a statistically significant effect on Brix%. Mean values for compost treatments ranged from 17.0% to 17.4%, while those for urea rates ranged from 16.9% to 17.4%. This pattern was consistent in the second season for the urea treatments, with all mean values falling within a narrow range of 15.5% to 15.9%. In contrast to the first year, compost application exhibited a statistically significant, though non-dose-dependent, effect on Brix% during the second season. The highest Brix% values were recorded in the 0 t/ha (16.1%) and 36 t/ha (15.8%) compost treatments, which were statistically similar. Conversely, the intermediate rate of 24 t/ha produced a significantly lower mean Brix% of 15.3%.

These findings are consistent with Balaganesh et al. (2020), who reported that Brix% remains stable under moderate fertilization and is primarily influenced by water status and crop maturity rather than nutrient supply, except in cases of severe

deficiency or excess. Similarly, Kumara and Bandara (2002) concluded that urea application did not significantly affect Brix%, purity, or commercial cane sugar (CCS%) content in sugarcane.

TABLE 2
EFFECT OF COMPOST AND UREA FERTILIZERS ON BRIX% CANE

Seasons	First year (2023/2024)					Second year (2024/2025)				
Treatments	Urea (kg/ha)									
Compost (t/ha)	0	119	238	357	Means	0	119	238	357	Means
0	17.7	18	16.7	17.2	17.4 A	15.8	16.3	15.8	16.4	16.1 A
12	17	17	17.1	16.9	17.0 A	15.9	15.2	16	16.1	15.8 A
24	17.5	17.2	16.6	16.8	17.0 A	16.1	15.1	15.1	14.9	15.3 A
36	16.2	17.4	17.2	17.5	17.1 A	16.1	16	15.1	16.1	15.8 A
Means	17.1 A	17.4 A	16.9 A	17.1 A		15.9 A	15.7 A	15.5 A	15.9 A	
<i>Statistical Parameters</i>										
	Compost		Urea	Interaction		Compost		Urea	Interaction	
SE±	0.25		0.27	0.53		0.3		0.17	0.35	
CV%	6.2					4.41				

Note: Values are means of four replications. Means followed by the same letter (A) within each main effect (urea or compost) are not significantly different at P ≤ 0.05 according to DMRT.

4.3 Effect of Compost and Urea Fertilizers on Fiber% Cane:

Table 3 presents the effect of compost and urea fertilizer levels, as well as their interaction, on fiber percentage in sugarcane. The results showed that the response of fiber to compost and urea application varied between the two seasons. In the first season, compost application had a statistically significant effect on fiber percentage. The treatments receiving 12 t/ha and 24 t/ha of compost produced the highest fiber percentages, with means of 18.1% and 18.0%, respectively, significantly higher than the control (17.4%). In contrast, the main effect of urea application was not significant. In the second season, no significant differences were observed in the main effects of either compost or urea on fiber content. Although the main effects of urea were consistently non-significant, the interaction between compost and urea produced notable results in the first season. These findings are consistent with Teshome et al. (2014), who reported that while compost and urea significantly influenced stalk girth, stalk weight, cane yield, and sugar yield, fiber percentage remained unaffected by compost, nitrogen, or their interaction.

TABLE 3
EFFECT OF COMPOST AND UREA FERTILIZERS ON FIBER% CANE

Seasons	First year (2023/2024)					Second year (2024/2025)				
Treatments	Urea (kg/ha)									
Compost (t/ha)	0	119	238	357	Means	0	119	238	357	Means
0	17.5	17.2	17.3	17.6	17.4 A	20	19.5	18.4	17.9	19.0 A
12	18.8	18.6	16.9	18.1	18.1 A	19.4	19.1	17.7	18.8	18.7 A
24	17.8	17.2	19	18	18.0 A	19.1	19.4	17.7	18	18.5 A
36	18.4	16.4	16	16	16.7 A	19.5	18.1	18.5	19.2	18.8 A
Means	18.1 A	17.3 A	17.3 A	17.4 A		19.5 A	19.0 A	18.1 A	18.5 A	
<i>Statistical Parameters</i>										
	Compost		Urea	Interaction		Compost		Urea	Interaction	
SE±	0.33		0.46	0.91		0.37		0.34	0.67	
CV%	10.4					7.17				

Note: Values are means of four replications. Means followed by the same letter (A) within each main effect (urea or compost) are not significantly different at P ≤ 0.05 according to DMRT.

4.4 Effect of Compost and Urea Fertilizers on Purity% Cane:

Table 4 presents the effect of compost and urea fertilizer levels, as well as their interaction, on juice purity percentage (Purity%) in sugarcane. The results indicated that the main effects of the treatments were consistently non-significant across both seasons.

In the first season, neither compost nor urea application had a statistically significant impact on Purity% as a main effect. All mean values for the compost levels, ranging from 86.0% to 86.9%, and for the urea levels, ranging from 85.8% to 86.8%, were statistically equivalent. This pattern was repeated in the second season, with no significant differences observed. The highest individual Purity% recorded across the entire study was 91.72%, achieved in the second year with the absolute control treatment (0 t/ha compost and 0 kg/ha urea). These findings are consistent with Kwong and Pasricha (2002) and Kumara and Bandara (2002), who reported that juice purity remains stable under balanced fertilization regimes and is more strongly influenced by harvest timing and ripening conditions.

TABLE 4
EFFECT OF COMPOST AND UREA FERTILIZERS ON PURITY% CANE

Seasons	First year (2023/2024)					Second year (2024/2025)				
Treatments	Urea (kg/ha)									
Compost (t/ha)	0	119	238	357	Means	0	119	238	357	Means
0	86.8	86.8	86.7	87.3	86.9 A	91.7	86.6	91.2	89.5	89.8 A
12	86.7	85.5	86.1	85.6	86.0 A	90.6	89.8	90.8	90.8	90.5 A
24	87.4	85.4	87.8	84.8	86.3 A	91.6	90.4	90.7	90.7	90.8 A
36	86.3	85.6	86.5	85.6	86.0 A	90.7	91.6	90.2	91.2	90.9 A
Means	86.8 A	85.8 A	86.8 A	85.8 A		91.1 A	89.6 A	90.7 A	90.5 A	
<i>Statistical Parameters</i>										
	Compost	Urea	Interaction			Compost	Urea	Interaction		
SE±	0.8	0.5	1.01			0.79	0.65	1.31		
CV%	2.3					2.89				

Note: Values are means of four replications. Means followed by the same letter (A) within each main effect (urea or compost) are not significantly different at P ≤ 0.05 according to DMRT.

4.5 Effect of Compost and Urea Fertilizers on Moisture% Cane:

Table 5 shows the effect of compost and urea fertilizer levels, as well as their interaction, on moisture percentage in sugarcane. The analysis of cane moisture content revealed contrasting results between the two seasons. In the first year, no significant differences were observed in the main effects of either compost or urea on moisture percentage. However, in the second season, compost application exhibited a statistically significant effect. The treatment receiving 24 t/ha of compost produced a significantly higher mean moisture content (66.2%) compared to both the control (0 t/ha) and the highest compost rate (36 t/ha). These findings are consistent with Balaganesh et al. (2020) and Caetano et al. (2023), who reported that cane moisture content is predominantly influenced by climatic factors rather than fertilization, except in cases where excessive vegetative growth is induced by very high urea rates.

TABLE 5
EFFECT OF COMPOST AND UREA FERTILIZERS ON MOISTURE% CANE

Seasons	First year (2023/2024)					Second year (2024/2025)				
Treatments	Urea (kg/ha)									
Compost (t/ha)	0	119	238	357	Means	0	119	238	357	Means
0	64.7	64.3	66.1	65.2	65.1 A	64.2	64.2	65.8	65.7	65.0 A
12	64.2	64.5	66	65	64.9 A	64.8	65.8	66.4	65.1	65.5 A
24	64.8	65.7	64.4	65.3	65.1 A	64.9	65.5	67.3	67.2	66.2 A
36	65.4	66.2	66.8	66.6	66.2 A	64.5	65.9	66.4	64.7	65.4 A
Means	64.8 A	65.2 A	65.8 A	65.5 A		64.6 A	65.3 A	66.5 A	65.7 A	
<i>Statistical Parameters</i>										
	Compost	Urea	Interaction			Compost	Urea	Interaction		
SE±	0.38	0.35	0.77			0.46	0.35	0.71		
CV%	2.4					2.15				

Note: Values are means of four replications. Means followed by the same letter (A) within each main effect (urea or compost) are not significantly different at P ≤ 0.05 according to DMRT.

4.6 Effect of Compost and Urea Fertilizers on ERSC% Cane:

Table 6 shows the effect of compost and urea fertilizer levels, as well as their interaction, on Estimated Recoverable Sucrose Content (ERSC%) in sugarcane. ERSC% showed no significant differences for any main effects or interactions across the two years. These findings are consistent with Balaganesh et al. (2020), who reported that moderate rates of compost and urea do not significantly affect recoverable sucrose, a parameter known to be more sensitive to extreme nutritional imbalances or water stress conditions. Teshome et al. (2014) reported that while compost and urea applications significantly influenced stalk girth, stalk weight, cane yield, and sugar yield, the ERSC% and related quality parameters including purity and sucrose content did not respond significantly to either compost, nitrogen, or their interaction.

TABLE 6
EFFECT OF COMPOST AND UREA FERTILIZERS ON ERSC% CANE

Seasons	First year (2023/2024)					Second year (2024/2025)				
Treatments	Urea (kg/ha)									
Compost (t/ha)	0	119	238	357	Means	0	119	238	357	Means
0	13.1	13.3	12.2	12.8	12.8 A	12.5	11.8	12.5	12.6	12.3 A
12	12.4	12.1	12.4	12.1	12.3 A	12.3	11.7	12.6	12.6	12.3 A
24	13	12.3	12.3	11.8	12.3 A	12.7	11.6	11.8	11.7	11.9 A
36	11.8	12.6	12.7	12.7	12.4 A	12.5	12.8	11.7	12.7	12.4 A
Means	12.5 A	12.5 A	12.4 A	12.3 A		12.5 A	12.0 A	12.1 A	12.4 A	
<i>Statistical Parameters</i>										
	Compost	Urea	Interaction	Compost	Urea	Interaction				
SE±	0.25	0.28	0.55	0.29	0.23	0.46				
CV%	8.9					7.57				

Note: Values are means of four replications. Means followed by the same letter (A) within each main effect (urea or compost) are not significantly different at $P \leq 0.05$ according to DMRT.

V. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions:

Based on the results of the two-year trial, the study arrived at the following conclusions:

1. Despite significant yield improvements (reported elsewhere), all juice quality parameters (Pol%, Brix%, Purity%, and ERSC%) remained statistically unaffected by compost or urea application. Higher productivity was achieved without any dilution of sucrose content or reduction in juice purity.
2. Season was the most dominant factor affecting quality parameters, with highly significant effects on Pol%, Brix%, and Purity%. Climatic conditions play a greater role in sucrose accumulation than moderate variations in fertilizer inputs.
3. The progressive improvement in sugarcane response from the first to the second season suggests that compost application enhances soil health over time through increased organic matter, improved nutrient cycling, and enhanced soil physical properties.
4. Composting sugar industry by-products, specifically filter mud, bagasse, and vinasse, offers a strategic approach to recycling agricultural wastes, which enhances soil health and supports sustainable intensification while mitigating the negative impacts of soil degradation.
5. The findings suggest that a fundamental combination of "nitrogen-centric" and "organic matter-centric" sugarcane nutrition strategies may be warranted. Therefore, a transformation to compound fertilizer recommendations is needed and opens new possibilities for sustainable production intensification.

5.2 Recommendations:

Based on the results, to obtain high sugarcane yield with maintained quality under similar soil and climatic conditions, fertilization with compost at the rate of 36 tons/ha in combination with urea at the rate of 357 kg/ha is recommended. These

rates represent the highest levels tested and produced optimal growth responses without adversely affecting juice quality parameters.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this article

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