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Variability in quality attributes of sugar cane (*Saccharium officinale*) clones as influenced by Nitrofertigation in Southern Nigeria

Abstract

An experiment was carried out in 2017 and 2018 planting seasons in Calabar, Southern Nigeria to evaluate the influence of nitrogen fertilizer on quality attributes of three clones of Sugarcane. The trial was laid out in 3 x 4 Split-plot in a randomized complete block design with 3 replications. The main plot was the three cane varieties (KN–10; OG–11 and OY–10), while the sup-plots consisted of the nitrogen fertilizer rates–0, 60, 90 and 120kgha-1N, (Symbolized N_1, N_2, N_3 and N_4 respectively). The results showed that none of the clones matured before the 12th month of growth, hence juice analysis took place from the 291st day, for better brix, pol, purity and C.C.S quality attributes. Varietal differences as influence by treatment was glaring. The variety KN–10 at the application of 60kgha^{-1}N had brix 19.5%; pol 18.4%; purity 85.5%; cane yield 73.53 (tons/ha); average yield of sugar 9.0 (tons/ha), compared with 0kgha^{-1} N, and these values were significantly ($P<0.05$) higher than values obtained from either OG -11 or OY–10, given similar experimental conditions. The highest fibre content 18.4% was obtained from OY–10, where 120 kgha^{-1} N was applied. Most of the variations due to nitrogen was accounted for by a quadratic type, response curve. These results are discussed in relation to future fertilizer experiments envisaged for the potential sugarcane land in Southern Nigeria.

Keywords: NPK, fertilizer application, clonal attributes, sugar cane germplasm, brix and pol content

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Introduction

Hardly are there any agronomic research conducted on sugarcane in Calabar, the South- South of Nigeria. Much of the researches done on sugarcane are done in the North and South West of Nigeria, inspite of the fact that much Sugar Cane is grown by farmers in the South by fragmentation. However, most of the industries using Sugar Cane as raw materials are found in Northern Nigeria and that has consequently limited production in the South, which is far away from the industries.

There are four Sugar Cane estates prominent in Nigeria:- Bacita, Numan, Sunti and Lafiagi. These estates grow sugarcane in relatively large scale while the majority of the small holder farmers grow soft sugar cane (Chewing Cane) on land holding 0.2–0.5 hectare.[1] Sugar Cane is grown in 25–30,000ha in Nigeria of which industrial cane covers 12,000ha.[2] Agboire et al.,[3] reported that fertilizer for cane production could be applied at 200kg N, 100kg P_2O_5 and 180kg K_2O/ha on Sandy loam soil containing 4.6% organic carbon; 0.07% organic matter; 0.62% total nitrogen; 0.050 meg/100g exchangeable K and 87.8% Sand; 11.0% Silt and 1.2% Clay. Sugar Cane is in high demand all over Nigeria for both individual and industrial uses and canes are sold in all big cities and State capitals across the Nation because of its nutritional value. There had been dearth of information on this crop in the south. It was on this consideration that this study was conducted in Calabar, Southern Nigeria, to evaluate the yield qualities of three clones of sugar canes, commonly grown in Nigeria, as influenced by nitrogen application.

Materials and methods

The trial was carried out in 2017 and 2018 planting seasons, in Calabar, Southern Nigeria, which lies between latitude 05^0 32^1 and 04^0 27^1 N and longitude 07^0 15^1 and 09^028^1E. The area is of humid tropical climate, characterized by high rainfall with two main seasons, dry and rainy seasons. The vegetation is tropical rain forest of humid agro-ecological zone in Nigeria. According to USDA System of classification.[4] Calabar Soils are typic paleuduct. The soil is acid sands derived from coastal plain sands, consisting of sand deposits which lie across Cross River and under lain by massive deposits of limestone, quartz, Fe and Al oxides which dominate the soil with kaolinite as clay mineral and the soil texture is sandy loam.[5,6]

Land preparation

The experimental field was cited on flat land at Calabar. The land was manually cleared with matchet, gathered together and removed. The area was leveled and marked out with wooden Pegs for planting. The initial soil characterization was already done in our previous studies.

Planting materials

The three varieties of sugar cane Germplasms used included: KN–10, with green stalk colour; OG -11, with brown stalk colour and OY–10, with purple stalk colour. These varieties were selected and obtained from Kano, Ogun and Oyo states to study their adaptability in Calabar, South South Nigeria.

Fertilizer

Since the average P^H of the soil was 4.4, no liming was essential as Sulphate of ammonia was being used extensively in this part of the country, and was chosen as the source of nitrogen for the study. Phosphate (P_2O_5) was applied as double super phosphate, potassium as muriate of potash (P_2O) and magnesium as magnesium sulphate

($MgS0_4$). A basal application of 100kg P_2O_5 and 180kg K_2O and 50 $MgS0_4$ was applied to all sub-plots as blanket application before planting.

Experimental design

The trial was carried out to determine the response of three sugar cane progenies to different levels of nitrogen (N), fixing phosphate (P_20_5) and potash (K_20) at 100kg $P_2{}^05$ and 180kg K_20/ha respectively. The design was split-plot design with 4 levels of nitrogen (0, 60, 90, 120 $kgha^{-1}$), replicated 3 times, with 48 sub-plots. The Germplasm (clones) formed the main treatment while the sub-plot was the fertilizer levels. An area of 2^2m was marked out per plot as sampling area.

Planting

The cutting materials or setts of 30cm long were selected, dipped in mercurial and insecticidal solutions drained off and then planted. Planting was 30 x 30 cm within rows and 50cm between rows, giving a plant population of 16, 135 plants per hectare.

Statistical analysis

Field data were subjected to analysis of variance (ANOVA) and means compared using Fishers Least Significant Difference at 5% probability level.[7] The result of some physico-chemical properties of the soil used for the experiment is presented in Table 1, in which the small P^H ranged between 4.2 to 4.6 with a mean of 4.4. On the average, the soil has organic matter 33.3g/kg; TN1.8g/kg; Bray 1P 9.9mg/kg; Ca 2.13 (cmol+) mg 0.5 (cmol +); K 0.4 (cmol +) and Na 0.3 (cmol +). Sand was 82%; Silt 7%; Clay 10.0%; BS 25% with textural class, SL. All the soil properties tested were within their critical levels recommended for soils in this study area.[5,7]

Cane sampling

The canes were first sampled at the age of 291 days and thereafter, at intervals of approximately three weeks. The sampling procedure is given in Table 1. Samples were taken at random and at each sampling, only one cane was taken from each clump.

Table 1 Sampling of sugar canes for analysis

Variety	1st Sampling	Subsequent Sampling
KN – 10	6 canes were taken from were for sugar analysis	As for KN – 10 above. sample row for sugar analysis
OG – 11	As for KN – 10 above	9 canes were taken from Sample row of which 5 were for sugar and 4 for fibre determination.
OY – 10	As for KN – 10 above.	As for OG – 11 above.

Chemical analysis

Analysis of juice was carried out 291 days after planting to enable the behaviour of brix, pol and purity of the cane to be traced. About 100ml of the juice was filtered with a 0.5mm mesh screen and read-off in a Sacharimeter to give the pol content of juice. About 5g each from sampling area was washed for fibre content determination (Table 1).[1,7]

Each sub-plot consisted of seven rows of canes. The two outermost rows and the terminal clumps of the other five rows acted as guard rows. Treatment of Samples and sub-sampling

Cane analysis

Analysis was conducted to determine the time of maturity, sugar and fibre contents of three clones. A series of analysis were carried out beginning when the canes were 219 days old, at approximately three weeks interval and terminating when they matured at 402 days.

Juice

$$\text{Brix, Pol and Purity} = \left[\frac{\text{Pol}}{\text{Brix}} \times \frac{100}{1}\right]$$

Each sample was first cleaned of trash and topped off. Then the canes were cut into approximately two equal halves-top and bottom halves. The juice was extracted separately for each half with a motorized Cane-crusher and the brix and pol were determined respectively.

Brix: This consists of total dissolved substance in the Juice.

Pol: Cane juice contains other optically active substance besides sucrose. The pol of a solution is the concentration of a solution of pure sucrose in water having the same optical rotation at the same temperature. The brix is the dissolved substance as determined by a hydrometer. After the brix was read off, 100ml of the juice was clarified with basic lead acetate, filtered and then read off in a Saccharimeter to give the POL.

(i) Fibre: Four canes were taken from each sub-plot and bulked according to treatment. Thus there were twelve canes for fibre analysis per treatment.

(ii) Yield: The terminal clump from the rest of the four rows in each sub-plot were discarded. The harvested area was therefore reduced to 0.0588–75 ha. The canes were cut below ground level, cleaned of trash, topped and weighed.

Results

Juice Analysis of Canes under different treatments (Table 2A-2C)

The average brix, pol and purity of the juice at different ages for the three clones are shown in Table 3A-C respectively. The highest brix content (19.5%) at 355 days was recorded by KN–10 where $60kgha^{-1}N$ (N_2) was applied and this value was significantly ($P<0.05$) higher than all other values given similar experimental conditions, (Table 2A). The lowest value (7.5%) at 291 days was recorded by OY–10 where $120kgha^{-1}N$ (N_4) was applied. Equally, the highest pol content at 402 days (19.8%) was recorded by OG–11, where $120kgha_{-1}N$ (N_4) was applied (Table 2B). Similarly, the highest percent purity (85.5%) was obtained from KN–10, at 402 days where $60kggha^{-1}N$ (N_2) was applied and this values was significantly ($P<0.05$), higher than all other values obtained from either OG–11 or OY–10 at any of the days or any other fertilizer level, throughout the study season (Table 2C). The highest nitrogen rate $120kgha^{-1}N$ and at any of the ages did not tend to significantly ($P<0.05$) influence the Brix, Pol and Purity of the three clones given similar experimental conditions.

The fibre contents of the three clones as influenced by nitrogen fertilizer application is presented in Table 3. The highest fibre content (18.4), was recorded by OY–10, where $120kgha^{-1}N$ was applied while the lowest values, (8.4%), was obtained from KN–10, where no fertilizer nitrogen was applied. Comparing the mean values of the

application of 120kgha^{-1}N (N_4) with that of 60kgha^{-1}N (N_2), there was 31.7% unit increase in fibre content when nitrogen fertilizer was increased from 60kgha^{-1}N to 120kgha^{-1}N.

Analysis of variance in the cane yield shows that there were significant differences at 1% level of probability (Table 4&5).

The results of the average yields of the three clones of sugar cane are presented in Table 5, in which the highest yield 73.53 ton/ha was obtained from KN–10, where 60kgha^{-1}N was applied while the lowest 17.50 ton/ha was obtained from OY–10, where 0kgha^{-1} was applied. The application of 60kgha^{-1}N tended to give higher yield of can in KN–10, and OG–11, than in OY–10. This is cost effective in that the farmer will not be spending much money to buy fertilizer for optimum yield.

Table 2A Results of Brix analysis of the three clones

N-levels		**NI**			**N2**			**N3**			**N4**	
Age (days)	291	355	402	291	355	402	291	355	402	291	355	402
Varieties		**Brix**			**Brix**			**Brix**			**Brix**	
KN – 10	14	18.5	16.6	15	19.5	17	14	15.2	16.3	12.1	10.6	13
OG - 11	11.5	13.2	15.1	10.7	12.6	14.4	12.5	13.2	14.1	7.5	8.3	10.1
OY - 10	10.2	12	14	9.3	10.5	13.1	10.3	11.4	12.6	7.5	8.3	10.1
LSD (P<0.05)	1.2	1.2	1.3	1.2	1.5	1.3	1.2	1.3	1.6	1.4	1.2	1.3

Table 2B Percentage pol content of three clones

N-levels		**NI**			**N2**			**N3**			**N4**	
Age (days)	291	355	402	291	355	402	291	355	402	291	355	402
Varieties		**Brix**			**Brix**			**Brix**			**Brix**	
KN – 10	10.5	13.3	15.1	13.2	15.6	18.4	10.6	12.1	15.6	10.4	11.8	14.6
OG - 11	9.5	10.6	12.5	12.0	16.7	19.8	9.5	10.0	14.4	8.6	10.6	13.4
OY - 10	8.4	9.0	10.2	10.4	14.1	16.2	8.3	9.3	12.0	7.1	8.8	12.2
LSD (P<0.05)	0.75	1.6	2.1	1.2	1.1	1.4	1.1	1.1	1.2	1.3	1.2	1.2

Table 2C Percentage purity of three clones

N-levels		**NI**			**N2**			**N3**			**N4**	
Age (days)	291	355	402	291	355	402	291	355	402	291	355	402
Varieties		**Brix**			**Brix**			**Brix**			**Brix**	
KN – 10	74.5	80.3	82.5	75.4	82.6	85.5	71.6	78.6	81.2	60.8	72.1	78.2
OG - 11	62.4	73.5	74.6	71.2	73.4	80.1	68.2	71.3	73.4	58.2	62.4	68.0
OY - 10	58.1	61.4	71.2	66.7	71.1	76.0	61.0	64.1	66.0	59.6	60.1	63.9
LSD (P<0.05)	1.2	1.2	1.6	2.4	1.8	3.2	3.1	3.2	6.1	1.2	1.3	4.5

Table 3 Mean Values of Fibre Contents (%) of the three Clones at 4 Nitrogen Levels

N-levels	**NI**	**N2**	**N3**	**N4**	**Mean**	**LSD**
Varieties						
KN - 10	8.4	10.3	12.2	14.1	11.25	1.5
OG - 11	9.0	12.1	14.2	16.0	12.83	1.8
OY - 10	16.8	14.4	16.5	18.4	15.00	2.1
Mean	9.4	12.3	14.3	16.2		
LSD (P<0.05)	0.5	1.5	2.0	1.8		

Table 4 Yield of sugar cane (ANOVA) analysis of variance

Source of variation DF	MS	F
Main plot		
Reps 3 - 1 = 2	3493.33	0.1498 NS
Clone 3 - 1 = 2	2677095.50	114.82
Error (a) 4	23314.14	-
Total 8	-	
Sub-plot		
N 4 - 1 = 3	25763.94	0.8402
Clone x N = 2 x 3 = 6	37767.66	1.231
Error (b) 6 x 3 = 18	30664.018	-
Grand Total 35	-	-

Table 5 Average yield (tons/ha) of clones in relation to nitrogen treatment

Treatment	Varieties		
	KN - 10	OG - 11	OY - 10
N1 O kg/ha	68.80	61.30	17.50
N2 60 kg/ha	73.53	70.13	24.73
N3 90 kg/ha	69.13	60.10	38.00
N4 120 kg/ha	71.25	70.28	30.30
LDS (P<0.05) SEM = 0.964 CV = 15.00%	2.1	1.2	5.1

Commercial cane sugar

The analysis of variance (ANOVA) of the main plot (Table 6) has shown that varietal difference among the three clones was significant (P<0.01). The sub-plot effect involving the effect of nitrogen on the three clones was significant (P<0.05). The interactions of variety x nitrogen was significant (P<0.01).

Table 6 Analysis of variance

Source of variation	DF	MS	F
Main plot			
Reps 3 - 1 =	2	0.1762	0.2157 NS
Clone 3 - 1 =	2	34.8988 4	2.7262
Error	4	0.8168	
Total =	8		
Sub-plot			
N = 4 - 1 =	3	2.6035	3.9039
Clone x N = 3 x 2 =	6	2.8473	1.2705
Error (b) = 3 x 6 =	18	0.6669	
Grand Total =	35		
		P<0.01	P<0.05

The analysis of variance (ANOVA) in Table 6 showed that the main effect of nitrogen fertilizer on the performance of the clones was significant (P<0.001), in which varietal differences in all parameters studied was glaring. The effect of nitrogen as it relate to varietal performance was significant (P<0.10). in the sub-plot, the interaction between nitrogen x variety was significant (P<0.05), in which the varieties had their maximum performance at different nitrogen levels.

Table 7 shows the interaction between nitrogen levels and varieties performance on yield (ton/ha), in which the application of 60kgha^{-1}N where KN–10 was planted gave 9.0 (ton/ha^{-1}) of sugar, which was significantly (P<0.05) higher than values obtained from all other varieties and N–rates given similar experimental conditions. The lowest sugar value 2.0 (ton/ha) was obtained from OY–10, where 60kgha^{-1}N was applied. This shows that different varieties of a crop reaction differently to the same fertilizer level.

Table 7 Average Yield (tons/ha) of Sugar as influenced by Nitrogen fertilizer application

Treatment	Varieties		
	KN - 10	OG - 11	OY - 10
N1 O kg/ha	7.4	6.5	2.1
N2 60 kg/ha	9.0	7.8	2.0
N3 90 kg/ha	7.5	6.5	3.2
N4 120 kg/ha	7.8	7.1	7.4
Mean	7.8	6.9	3.6
LDS (P<0.05)	0.3	0.3	1.2

From Table 8, the clonal effect on Commercial Cane Sugar C.C.S was highly significant while that of N was significant at 5% probability level only. Again, it was found that clones KN–10 and OG–11, were better yielders of Sugar. Table 8, also indicates that the highest C.C.S value (12.98) was obtained from KN–10, where 60kgha^{-1}N was applied while the lowest (7.13) came from OY–10, where 120kgha^{-1}N was applied.

Table 8 Average commercial cane sugar (C.C.S) of three clones as influenced by Nitrogen fertilizer treatment

Treatment	Varieties		
	KN - 10	OG - 11	OY - 10
N1 O kg/ha	10.95	10.95	8.55
N2 60 kg/ha	12.98	11.62	8.05
N3 90 kg/ha	10.05	10.11	9.12
N4 120 kg/ha	9.00	8.25	7.13
LDS (P<0.05)	1.3	1.2	0.50
SEM =	0.60		
C.V =	4.00%		

Most of the variations due to N application could be accounted for by a quadratic type response curve. Figure 1 showed that maximum percentage sugar was close to N_2. From the analysis of the data, the indicated maximum C.C.S or percentage sugar would be at approximately 60kgha^{-1}N. Since sugar in the cane is a products of weight of canes and C.C.S, the results in Table 8 will be related to C.C.S. In this case, KN–10 and OG–11 are significantly (P<0.05) high yielding in Sugar than OY–10 at the application of 60kgha^{-1}N (N_2) under similar experimental conditions.

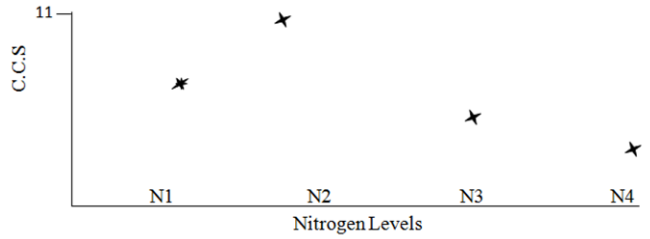

Figure 1 Response of CCS to nitrogen.

Discussion

The incorporation of NPK mixture into the soil in this study was essential to the establishment of healthy crop.[2,8,9] The phosphate promotes a strong root system which is basic to the rapid early growth of primary shoots. Early records in this work showed that none of the clones matured before the 12th month of growth. Therefore, analysis of the juice only took place from the 291st day to enable the content of brix, pol, purity and C.C.S in the cane to be ascertained.[10,11] As the brix only gives a rough indication of the sugar content, it is the C.C.S that determines maturity and thus the time of harvest.[6,12] In this study, the brix, pol, purity and C.C.S values were higher in the lowest level of nitrogen application 60kgha^{-1}N indicating that the cane quality is not related to high levels of nitrogen in this study area. Similar results were earlier reported.[3,13] The implication is that, Sugar content of mature Cane is retarded by high rate of N. there was therefore inverse relationship between increased N–levels and Sugar content of the three clones.

In the three clones, the fibre content increased with a corresponding increase in N-fertilization even in the early stages of the experiment,[6,13] this positive effect of applied N on the fibre content is attributed to the lignifications process occurring later in the season, requiring lower rates of N; rather than higher rates of N.[10,14,15] Thus, the positive effect of applied N on the fibre content coupled with its effect in reducing the brix, pol, purity and C.C.S values at higher rates later in the season led to the high fibre contents of the canes from plots with high N–rates.[16–18] It was noted at all stages of growth that N–fertilizer was adequately required to keep the canes at their optimizing performance.[19] As the canes mature, the change from N increasing to rather N retarding quality occurred at the same time, such that the effect of N fertilizer accounts for only 8% to cane quality, later in the season. It was also observed that the rate of post-sugar formation seems likely to be related to the period of the formation of pre-cane quality, earlier in the season. More investigation may be required before the relationship could be meaningfully understood.[20]

Conclusion

An experiment carried out to evaluate four levels of nitrogen with three clones of sugar cane was laid out in sandy loam soil. During the experiment, measurements of brix, pol, purity, C.C.S and fibre contents were determined. Varietal differences were noted in all parameters measured. The evidence derived from this study showed that high level of N above 60kgha^{-1} was detrimental to quality of cane. Fertilization of either of the three clones with N-fertilizer at 60kgha^{-1}N, would be cost effective with good quality canes and greater economic returns to the farmer. Most of the variations due to nitrogen were accounted for by a quadratic type response curve. Maximum sugar would be produced using 60kgha^{-1}N.

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Competing interest

The authors declare that there are no competing interests in this manuscript.

Author's contribution

All authors contributed immensely to the development of this manuscript from the design, writing of manuscript sections, statistical analysis, proof reading/editing and financial contribution.

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