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EFFECT OF NITROGEN FERTILIZER RATES ON THE ESTABLISHMENT AND YIELD OF NEW SELECTED SUGARCANE CULTIVARS IN KIBOS, KISUMU COUNTY, KENYA

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Abstract

The sugar industry plays an important role in economic development of Kenya. Nitrogen is the primary nutrient limiting sugarcane production throughout the world. A study was conducted in Kibos from 2015 to-2018 on the effect of nitrogen fertilizer rates on the yield of newly released cane cultivars. The aim was to determine the optimal nitrogen rates for the new sugarcane cultivars and to analysis the cost benefits of N fertilizer rates on new sugarcane yields. The treatments consisted of 11 cane cultivars KEN 98-367, KEN 98-530, KEN 98-533, KEN 98-551, KEN 00-13, KEN 00-3548, KEN 00-3811, EAK 73-335, KEN 82-121, KEN 82-601, KEN 82-493 and 3 levels of N fertilizer rates; 0kg Nha^{-1}, 80kg Nha^{-1} and 160 kg Nha^{-1} as top-dress at five months after planting. The experiment was laid out as 11 x 3 factorial in a randomized complete block design (RCBD) having three replications with a gross plot size of 5 rows 6m long and spaced at 1.2 m apart. Clean seedcane aged 10 months was used. The trial was harvested at 17 months for plant crop (PC) and 16 months for ratoon1 (R1). Data was analyzed by ANOVA using GENESTAT vs 19.0. The results showed that significant differences ($p<0.05$) were noticed in girth, stalk heights, R1sugar-

INTRODUCTION

Sugarcane (*Saccharum spp)* is the world's primary sugar crop and it is basically a tropical crop whose yield is significantly affected mostly by soil fertility. Sugar industry plays an important role in economic development of Kenya as it generates about KES 12 billion annually (KESREF 2014) and supports approximately 6 million Kenyans, (KSB, 2020). The increase in sugar production has largely come about as a result of breeding for high cane yield and sugar content. Currently there are many cultivars being planted in Kenya, some imported and others bred locally. Eight cultivars, KEN 98-367, KEN 98-530, KEN 98-533, KEN 98-551, KEN 00-13, KEN 00-3548, KEN 00-3811 and KEN 00-5873 were released in 2014 (Kenya Gazette June; July, 2014) and three cultivars KEN82-121, KEN82-493 and KEN82-601 were released in 2011 (KESREF, 2013). No appropriate nitrogen fertilizer rates accompanied the cultivars by the time of release.

Nitrogen (N) is the primary nutrient limiting sugarcane production throughout the world (Wiedenfeld and Enciso, 2008). The large amounts of N fertilizer applied to most cropping systems support high yields (Robinson *et al.,* 2007). Early and late N fertilizer application results in lowered cane yield, while the late fertilizer application results in lower sugar yield (Wiedenfeld, 1997). (Wood, 1990) reported that in most sugarcane producing countries of the world, NPK fertilizer ratios of 2:1:3 or 2:1:2 or 3:1:5 are commonly used.

Nitrogen use efficiency (NUE) has been well studied in many crop species, especially grain crops, where kernel N content is a key harvest index (Whan *et al.,* 2007). In contrast NUE in sugarcane has not been properly understood, since N is an insignificant component of the harvested product. However, increasing environmental concerns especially from pollution from N run off arising from excessive fertilization demand an improved understanding of NUE in sugarcane, so that applied N is effectively utilized (Whan *et al.,* 2007). Moreover, unlike in cereals, the longer span of sugarcane growth presents different challenges for efficient N use.

It has been reported that high Nitrogen supply can decrease the sucrose concentration in fresh millable stalks and consequently decrease the commercial value of the stalks (Grisham *et al*., 2005). Among the major nutrients, nitrogen plays a great role not only in increasing the yield but also in influencing juice-quality. High tissue nitrogen leads to continued vegetative growth and thus delays maturity; it produces late tillers and water shoots; it increases sheath moisture and soluble nitrogen content in the juice. Thus low sucrose, high reducing sugar contents and lower purities are common under excess nitrogen which ultimately leads to higher molasses (Grisham *et al*., 2005; Weidenfeld and Ensico, 2008). Gilbert *et al* (2008) reported that different N rates application rates influenced yield by either increasing or decreasing. Singels and Donaldson (2000) found that higher N fertilized cane showed higher cane yield. Therefore it is important that at the time sugarcane cultivars are released recommended fertilizer rates for economic recovery of juice sucrose and good millable stalk is a requisite.

Economic feasibility of the fertilizer practices is an essential element of improving crop productivity (Kadian 0*et al*., 1981). Very often the farming is based on sound economics and the farmers generally adopt only those improved practices, which are more paying and easily workable. The studies done on the comparative economics of different fertilizer levels has shown that there is no additional income from the control plots, which did not receive any fertilizers. The calculated value cost ratio from different fertilizer applications varied between 5.78 and 10.36. (Khan *et al*., 2005) reported that sugarcane applied with 200 kgN ha^{-1} significantly out-yielded control and gave comparatively higher value cost ratio than the other treatments that had lower rates. However, they further demonstrated that all other fertilizer levels were found highly profitable over the control. This shows that the use of fertilizers in balanced amount will always remain profitable for the sugarcane growers.

Kenya Agricultural and Livestock Research Organization (KALRO)-Sugar Research Institute (SRI) has the mandate to develop and release new sugarcane cultivars to the cane growers in Kenya (KESREF, 2001). When a new cultivar is released it has to be accompanied by agronomic packages so that its full potential is realized. In view of this, it was important to test the cultivars that were released in 2011 and 2014 using different N fertilizer rates to determine their nitrogen use efficient for optimal fertilizer use as this was not done at the time of release where blanket nitrogen rate of 100kgN ha^{-1} application was used. Currently the practice is, the time and method of applying as well as fertilizer doses given vary widely across the sugar zone and farmers apply any rate during the year. Inadequate, imbalanced and untimely fertilizer application and inconsistent planting dates contribute to the poor crop performance.

Limited work has been done to determine the optimal nitrogen fertilizer rate and nitrogen use efficiency of these new sugarcane cultivars. Determining appropriate N rates in the new sugarcane cultivars is important for effective use of fertilizer. Therefore the objectives of the study were, 1) to determine the optimal nitrogen fertilizer rates for the eleven new released sugarcane cultivars, 2) to analysis the cost benefits of N rates on eleven new sugarcane yields.

MATERIALS AND METHODS

A field experiment was conducted in Kibos, during 2015-2018. Kibos is in humid area and is situated 16 km North-East of Kisumu City, latitude 0°2'N and longitude 34°48'E. The mean monthly maximum temperature is 31°C, and means monthly minimum temperature is 23°C. The mean annual rainfall is 1487 mm. The altitude is 1240 m above sea level (KESREF, 2001). The soil of the study area was mainly Nitisols (KESREF, 2001). Land preparation was done using a disc plough, and thereafter left to weather for 21 days before harrowing. Furrowing followed immediately.

Chemical analysis of experimental soil was conducted before planting the crop. The procedures used for chemical analysis of all the aforementioned soil are given in "Analysis manual of soil".

The treatments consisted of 11 sugarcane cultivars KEN 98-367, KEN 98-530, KEN 98-533, KEN 98-551, KEN 00-13, KEN 00 -3548, KEN 00-3811, EAK 73-335, KEN 82-121, KEN 82-601, KEN 82-493 and 3 levels of N fertilizer rates; 0kg Nha^{-1}, 80kg Nha^{-1} and 160 kg Nha^{-1} as top-dress at five months after planting.

The experiment was laid out as 11 x 3 factorial thus 11 sugarcane cultivars and three N rates as a top-dress in a randomized complete block design (RCBD) having three replications with a gross plot size of five rows 6m long and spaced at 1.2 m apart. Clean seedcane of the 11 cultivars aged 10 months was used and 24 of the three budded setts was planted in each furrow. Phosphorus (P) was applied at 80kgP ha^{-1} in furrows at the time of planting in the form of TSP (Tripple Supper Phosphate) and while N fertilizer was applied in the form of urea as per treatments. Confidor was applied @ 200 L ha^{-1} at planting to control the termites. Weeds in the crop were controlled manually. The crop was harvested at the age of 17 months and 16 months for plant and ratoon 1 crops respectively

Data collected

Sugarcane yield components

Stalk girth (cm)

Five cane stalks at harvest were measured by Vernier caliper from each treatment and averaged. Stalk girth is one of the determinants of cane yield.

Cane length

Stalk length of ten canes randomly selected was measured (cm) from bottom to apices at the time of harvest and then averaged.

Stalk population;

The millable cane from the net plot of 21.6 m^2 from all treatments at harvest were counted and their number recorded.

Cane yield at harvest

The millable cane from 21.6m^2 of each plot were topped, striped and determined in kg by electronic balance then computed to Tons of Cane per Hectare (TCH).

Cane quality (pol % juice) determination

A sample of 6 millable cane stalks (representative sample) randomly taken from each treatment were collected immediately after harvest and cleaned. Two of the stalks for juice analysis were cut at a third top, next two at a third middle and last two a third bottom (Anonymous, 1970).These parts were mixed and crushed to determine pol% juice, which was determined by Saccharimeter

Economic data

To assess the costs and benefits associated with different treatments the partial budget technique as described by CIMMYT (1988) was applied on the yield results. Economic analysis was done using the prevailing market prices for inputs at planting and for outputs at the time the crop was harvested. All costs and benefits were calculated on per hectare basis in Kenya shillings (KES ha^{-1}). The following concepts used in the partial budget analysis are defined as follows: Mean cane yield is the average yield (t ha^{-1}) of each treatment. The field price of cane yield is its point-of- sale which is calculated from tonnage price less harvesting cost per ton and the gross field benefit (GFB) ha^{-1} is the product of field price of cane and the mean yield for each treatment.

$$MRR\ (between\ treatment, a\ \&\ b) = \frac{Change\ in\ NB(NBb - NBa)}{Change\ in\ TCV\ (TCVb - TCVa)} \times 100$$

Data analysis

Data was analyzed by analysis of variance (ANOVA) using GENSTAT vs 19 and means separated by least significance difference (LSD) at 0.05 level of significance

Table 1: Chemical soil analysis

Site- Kibos	P^H (H_2O)	Pppm	N%	Ca m.e	% C	Mg m.e	K m.e	CEC m.e
Field 13	5.3	14.3	0.22	3.4	1.5	1.31	0.3	9.4

Results and discussion

Sugarcane yield components

The sugarcane yield components consisted of, girth, stalk height and millable stalk population. The three components are the determinants of cane yield.

Girth

Significant differences were noticed in girth between the cultivars with KEN98-367 showing the highest thickness and KEN82-121 the lowest (Table 2). No significant differences were seen in nitrogen fertilizer rates and crop class (Table 1). The differences noticed in the cultivars girth might be attributed to varietal characteristics. There were no interactions between the treatments.

Stalk height at harvest

Stalk heights of crop class differed significantly (*P>0.05*) with ratoon 1 (R1) crop being taller than the plant crop (PC) (Table 2). The stalk heights of cultivars differed significantly (P>0.05). The cultivar KEN98-551 was significantly taller than other cultivars. Cultivar KEN82-493 was the shortest (Table 2). The nitrogen fertilizer rates did not influence the cane stalk heights. The differences observed in crop heights might be probably due to varietal differences and erratic rainfall experienced during the crop development period. No interactions between the treatments were observed.

Millable stalk population

The millable stalk population of crop class, cultivars and nitrogen fertilizer rates did not show significant differences (Table 3).

Sugarcane yield

There were significant differences in the yield among the cultivars only in Ratoon 1 (Table 4). On average cultivar KEN 00-3811 showed significantly superior stalk yield (tha^{-1}) than other cultivars. The cultivar EAK73-335 had the lowest yield. The cane yield of crop classes differed significantly with the yield of plant crop being superior to ratoon1 by 31% (Table 4). The nitrogen fertilizer rates influenced the cane yields in the first ratoon crop but not in the plant crop. This is in agreement with (Gilbert *et al*., 2008) who reported that different N rates application on sugarcane influenced yield by either increasing or decreasing. No interactions were seen between the treatments. It was expected that there will be differences in fertilizer rates for both plant and ratoon 1 crop, but this was contrary. The no response seen in the nitrogen fertilizer rates in the plant crop could be attributed to the imbalance of nutrients and nitrogen availability in the soil at planting time (Table 1). The response of fertilizer rates in ratoon 1 crop could be attributed to the depletion of initial nitrogen that was utilized by the plant crop.

Sugarcane pol% Juice

No significance differences were seen on sugarcane pol% juice between cultivars, crop class and nitrogen fertilizer rates. Similarly there were no interaction effects on the treatments (Table 5). This concurs with (Grisham *et al*., 2005) who reported that application of different nitrogen fertilizer rates can either decrease or has no effect on the sucrose concentration in fresh millable stalks of sugarcane.

Table 2; Girth and stalk height of the sugarcane cultivars as affected by nitrogen fertilizer rates

			Cultivar										
	CC	Rates	KEN98-367	KEN82-493	KEN82-601	KEN98-530	KEN98-551	KEN98-533	KEN00-13	KEN00-3548	KEN00-3811	EAK73-335	KEN82-121
Girth	PC	R1	2.6	2.43	2.57	2.6	2.55	2.6	2.47	2.6	2.6	2.53	2.57
		R2	2.63	2.57	2.67	2.57	2.6	2.53	2.67	2.53	2.57	2.57	2.5
		R3	2.63	2.53	2.53	2.57	2.65	2.57	2.6	2.5	2.53	2.53	2.57
	R1	R1	2.83	2.53	2.63	2.57	2.71	2.8	2.53	2.45	2.5	2.53	2.5
		R2	2.7	2.4	2.63	2.47	2.53	2.63	2.5	2.55	2.57	2.57	2.53
		R3	2.77	2.47	2.55	2.53	2.5	2.7	2.65	2.53	2.6	2.53	2.4
Stalk height	PC	R1	249.9	228.33	259.13	232	265.26	207.8	232.7	221.26	232.3	194.43	247.33
		R2	247.1	230.77	237.77	235.67	268.81	208.67	241.13	228	244.77	206.3	238.43
		R3	232.63	246	249.67	223.87	265.96	229.9	256.9	232.61	224	208	228.8
	R1	R1	289.2	237.73	275.53	279.3	298.27	293.06	274.27	293.78	291.17	260.07	288.23
		R2	280.53	259.83	282.63	279.07	290.87	300.3	274.73	245.28	294.43	248.53	280.53
		R3	301.3	236.73	292.56	273.6	275.63	279.21	286.13	238.53	291.37	282.53	267.7

Girth: CV%= 0.3and LSD $_{0.05}$=0.095, Stalk height: CV%= 3.3 and LSD $_{0.05}$=17.726.

Table 3: Millable stalk population of the sugarcane as affected by nitrogen fertilizer rates

		Cultivar										
	Rates	KEN98-367	KEN82-493	KEN82-601	KEN98-530	KEN98-551	KEN98-533	KEN00-13	KEN00-3548	KEN-00-3811	EA-K73-335	KEN82-121
PC	R1	64,352	60,495	68,981	56,944	32,148	54,630	66,356	51,130	63,579	43,208	59,259
	R2	77,162	57,870	61,727	43,519	55,296	69,907	78,088	62,963	47,532	63,889	63,273
	R3	70,681	60,648	58,949	65,741	54,370	63,579	71,449	46,963	79,319	46,759	69,907
R1	R1	60,185	61,727	53,394	69,134	57,560	64,727	59,106	51,505	71,449	58,644	61,227
	R2	58,949	66,819	48,764	70,060	69,755	78,088	68,519	48,264	70,986	58,644	74,847
	R3	57,255	51,389	65,250	55,556	56,329	85,097	85,069	65,741	78,088	58,644	71,759

CV%= 24.8 and LSD $_{0.05}$=28.982.

Table 4: sugarcane yield of sugarcane cultivars as affected by nitrogen fertilizer rates

Variety	**Yield (TCH)**						
Fertilizer rate	**Fertilizer rate 0 kgN ha^{-1}**		**Fertilizer rate 80 kgN ha^{-1}**		**Fertilizer rate 160 kgN ha^{-1}**		**Mean**
Crop cycle	**Plant**	**Ratoon 1**	**Plant**	**Ratoon 1**	**Plant**	**Ratoon 1**	
KEN 98-367	99.91	66.59	114.74	62.04	98.65	61.27	83.86
KEN98-530	83.11	66.74	70.04	69.98	91.73	56.79	73.90
KEN98-551	89.83	61.02	89.27	71.53	82.54	61.27	77.51
KEN98-533	78.64	68.07	97.57	63.12	104.63	55.67	75.45
KEN00-13	89.63	62.19	100.47	69.21	100.20	84.44	82.73
KEN00-	81.03	53.07	74.07	59.51	86.29	65.20	66.76
KEN00-	94.75	72.26	76.28	74.00	75.68	81.22	84.95*
EAK73-335	64.33	58.72	78.63	61.11	62.36	60.41	64.27*
KEN82-121	87.88	60.37	93.04	74.00	98.13	45.29	75.93
KEN82-493	78.08	61.19	71.26	63.96	81.00	50.46	67.24
KEN82-601	97.68	58.33	87.68	49.92	88.09	68.33	72.87

CV%= 24.5 and LSD $_{0.05}$=14.930

Economic analysis

Marginal Rate of Return (MMR) for cultivar and nitrogen fertilizer rates

KEN98-551 at rate 0kgNha^{-1} had the best returns given the zero cost that varied and a return of 383,400 while KEN00-3548 at 80kgNha^{-1} was the worst in term of performance thus returns given a varying cost of 14,000. The marginal rate of return indicates the gains to the famer for adopting a certain cultivar with a specified nitrogen regime. In the table 6, moving from KEN00-3548 of 80kgNha^{-1} to KEN82-121 of 160kgNha^{-1}, the farmer will gain 9.76% in terms of net benefit and moving from to KEN82-121 of 160kgNha^{-1} to KEN98-533 of 160kgNha^{-1}, there will be 0% gain in net benefits and that's the trend as shown by the MRR% column in the table6

Table 6: Marginal Rate of Return for cultivar and nitrogen fertilizer rates

Variety	Rates	Tch	cost that vary	Marginal cost	Revenue	Net benefit	Marginal NB	MRR%
KEN00-3548	80kgNha^{-1}	10.3	14000		46350	32350		
KEN82-121	160kgNha^{-1}	45.3	28000	14000	203850	175850	143500	9.76
KEN98-533	160kgNha^{-1}	48.1	28000	0	216450	188450	12600	0.00
KEN00-3548	0kgNha^{-1}	43.9	0	28000	197550	197550	9100	307.69
KEN82-493	160kgNha^{-1}	50.5	28000	28000	227250	199250	1700	1647.06
KEN82-601	80kgNha^{-1}	49.9	14000	14000	224550	210550	11300	123.89
KEN82-601	160kgNha^{-1}	55.5	28000	14000	249750	221750	11200	125.00
KEN98-530	160kgNha^{-1}	56.8	28000	0	255600	227600	5850	0.00
EAK 73-335	160kgNha^{-1}	60.5	28000	0	272250	244250	16650	0.00
KEN98-367	160kgNha^{-1}	61.3	28000	0	275850	247850	3600	0.00
KEN98-551	160kgNha^{-1}	61.3	28000	0	275850	247850	0	0.00
KEN82-121	0kgNha^{-1}	57.2	0	28000	257400	257400	9550	293.19
KEN98-493	80kgNha^{-1}	61	14000	14000	274500	260500	3100	451.61
EAK73-335	80kgNha^{-1}	61.1	14000	0	274950	260950	450	0.00
KEN82-601	0kgNha^{-1}	58.3	0	14000	262350	262350	1400	1000.00
EAK73-335	0KgNha^{-1}	58.7	0	0	264150	264150	1800	0.00
KEN98-367	80kgNha^{-1}	62	14000	14000	279000	265000	850	1647.06
KEN00-3548	160kgNha^{-1}	65.2	28000	14000	293400	265400	400	3500.00
KEN98-533	80kgNha^{-1}	63.1	14000	14000	283950	269950	4550	307.69
KEN98-533	0kgNha^{-1}	60.6	0	14000	272700	272700	2750	509.09
KEN82-493	0kgNha^{-1}	61.2	0	0	275400	275400	2700	0.00
KEN00-13	0kgNha^{-1}	62.2	0	0	279900	279900	4500	0.00
KEN00-13	80kgNha^{-1}	69.2	14000	14000	311400	297400	17500	80.00
KEN98-367	0kgNha^{-1}	66.6	0	14000	299700	299700	2300	608.70
KEN98-530	0kgNha^{-1}	66.7	0	0	300150	300150	450	0.00
KEN98-530	80kgNha^{-1}	70	14000	14000	315000	301000	850	1647.06
KEN00-13	160kgNha^{-1}	73.2	28000	14000	329400	301400	400	3500.00
KEN98-551	80kgNha^{-1}	71.5	14000	14000	321750	307750	6350	220.47
KEN00-3811	80kgNha^{-1}	74	14000	0	333000	319000	11250	0.00
KEN82-121	80kgNha^{-1}	74	14000	0	333000	319000	0	0.00
KEN00-3811	0kgNha^{-1}	72.8	0	14000	327600	327600	8600	162.79
KEN98-3811	160kgNha^{-1}	81.2	28000	28000	365400	337400	9800	285.71
KE98-551	0kgNha^{-1}	85.2	0	28000	383400	383400	46000	60.87

Conclusions

The study has established that;

- Application of nitrogen fertilizer on sugarcane cultivars plant crop showed no response. The response was noticed in cultivars ratoon 1. Therefore no appropriate nitrogen fertilizer rate could be recommended.
- The marginal rate of return indicated the gains to the famer by adopting a particular cultivar with a specified nitrogen regime

Recommendation

There is a need for further studies to be conducted on Kibos-SRI soil before appropriate nitrogen rates for the new sugarcane cultivars can be recommended

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