

EFFECT OF NITROGEN FERTILIZER ON GROWTH, YIELD AND QUALITY PARAMETERS OF THREE SUGARCANE (*SACCHARUM OFFICINARUM* L.) VARIETIES

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ABSTRACT

This study examines the effects of nitrogen on the growth, yield and quality of three sugarcane varieties under irrigated conditions in the low country dry zone of Sri Lanka. Three sugarcane varieties (SL96-128, SL04-624 and SL8306) were tested at four nitrogen fertilizer levels (0, 100, 200, 300 kg/ha) in a split plot design with four replicates. Selected growth, yield and quality parameters were studied in this field experiment. The results of the study demonstrated that application of 100kg/ha or 300kg/ha N fertilizer has shown highest girth of stem (cm), partitioning biomass to millable stalk (PBMS), brix and pol percentage in all three varieties, SL04-624, SL8306 and SL96-128. In addition, variety SL04-624 have shown highest total above ground biomass production (dry matter) (41987.8kg/ha), partitioning biomass to millable stalk (PBMS) (74.5%), brix (19.4%), pol (17.1%) and pure obtainable cane sugar (POCS) (12.3%). Therefore 100kg/ha (N2) could be concluded as the best rate of N fertilizer application for the varieties tested in this study considering the cost of production, environmental and groundwater pollution. SL04-624 could be recommended as the most suitable variety for low country wet zone of Sri Lanka responding to 100kg/ha N fertilizer.

Key words: growth, nitrogen, fertilizer, quality, sugar cane, yield

Introduction

Sugarcane (*Saccharum officinarum* L.) is the habitant of tropical regions of the world. The genus *Saccharum*, to which sugarcane belongs even derived its name from the Greek word ‘Sakcharon,’ meaning sugar (James 2004). Sugarcane crop can be grown under varied Agro ecological conditions ranging from tropical to subtropical climate of Sri Lanka. Sugarcane producing area and production of sugarcane has been fluctuating from year to year depending upon climatic conditions and price policy. The plant produces sugar as the main product and other co-products such as ethanol used by pharmaceutical industry and as fuel,

biogases for paper and chip board manufacture and press mud as a rich source of organic nutrients for crop production even though the total sugarcane production in the country is only enough for producing 9% of sugar of total requirement of the country.

Economical value of Sugarcane

Sugarcane is one of the important commercial crops and is in inescapable positions in agricultural economy of Sri Lanka. Sugarcane known to be under cultivation in India since time immemorial and mentioned in Indian writings of the period 1400 to 1000 BC (Barber, 1931). Puranas and various ancient literatures have

ample description of sugarcane and products derived from it. This 'Noble cane' belonging to the species *Saccharum officinarum* is being known to be cultivated in New Guinea about 8000 years ago for chewing purpose (Miraj, 2016). Now, the crop is cultivated throughout the tropical and subtropical regions mainly for production of sugar, a natural sweetener. Though the majority of sugarcane produced is used for sugar, it is also being processed into less refined and healthier forms of sweeteners like jaggery and Khandsari (Shahi, 1999). In recent years, the crop has gained more attention as a bio energy crop for ethanol production and co-generation of power.

The time of harvest is crucial for the profitability. This depends on the interaction between environment and the crop in relation to sucrose content or commercial cane sugar content. It also depends on the economics of harvesting, transport and milling operations. The opportunity exists to use N management to maximize the profit by manipulating the commercial cane sugar content in fresh millable stalks through improving brix and pol percent at different crop ages. However, limited information is available on the determinants of sucrose accumulation over time under variable N supply and in different varieties.

Medicinal value of Sugar cane

Sugarcane juice is extensively used as a nonalcoholic energy drink especially during the warmest periods of the year in the Asian and other sugarcane growing countries (Swaminathan, 1995). Usually, roller crusher is used to obtain the juice by crushing the cane and consuming it alone or with the addition of ginger, lime etc. to improve the taste. It is better to consume fresh as the preservation deteriorates the quality of the juice due to the presence of simple sugars. Refined table sugar and

unrefined jaggery are produced from sugarcane juice. According to the research findings, sugarcane juice has revealed the presence of 75 to 85% water, 10 to 21% sucrose (non-reducing sugar), 10-15% fiber, 0.3 to 3% reducing sugars like glucose and fructose and other organic and inorganic compounds (Swaminathan, 1995). Furthermore, it is said to be the richest source of phenolic acids, glycosides and flavonoids.

Sugarcane juice extensively used in various medical systems including Ayurveda, Unani and Siddha due to its medicinal properties (Warrier *et al*, 2010). In Ayurveda, sugarcane juice is recommended as a pacifier of the *Tridosha* (the 3 somatic humors of the body; *Vata*, *Pitta* and *Kapha*) and a nutritional drink (Kritikar and Basu, 1991). Sugarcane juice is used traditionally as a diuretic or as medications that promote the increased expulsion of water and salts as urine (Karthikeyan and Samipillai 2010), aphrodisiac (stimulating sexual desire) (Karthikeyan and Samipillai 2010), coolant, laxative (substances that increase bowel movements) (Karthikeyan and Samipillai 2010), demulcent (relieves irritation or inflammation) (Karthikeyan and Samipillai 2010), blood purifier, antiseptic and tonic (Khare 2007; Karthikeyan and Samipillai 2010). Moreover, sugarcane juice is therapeutically indicated in hiccups, leprosy and intestinal pathologies (Kirtikar and Basu 1991; Karthikeyan and Samipillai 2010).

Nitrogen fertilizer on sugarcane growth and yield

Nutrients application is the essential agriculture practice for the growth and yield sugarcane crops. The amount of nutrient requirement and the effect on the crop varies depending on the crop varieties (El-Geddawy *et al.*, 2012). Understanding responses to the nutrient levels under which plants are grown

is an important factor for efficient crop production. These responses differ considerably among species and cultivars based on their habitat and genetic determinants and may involve changes in growth, water relations and plant carbon, nutrient and hormonal balance.

Nitrogen (N) is a key restrictive factor for continuous sugarcane output. A proper amount of N-fertilizer can remarkably increase tillering and thus results in an early population with high yield, which can increase output (Ahmed et al., 2009). Nitrogen is the most important nutrient involved in photosynthesis. In a number of species, the light-saturated photosynthetic rate has been shown to be a function of leaf N content, which in turn is a function of N availability (Evans 1989). Reduced photosynthetic rates under N stress are due mainly to low concentrations of photosynthetic enzymes (Chapin, 1991), as N is a major component of soluble and structural proteins involved in photosynthesis.

Nitrogen stress also causes a decline on stomata conductance, and this could be another factor responsible for reduced photosynthetic rates under N stress. Nevertheless, high intercellular CO₂ concentrations observed inside leaves of plants grown under low N supply suggest that stomata limitation of photosynthesis is reduced under these conditions and that the CO₂ uptake rate in N-stressed plants is limited primarily by reduced biochemical capacity for photosynthesis (Evans 1983). The management of N fertilizer is central to profitable and sustainable sugarcane (*Saccharum officinarum* L.) Production. Yield limitations imposed by inadequate N supply can have a negative impact on profitability. Conversely, N application in excess may have potential deleterious off-

farm impacts on the environment and can also reduce sugar quality and profitability. Numerous studies have shown that high N application decreases sucrose concentration in fresh millable stalks (Borden 1948, Wood 1990, El-Geddawy et al., 2012, Chapman 1994).

Sugarcane and its by products are very important and we are very much dependent on the foods which are related to sugarcane by products in our daily life. Because of the very low sugarcane cultivation and production in our country, sugarcane byproducts from foreign countries are imported in huge amounts to fulfill daily needs. If a solution is found by doing this research, which will help us to select the correct N fertilizer dosage for crop variety to enhance the domestic cane production and try to minimize the import of cane product (sugar).

The main objective of this research was to evaluate the performance of three sugarcane varieties under different rates of N fertilizers. The specific objectives of the study were to determine the effects of nitrogen on growth, yield and quality parameters of three sugar cane varieties (i.e.: SL-96-128, SL-8306 and SL-04-624).

Methodology

Study area

The experiment was conducted at the Seed cane production farm at Sugarcane Research Institute (SRI), Vannerikulam, Kilinochchi in Northern Province of Sri Lanka. The study was carried out in a place which located in low country dry zone (DL3) of Sri Lanka, where the annual average rainfall and temperature are 139.6mm and 29. 31°C respectively. The soil is sandy loam, which belongs to the great group Alluvial soils.

This study was conducted from June 2023 to June 2024.

Research design/ Experimental design.

Four nitrogen rates (N1, N2, N3 and N4) i.e., 0, 100, 200 and 300 kg/ha of N were tested in three varieties of sugarcane; SL-96-128, SL-8306 and SL-04-624 used in a factorial experiment. These 12 treatments were tested in a split plot design, by having nitrogen treatment in main plots and varieties in sub plots with four replicates. The individual plot/block size was 07 m×5 m (4 rows) and the spacing between rows was 1.37 m as recommended by SRI. A

space of 2.5 m was maintained between plots/Blocks (total 4 plots/Blocks).

Fertilizer calculations

The fertilizer rates were calculations according to this research and as per the SRI recommendations and protocols (Table 1).

Field/Land selection

The research field was selected as a level topography and the homogenous soil type, and the place was selected which is easy for irrigation process. Initial soil analysis is given in Table 2. Land preparation was done as recommended by the Sugarcane Research Institute.

Table.1: Standard fertilization system (times and ratios) of SRI

Fertilizer	Duration & Fertilizer application ratio (according to SRI scales)		
	Basal	45DAP	90DAP
Urea	20kg/acre	40kg/acre	60kg/acre
MOP	44kg/acre	No	46kg/acre
TSP	80kg/acre	No	No

*DAP-Days after planting

Table 2: Soil analytical data (done by SRI)

pH	Conductivity(mS/cm)	Texture class	Organic carbon (%)	Total N(ppm)	Exchangeable K(ppm)
8.95	0.635	Sandy loam	2.45	ND	ND

*ND- Not detectable at parts per million range(ppm)

*Results are reported on dry weight basis.

Seed cane collection and treatment

All three varieties of sugarcane were collected from the sugarcane farm itself. The sugarcane was harvested or cut by the knife which is specially used by SRI only for

sugarcane harvesting or cutting process. As planting materials, eight months old three budded stems (one-foot length) cuttings were used. It was not necessary to treat planting materials prior to field planting as

they have already been treated on the farm itself.

Field establishment

After preparation, stem cuttings were directly established on the field as per the research experiment layout described above. Eight months old three budded stem cuttings (one- foot length) were planted in a linear method. Thirty-six cuttings were planted in a plot (4 plots×36=144 cuttings). Three cuttings were planted in a 1m length planting area which were set up in a row. Fertilization was done in three times such as basal (with the time of planting), 45DAP (1st top dressing) and 90 DAP (2nd top dressing).

Irrigation

Irrigation was done 3days interval for one month since the planting process (to avoid drought due to hot weather condition), after that the irrigation was done once a week as the plant growth, and sometimes, the irrigation was done once a fortnight due to rain and plenty of moisture in the field. No irrigation occurred due to continuous rain for the last 2 months. Irrigation was done using furrow irrigation method. Weeding was done by hand or manually whenever needed.

Data collection

The process of data collections on the growth parameters and biomass accumulation were done at 135 DAP and 240 DAP respectively but yield and quality parameters (juice quality) were done at 290 DAPS.

Growth parameters and biomass accumulation

Randomly selected a plant in each planting area of every block was used to estimate the growth parameters such as girth of stalk (to

take girth of a stalk- the girth of top, mid and bottom parts were taken, and the average was calculated as the girth of a stalk).

Randomly selected plants in each planting area(1m) of every block was cut at ground level to estimate total above ground biomass production (kg/ha). These parameters were measured at 240 DAP. Partitioning biomass to millable stalk (PBMS) was calculated using the following equation:

$$PBMS = \frac{\text{Stalk dry matter}}{\text{Total above ground biomass}} \times 100$$

Weight of each and every fresh and oven dried plant part was weighed.

Total above ground biomass(dried)(TAGM) was estimated and by using the above equation, the partitioning biomass to millable stalk (PBMS-%) was calculated.

Yield parameters

Number of millable stalks/ Number of millable canes per hectare (NMC) was estimated by counting all the cane stalks in each planting area of entire plot and it was converted to hectare scale. The cane height and the cane weight were measured by cutting randomly selected cane stalks in each planting area of all plots. These parameters were measured at 290 DAP. Then the fresh millable cane yield(kg/ha) was estimated by using the following equation.

$$\text{Cane yield} = \text{Weight of the stalks (kg)} \times \text{Number of stalks in a hectare (h)}$$

Quality (Juice quality) parameters

Each sugarcane stalk (about 5 stalks from each planting area) was used to extract juice to measure juice quality parameters i.e. brix%, pol%, purity, pure obtainable cane sugar (POCS) and fiber content in the cane.

- The brix and pol values in stalk juice were measured directly by using brix Refractometer (Atago RX-IP) and Polarimeter (Jasco-P2000) respectively. The apparent purity and POCS were calculated using the following Equations:
- **Apparent purity** = $\frac{\text{pol}\%}{\text{brix}\%} \times 100$
- **POCS%** = $3P / 2 \{1 - ((F + 5) / 100)\} - B / 2 \{1 - ((F + 3) / 100)\}$

The fiber content was estimated by measured the fresh cane weight and oven dried weight. The cane was cut into small pieces and put into the oven at 108^o c for 48 hours to get dry weight. The following equation was used to estimate fiber content (bagasse percentage) of cane.

$$\text{Fiber content} = \frac{\text{Cane dry weight}}{\text{Cane fresh weight}} \times 100$$

Data analysis

Analysis of variance (ANOVA) of the measured data was carried out using the SPSS statistical package to check treatment effect of experiment considering a 0.05 significance level.

Results and Discussion

Growth parameter

Girth of stalk(cm)

Figure 1 shows the effect of different rates of nitrogen application on mean girth of stalks of three different varieties (SL04-624, SL8306, SL96-128) of sugarcane plants. The variety SL04-624 showed significantly highest ($P \leq 0.05$) girth of stalks (7.2cm) in treatment N4 which is significantly different from N1(0 kg/ha) and N3 (200kg/ha) treatment, but not significantly different from N2 (100kg/ha) treatment. The lowest girth of stem (6.1cm) was observed in treatment N1 with no N fertilizer. The

variety SL8306 with N2 treatment showed significantly ($P < 0.05$) highest girth of stem (7.2cm) and there was a significant different between treatments N1, N3 and N4. The lowest girth of stem (5.3 cm) was observed in N1 treatment with no N fertilizer. Significantly ($P \leq 0.05$) highest girth of stalk (8.4cm) was observed in variety SL96-128 with the 100 kg/ha of nitrogen application (N2). However, girth of stalk in N2 treatment of variety SL96-128 is not significantly different from N3 (200 kg/ha) and N4 (300kg/ha) N applied treatments. The lowest girth of stalk (6.5cm) was obtained under N1 treatment with no nitrogen fertilizer application for the variety SL8306. Yahaya *et al.*, (2010) has shown that nitrogen has significant influence on cane growth, which agrees with this study results.

Biomass accumulation

Total above ground biomass (dry matter) (TAGM)

According to Figure 2, N4 has given significantly ($P \leq 0.05$) highest TAGM (41987.8kg/ha) for variety SL04-624 and the lowest (15481.5kg/ha) was observed in treatment N1 (0kg/ha). However, TAGM (dry matter) of treatment N4 (300kg/ha) is not significantly different from treatment N2 of variety SL04-624. The variety SL8306 showed significantly ($P < 0.05$) highest TAGM (35375.8 kg/ha) in N4 (300kg/ha) treatment but not significantly different from N2 (100kg/ha) and N3 (200kg/ha) treatments. The lowest total above ground biomass (dry matter) was obtained in N1 treatment (15481.5kg/ha) with no nitrogen fertilizer application for the variety SL8306. The variety SL96-128 has shown the highest (55938.1kg/ha) total above ground biomass (dry matter) with the 100 kg/ha of nitrogen application (N2). However, this result in N2 treatment of variety SL96-128 is not

significantly different from the total above ground biomass (dry matter) of the N1 (0 kg/ha), N3 (200 kg/ha) and N4 (300kg/ha) N

applied treatments. Therefore, the N applications do not have any positive effect on the variety SL96-128.

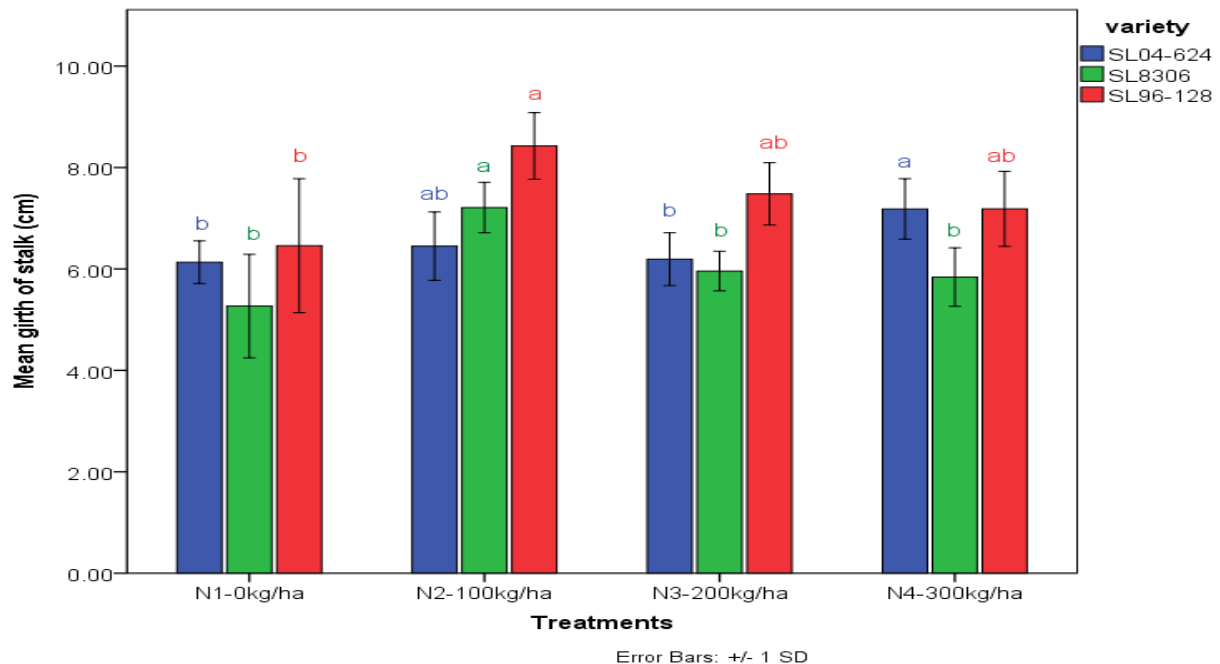


Figure 1: Effects of treatments on girth of stalk for plant varieties (cm). A significant level for the graph was prepared based on 0.05. Means with same letters are not significantly different between treatments ($P \geq 0.05$).

Kumara and Bandara (2001) reported that fertilizer N application is mandatory in intensive sugarcane cultivation which requires a high amount of nitrogen as a nutrient to produce high biomass and this agrees with the results obtained in this study. Gana (2008) reported that a proper amount of N fertilizer can remarkably increase tillering and thus results in an early population with high yield, which can increase output.

Partitioning biomass to millable stalk (PBMS%)

Treatment N4 (300kg/ha) reported significantly highest ($P \leq 0.05$) (74.5%)

PBMS of variety SL04-624 (Figure 3). But N4 treatment is not significantly different from N2 and N3 treatments. The variety SL04-624 shown lowest PBMS (62.45%) in treatment N1 where no N fertilizer was applied. The variety SL8306 showed the significantly ($P \leq 0.05$) highest PBMS (71.8%) in treatment N4 and it was significantly different from N1, N2 and N3 treatments. The lowest PBMS (56.4%) was shown in treatment N1. Significantly ($P \leq 0.05$) highest PBMS (73.6%) was recorded in SL96-128 for N4 (300kg/ha) treatment. However, N4 treatment is not significantly different from N2 and N3 treatments. The significantly ($P \leq 0.05$) lowest PBMS (57.6%) was obtained under N1 (0 kg/ha) treatment in variety SL96-128.

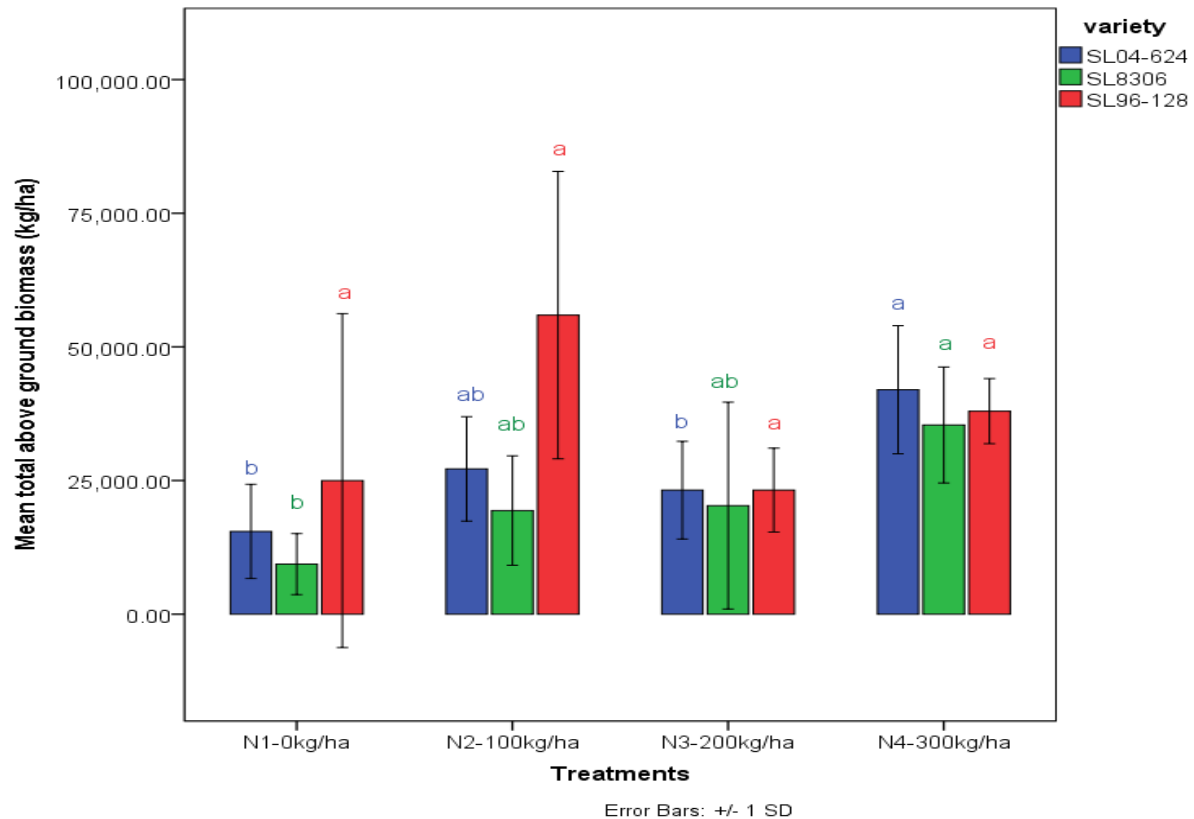


Figure 2: Effects of treatments on total above ground biomass of stalks for plant varieties. A significant level for the graph was prepared based on 0.05. Means with same letters are not significantly different between treatments ($P \geq 0.05$).

Evaluation of yield parameters

Number of millable canes per hectare (NMC/h)

No significant difference of NMC/h was observed in all three varieties under different N rates.

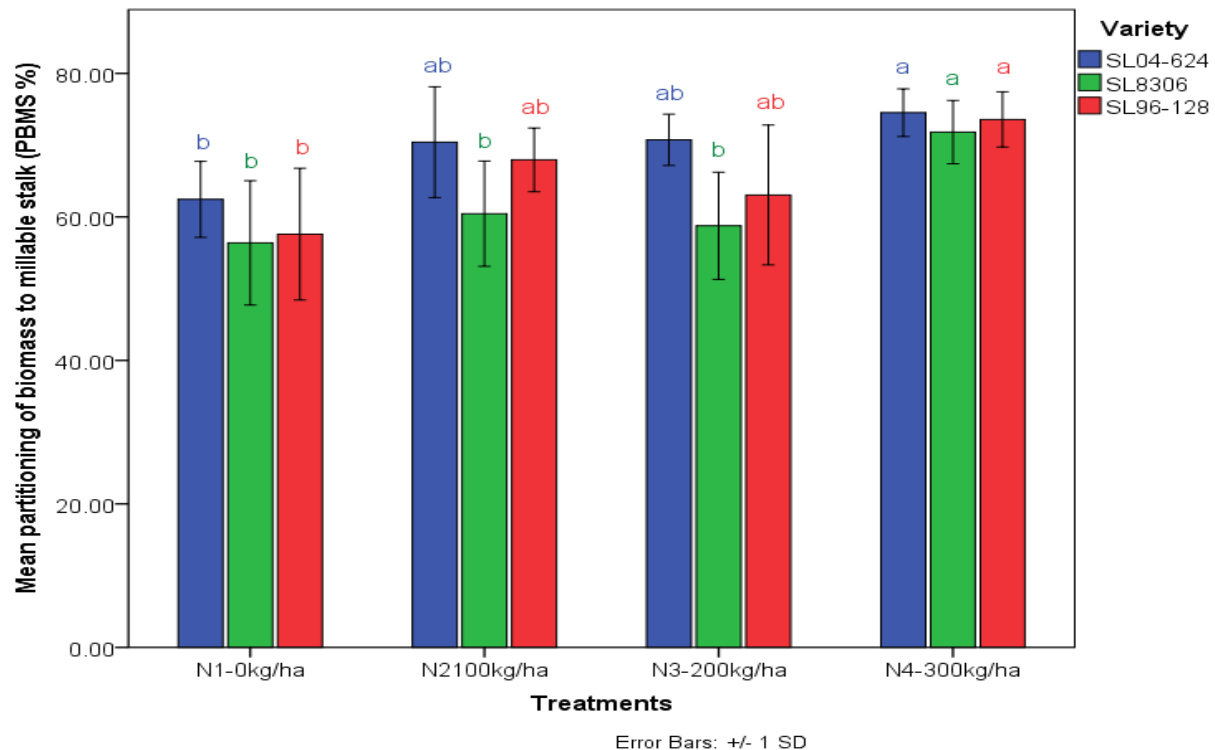


Figure 3: Effects of treatments on partitioning of biomass to millable stalk for plant varieties. A significant level for the graph was prepared based on 0.05. Means with same letters are not significantly different between treatments ($P > 0.05$).

Cane height (m)

According to the results (Figure 4), treatment N2 (100kg/ha) gave the highest cane height (2.1m) for SL04-624 and lowest (1.78m) under the treatment N3 (200kg/ha). However, these treatments are not significantly different from each other. The variety SL8306 showed the significantly ($P \leq 0.05$) highest mean cane height (2.2m) under N2 treatment and it is not significantly different from N4 treatment. The lowest mean cane height (1.3m) for treatment N3 and it is not significantly different from N1 treatment. The variety SL96-128 given highest mean cane height (2.1m) under N2 (100kg/ha)

treatment and the lowest cane height (1.7m) obtained under N3 (200kg/ha) treatment. However, these treatments are not significantly different from each other. El-Geddawy *et al.*, (2012) reported that insufficient or ill-timed supply of N-fertilizer applied to sugarcane would result in poor growth, such as narrow leaves, thin stems, and short internodes while excessive application of synthetic N-fertilizer leads to a cost increase, acidic soil, eutrophic water and non-point pollution and finally decreases the sugar content (Muchow *et al.*, 1996), especially at the sugar accumulation stage. These study results indicate the importance of identifying the correct dosage of nitrogen fertilizer to optimize the yield.

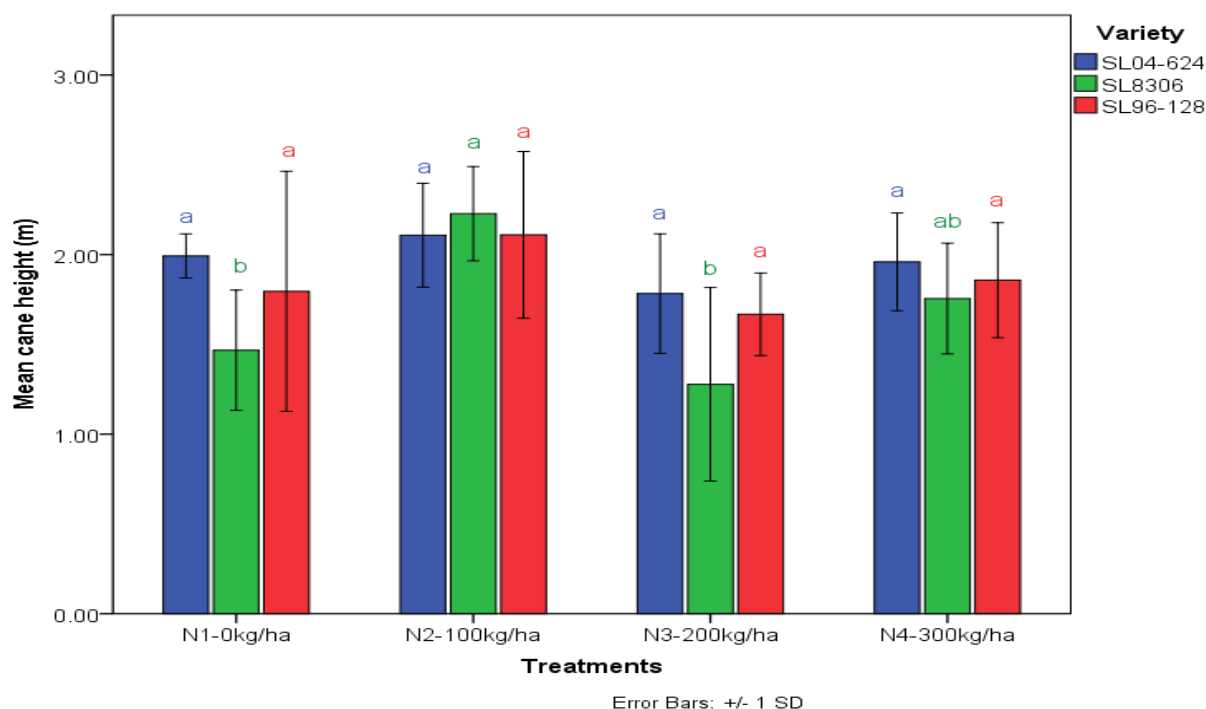


Figure 4: Effects of treatments on cane height for plant varieties. A significant level for the graph was prepared based on 0.05. Means with same letters are not significantly different between treatments ($P \geq 0.05$).

Cane yield (kg/h)

According to the results of cane yield in all three varieties SL04-624, SL8306, SL96-128, treatments are not significantly different from each other. Therefore, these varieties are not influenced by the treatments of N fertilizer.

Evaluation of Quality Parameters (Juice Quality)

Brix (%)

According to the results, in variety SL04-624, treatment N4 has shown the significantly ($P \leq 0.05$) highest brix% (19.4) and this treatment is not significantly different from the brix % of treatment N2 but significantly different from treatment N1 and N3 (Figure 5). The lowest brix % (13.7) was obtained in treatment N3 with 200kg/ha N fertilizer. The variety SL8306 showed the significantly ($P \leq 0.05$) highest mean brix%

(16.9) for N4 treatment and this treatment is not significantly different from treatment N2. The lowest brix % (11.6) was observed in treatment N3. The results showed that the variety SL96-128 gave significantly ($P \leq 0.05$) highest mean brix % (15.5) under N4 treatment and this brix % is not significantly different from that of N2 treatment. The lowest brix% (10.7) was obtained under N3 treatment for the variety of SL96-128.

pol (%)

According to the results (Figure 6), in variety SL04-624, treatment N4 (300kg/ha) has shown the significantly highest ($P \leq 0.05$) pol% (17.1) and this treatment is not significantly different from N2 (100kg/ha) treatment. The lowest pol% (11.1) was obtained for treatment N3 (200kg/ha). The variety SL8306 showed significantly ($P \leq 0.05$) highest mean pol% (14.3) in N4

treatment and this treatment is not significantly different from treatment N2. The lowest pol% (7.4) was observed in treatment N4.

According to the figure, the variety SL96-128 has shown the significantly highest

mean pol % (12.8) under N4 treatment and this treatment is not significantly different from treatment N2. The lowest pol% (7.60) was obtained under N3 treatment.

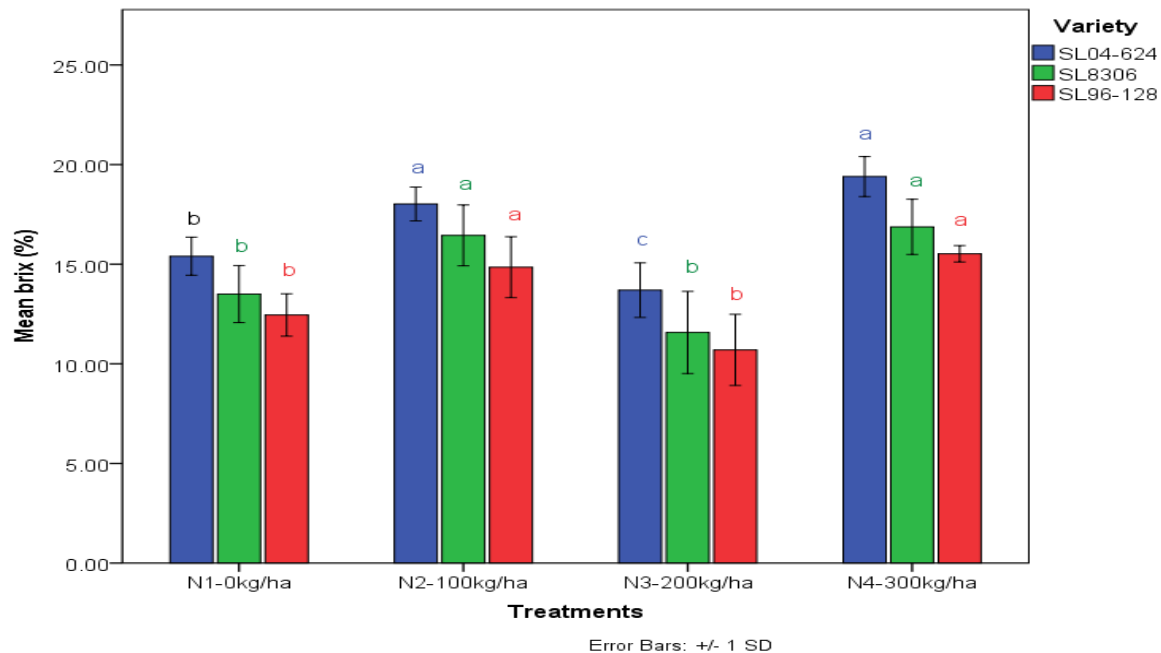


Figure 6: Effects of treatments on pol % for plant varieties. A significant level for the graph was prepared based on 0.05. Means with same letters are not significantly different between treatments ($P \geq 0.05$).

Pure obtainable cane sugar (POCS%)

According to Figure 7, significantly ($P \leq 0.05$) highest POCS (12.3%) was observed in treatment N4 (300kg/ha) in variety SL04-624, and this treatment was not significantly different from N2 (100kg/ha) treatment. The lowest POCS (7.7%) was observed in treatment N3 (200kg/ha). Furthermore, variety SL8306 has shown significantly ($P \leq 0.05$) highest

POCS% of 10.2 and in treatment N4 and this is not significantly different from that of N2 treatment. The lowest POCS of 4.2% was shown in treatment N3. In variety SL96-128, N4 has shown the highest POCS (8.8%) in N4 treatment. The lowest POCs of 4.7% was observed in treatment N3 and this treatment is not significantly different from treatment N1.

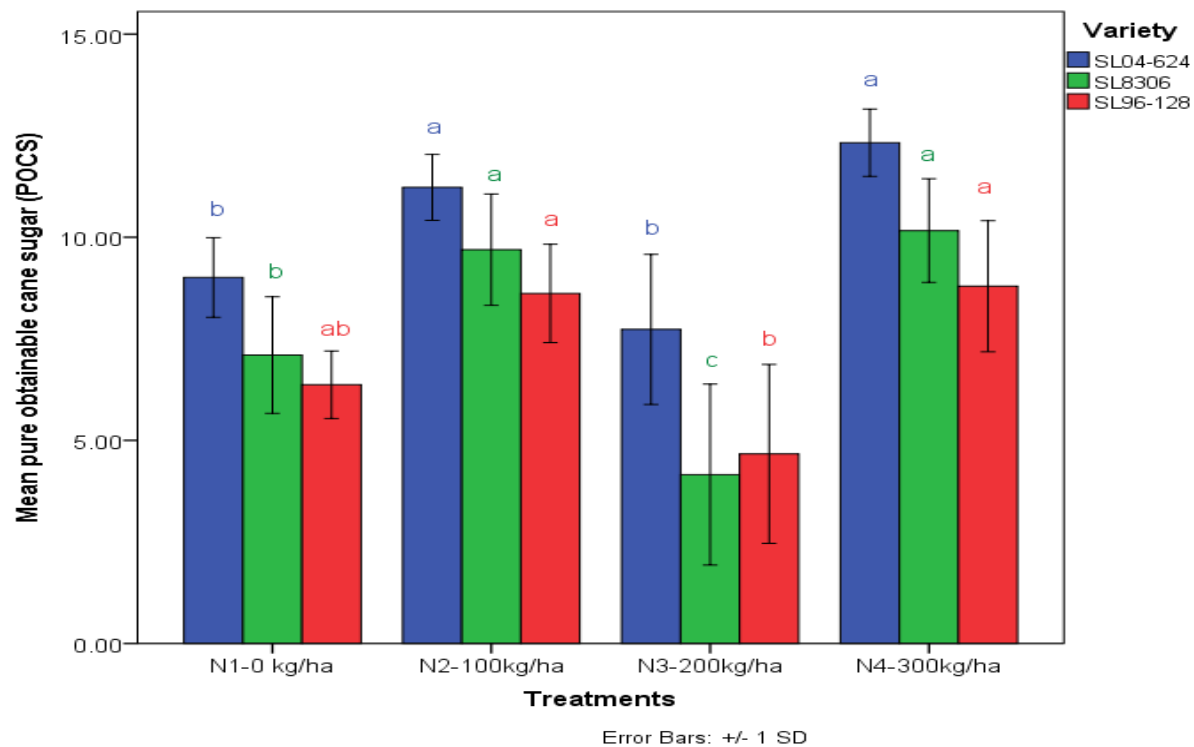


Figure 7: Effects of treatments on pure obtainable cane sugar (POCS) for plant varieties. A significant level for the graph was prepared based on 0.05. Means with same letters are not significantly different between treatments ($P \geq 0.05$).

Conclusion

The results of the study revealed that application of 300kg /ha N fertilizers has shown significantly highest girth of stem, total above ground biomass production (dry matter), partitioning biomass to millable stalk, brix and pol percentage, and pure obtainable cane sugar (POCS) in the sugar cane variety SL04-624, but the results were not significantly different from 100kg/ha N application treatments. Therefore 100k/ha could be concluded as the best rate of N fertilizer application considering the cost of production, environmental and groundwater pollution.

Furthermore, study results showed that that application of 100kg/ha N fertilizer has shown significantly highest girth of stem (cm) and cane height (m) in sugar cane variety SL8306. Further 300kg/ha N

fertilizer has shown significantly highest total above ground biomass production (dry matter), partitioning biomass to millable stalk (PBMS), brix and pol percentage and pure obtainable cane sugar (POCS%) in SL8306 sugar cane variety, but this treatment was not significantly different 100kg/ha (N2) treatment. Therefore 100k/ha (N2) could be concluded as the best rate of N fertilizer application for the variety SL8306 considering the cost of production, environmental and groundwater pollution.

In variety SL96-128, 100kg/ha N fertilizer has shown significantly highest girth of stem and 300kg/ha N fertilizer has shown significantly highest brix %, partitioning biomass to millable stalk (PBMS) and pol percentage. But this treatment is not significantly different from 100kg/ha N application. Therefore 100k/ha (N2) could

be concluded as the best rate of N fertilizer application for the variety SL96-128 considering the cost of production and environmental and groundwater pollution.

When compared among the sugar cane varieties, 300kg/ha N fertilizer application has increased the growth, yield and quality parameters than 100kg/ha N fertilizer application. However, 100kg/ha N fertilizer applied results are not significantly different from 300kg/ha N application. Among all three varieties, SL04-624, showed the highest total above ground biomass production (dry matter), partitioning biomass to millable stalk (PBMS%) brix and pol percentage and pure obtainable cane sugar (POCS). Therefore, considering growth, yield, quality, cost of production and groundwater pollution SL04-624 could be the good variety responding to the 100kg/ha N fertilizer.

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