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Variations in soil pH, N, P and K due to influence of rates, split applications of nitrogen fertilizer and ratoon crop of sugarcane varieties

G Oindo Achieng[1*], P Okinda Owuor[1], C Ogutu Omondi[2], G Onyango Abayo[2]

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Author Affiliation:
[1]Department of Chemistry, Maseno University, P.O. Box 333-40105, Maseno, Kenya
[2]Kenya Sugar Research Institute, Kisumu, P.O. Box 44-40100, Kisumu, Kenya

[*]**Corresponding Author**
Department of Chemistry, Maseno University, P.O. Box 333-40105, Maseno,
Kenya
Email: georgeoindoachieng@gmail.com

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ABSTRACT

Fertilizer Best Management Practices (BMPs) include soil testing that is performed to determine the availability of essential elements for profitable and productive yields of crops. The objective of this research was to establish the influence of nitrogen fertilizer either applied in single or split to ratoon crops of new (D8484) and old (CO421) varieties on soil nutrient levels. The experimental design was a 2x4x3 split split-plot on a continuation of research at the Sugar Research Institute, Opapo, where the plant crop received similar treatments. Analysis of soil nutrient levels was done using recommended methods. The results revealed that despite the randomization of the treatments, the pH was lower ($p \leq 0.05$) in D8484 plots than the CO421 plots. However, both at the start and harvest of ratoon, the pH remained within the range suitable for sugarcane growing. A general decline in soil pH with high rates of nitrogen was observed. Precisely, there was a higher pH decline at 15-30 cm soil depth compared to 0-15 cm soil depth. On the other hand, splitting nitrogenous fertilizer application did not affect the soil pH. The varieties did not influence soil nitrogen levels at the beginning of the ratoon and harvest. Although soil nitrogen level was low where nitrogen had not been applied, this was only significant ($p \leq 0.05$) for variety CO421 at the start of ratoon. Splitting nitrogen application recorded a significantly ($p \leq 0.05$) lower effect on soil nitrogen levels for variety D8484 than CO421 at the start of ratoon at 15-30 cm soil depth. There were no significant effects of the treatments on soil P levels. Soil K considerably ($p \leq 0.05$) dropped due to variety D8484 at 0-15 cm at harvest and both start of ratoon and harvest at 15-30 cm soil depth. It is concluded that variety D8484 acidifies the soil more than CO421. However, the pH endured the levels appropriate for sugarcane growth both at the start of the ratoon and harvest. Current agronomic practices did not lead to much change in soil N and P. The study recommends that soil sampling and testing should not be frequently done since the treatment effects on soil physico-chemical parameters could manifest after a long period.

Keywords: Agronomic practices, soil depth, sugarcane varieties, treatment effect

1. INTRODUCTION

Sugarcane (*Saccharum officinarum L.*) is a commercial crop grown in tropical and sub-tropical regions for sugar production in climates ranging from hot and dry near sea level to cool and moist at high elevations (Plaut et al., 2000). Other than the main product, sugar, it produces valuable co-products such as alcohol used by the pharmaceutical industry and as fuel, bagasse for paper and chipboard manufacture and press mud as a rich source of organic nutrients for crop production (Kumar et al., 1996; Lingle et al., 2000). In Kenya, the sugarcane industry is a key employer and a contributor to the national economy, supporting approximately 250,000 small-scale farmers that supply 92% of cane. As documented by the Kenya Sugar Board (2010-2014), the crop saves Kenya over Kshs. 19.3 billion yearly in foreign exchange and contributes tax revenues. Several new sugarcane varieties considered high-yielding and early maturing have been introduced in Kenya's sugar industry (Wawire et al., 2006; KESREF, 2007; GOK, 2009).

The new varieties are being subjected to the same agronomic inputs as late-maturing varieties. Most of the soils where sugarcane is grown in Kenya are low in soil nitrogen (Jaetzold et al., 2005). It is, therefore, mandatory to use nitrogen fertilizer in sugarcane farming (Sreewarome et al., 2007). The range of nitrogen fertilizer rates currently in use is 100-120 kg N/ha applied in a single dose were established and recommended in the 1980s (KESREF, 2010). Research carried out on early maturing varieties has indicated the applicability of different fertilizer rates (Snyder and Bruulsema, 2007). Trials have not been done on the new varieties to establish if they require the same rates as the old late-maturing varieties. Again, nitrogen fertilizer is costly and disorganised application such as incongruous rate, time and placement technique could be the principal source of low performance and nitrogen fertilizer loss through nitrate leaching, nitrate de-nitrification and ammonia volatilization (Dalal and Meyer, 1986). Consequently, the exhaustion of plant-available soil nitrogen over time rationalizes the need for split application (Wiedenfeld, 1997). Nevertheless, the application of nitrogen fertilizer increases the amount of N lost to the environment; thus, rigorous sugarcane farming faces the challenge of environmental impacts of nitrogen fertilizer use (Eickhout et al., 2006). Higher rates of nitrogen fertilizer have been reported to cause a great decline in soil pH (Graham et al., 2000), detrimental impacts on water quality (Eickhout et al., 2006) and enhancing emissions of the potent greenhouse gas, nitrous oxide (Bouwman et al., 2002).

A drop in soil pH influences the soil chemistry, therefore, the availability and concentrations of metals (GWRTAC, 1997). Deteriorating soil fertility as a result of exhaustion of the essential nutrients, especially nitrogen, potassium and phosphorous, lessen sugarcane yields (Bell et al., 2001; Garside et al., 2003). Suffice to mention that these essential nutrients play key roles in sugarcane physiology, growth and development (Malavolta, 1994; Rice et al., 2002) and their availability to plants can be influenced by the application of nitrogenous fertilizers. A decline in soil fertility in old sugarcane lands or low soil fertility in newly opened sugarcane fields may be one of the causes of the declining or low yields (Kumar and Verma, 1997). It is necessary to practise farm management strategies that dispense a balanced source of nutrients to the plant. Sugarcane is a very exhaustive and extracting crop that removes nutrients from the soil (Cooke, 1982; Yadav and Prasad, 1992). The variations in the soil physico-chemical parameters status at ratooning and at harvest of ratoon crops due to sugarcane varieties, nitrogen fertilizer rates and application method are not known. Actually, how soil nutrient levels as well as soil pH of early and late-maturing sugarcane varieties are influenced by the agronomic inputs under Kenya sugarcane growing conditions is not reported. CO421 is an old and late maturing variety while D8484 is a new high-yielding early maturing variety released in 2007 (GOK, 2009) widely cultivated in Western Kenya. Their influence on soil nutrients has not been compared. A previous study by Sadej and Przekwas, (2008) on wheat plants displayed a rise in total nitrogen content with increasing nitrogen fertilizer rates in the uppermost soil layer and soil nitrogen content decreased with soil depth. Soil acidification and decreased soil nitrogen content were recorded (Haynes and Hamilton, 1999) with sugarcane cropping. The lack of a significant increase in soil nitrogen levels despite an increase in nitrogen rates was reported by Sadej and Przekwas, (2008).

However in other studies (Haynes and Hamilton, 1999; Walker et al., 2007) significant ($p \leq 0.05$) increase in soil nitrogen levels was observed. Non-significant responses of P and K due to fertilizer treatments have been witnessed (Schroeder et al., 1993; Abou-Khalifa, 2012; Graham et al., 2000). Similar reports were also observed and reported by other researchers (Mandal et al., 2012; Das, 2000; Walker et al., 2007). However, the findings are not in agreement with the reports by Muhammad et al., (2010), Walker et al., (2007) and Debiprasad et al., (2010) in which they observed a significant ($p \leq 0.05$) rise and decline in the soil chemical parameters due to the treatments. Determination of soil nutritional status due to the treatment effects has not been done for the ratoon sugarcane varieties in western Kenya. The objective of this research was to determine the variations in soil pH, N, P and K levels with varieties, nitrogen rates and split applications at the start and harvest of ratoon crop.

2. MATERIALS AND METHODS

Description of the study site

The trial was a furtherance of a research project conducted at Sugar Research Institute (SRI) in Opapo, whose features as described by Jaetzold et al., (2007) are itemized in Table 1. The research area was also presented in Figure 1.

Table 1 Description of the study site

Parameter	Descriptions/Values
Position	25 km west of Rongo town
Altitude	1454 m above sea level
Latitude	0^o 30′ S
Longitude	34^o 30′ E
Mean annual rainfall (av. Of 12 years, 2001-2013)	1770 mm
Mean monthly temperature	23 °C
Relative humidity (mean)	70.1%
Soil type	Eutric planosols (%C=1.38, %N=0.40)
Climate	Humid
Major agricultural activity	Sugarcane cultivation
Agro ecological zone	Low Midland 1 (LM_1)

Source: Jaetzold et al., (2007)

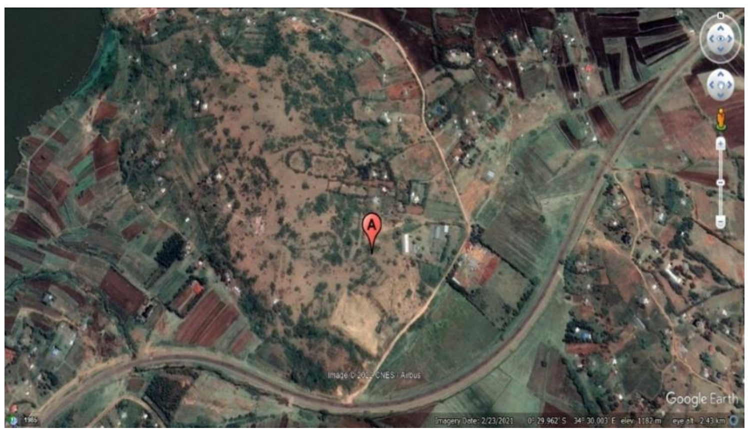

Figure 1 The study area

Experimental design and treatments

The trial design was a 2x4x3 split split-plot (72 plots) where sugarcane varieties CO421 (V_1) and D8484 (V_2) were the main plots while nitrogen (N) rates and the number of splits were the subplots and sub-sub-plot factors, correspondingly, with three replications. Every sub-plot comprised seven rows of sugarcane and measured 1.2 m wide x 10 m long (84 m^2) (Appendix 1). Nitrogenous fertilizer (urea) was applied in every plot depending on the assigned levels and splitting schedule. The levels were 0, 60, 120 and 180 kg N/ha per crop (R_1, R_2, R_3 and R_4, correspondingly), which were applied once (S_1) in the third month after ratooning (3 MAR), split into two halves (S_2) and each half applied at the third and sixth months after ratooning (6 MAR) and split (S_3) in the ratio of 4:3:3 and applied at the third, sixth and ninth months after ratooning (3, 6 and 9 MARs), respectively.

Soil sampling, preparation and analysis

Initial soil sampling at the start of ratooning was done to determine the dynamics of treatment effects. Final soil sampling and analysis from the site were also done at harvest of the ratoon crop to determine the influence of treatments on soil pH, N, P and K at 0-15 and 15-30 cm depths in which 1 kg soil samples from each plot were taken randomly at each depth using a stainless-steel soil auger. The samples were cleaned of plant and other debris, air-dried under the shade then ground to pass through a 2 mm sieve and a scoop (10 g) was used to analyze for pH, P, K and 1 g for N (Okalebo et al., 2002).

Soil pH

Soil pH was determined (from a 10 g soil sample) in a 1:2.5 soil: Water suspension as described by Okalebo et al., (2002) using a pH meter (Mettler Toledo FG2K, China).

Total Nitrogen (N)

Total N was estimated by distilling (249751, Europe) the ammonia trapped in boric acid mixed indicator solution. The amount of NH_3 trapped was estimated by titrating with standard acid according to the Kjeldahl procedure (Okalebo et al., 2002).

Available phosphorus (P)

Available phosphorus was extracted by adding 15 mL of 1:1 HCl-H_2SO_4 acid mixture to 10 g soil sample and allowing it to stand for 1 hr, adding activated charcoal and shaking for 10 minutes then filtering. Five millilitres (5 mL) of the aliquot and laboratory blanks were each pipetted into 50 mL volumetric flasks and 1 mL of ammonium-vanadomolybdate reagent was added and diluted to the mark with de-ionized water for colour development. For the calibration curve, volumes of 0, 1, 2, 3, 4 and 5 mL standard stock solutions were pipetted and 10 mL of ammonium-vanadomolybdate reagent was added into 100 mL volumetric flasks and the procedure was repeated using a UV-Visible spectrophotometer (Shimadzu 3700 DUV, China) at a wavelength of 430 nm (Okalebo et al., 2002).

Available potassium (K)

Available potassium was measured by taking five millilitres of the extracted sample and laboratory blanks into 50 mL volumetric flasks and diluting to the mark with de-ionized water and running through the flame photometer (Jenway PFP7, UK) under calibration curve of standards 0, 25, 50 and 100 ppm as described by Okalebo et al., (2002).

Data analysis

The generated data were statistically analysed using Statistical Analysis System (SAS) Version 9.2 (SAS Inc., 2002) as a 2x4x3 split plot design. An analysis of variance (ANOVA) using the general linear models (GLM) procedure was done on the various factors to determine any significant ($p \leq 0.05$) treatment effects.

3. RESULTS AND DISCUSSION

Variations in soil pH due to varieties CO421 and D8484

Results on the variations of soil pH due to sugarcane varieties at 0-15 cm and 15-30 cm are presented in Tables 2 and 3, respectively. The plots had received similar treatments in the plant crop. This could have carry-over effects on the soil pH and nutrients in the ratoon crop. Surprisingly, despite the randomization of the treatments, the pH was lower ($p \leq 0.05$) in D8484 plots than the CO421 plots. However, both at the start of the ratoon and harvest, the pH remained within the range appropriate for sugarcane farming (Blackburn, 1984).

Table 2 Effect of nitrogen fertilizer rates and split applications on soil pH (0-15 cm depth) at start and harvest of ratoon crop

START OF RATOON CROP							HARVEST OF RATOON CROP					
Var	N Rate	N Split			Mean rate	Mean var	N Rate	N Split			Mean rate	Mean var
		S1	S2	S3				S1	S2	S3		
	0	6.30	6.21	5.00	5.84		0	4.88	5.01	4.99	4.96	
	60	5.78	5.86	4.52	5.39		60	4.68	4.71	4.78	4.72	
	120	5.94	6.05	5.12	5.70	5.52	120	4.94	4.76	4.68	4.79	
	180	4.73	5.76	5.02	5.17		180	4.91	4.65	4.88	4.81	4.82
CO421	Mean split	5.69	5.97	4.92			Mean split	4.85	4.78	4.83		
	CV%		12.35				CV%		6.54			
	LSD p≤0.05		0.58		0.11		LSD p≤0.05		NS		NS	
	0	5.64	4.80	5.51	5.32		0	4.94	4.86	4.72	4.84	
	60	5.94	4.86	5.48	5.43		60	4.65	4.75	4.72	4.70	

D8484	120	5.65	4.01	6.00	5.22	5.20	120	4.56	4.66	4.37	4.53	4.62
	180	5.36	4.78	4.36	4.83		180	4.65	4.39	4.20	4.41	
	Mean split	5.65	4.61	5.34			Mean split	4.70	4.67	4.50		
	CV%		11.70				CV%		6.59			
	LSD p≤0.05		0.51		NS		LSD p≤0.05		NS		0.29	
Overall means	0	5.97	5.51	5.26	5.58		0	4.91	4.94	4.86	4.90	
	60	5.86	5.36	5.00	5.41		60	4.66	4.73	4.75	4.71	
	120	5.79	5.03	5.57	5.46		120	4.75	4.71	4.52	4.66	
	180	5.05	5.27	4.69	5.00		180	4.78	4.52	4.54	4.61	
	Mean split	5.67	5.29	5.13			Mean split	4.78	4.72	4.67		
	CV%		12.05				CV%		6.57			
	LSD p≤0.05		0.38		0.04	0.31	LSD p≤0.05		NS		0.21	0.15

CV-Coefficient of variation, LSD-Least significant difference, NS-Non-significant, N-Nitrogen, Var-Variety, CO421 and D8484- Sugarcane varieties

Table 3 Effect of nitrogen fertilizer rates and split applications on soil pH (15-30 cm depth) at start and harvest of ratoon crop

START OF RATOON CROP							HARVEST OF RATOON CROP					
Var	N Rate	N Split			Mean rate	Mean var	N Rate	N Split			Mean rate	Mean var
		S1	S2	S3				S1	S2	S3		
CO421	0	5.23	5.23	5.56	5.34	5.17	0	4.53	4.79	4.43	4.58	4.47
	60	5.03	5.04	5.18	5.09		60	4.32	4.38	4.36	4.35	
	120	5.26	4.97	4.92	5.05		120	4.62	4.54	4.43	4.53	
	180	5.36	5.01	5.28	5.22		180	4.46	4.29	4.47	4.41	
	Mean split	5.22	5.06	5.24			Mean split	4.48	4.50	4.42		
	CV%		7.72				CV%		7.64			
	LSD p≤0.05		NS		NS		LSD p≤0.05		NS		NS	
D8484	0	5.37	5.39	5.24	5.33	4.98	0	4.51	4.32	4.20	4.35	4.26
	60	5.06	5.17	5.09	5.11		60	4.23	4.32	4.34	4.30	
	120	4.82	5.07	4.60	4.83		120	4.29	4.24	4.13	4.22	
	180	4.90	4.46	4.56	4.64		180	4.39	4.32	3.83	4.18	
	Mean split	5.04	5.02	4.87			Mean split	4.36	4.30	4.13		
	CV%		7.17				CV%		8.20			
	LSD p≤0.05		NS		0.35		LSD p≤0.05		NS		NS	
Overall means	0	5.30	5.31	5.40	5.34		0	4.52	4.56	4.31	4.46	
	60	5.05	5.11	5.14	5.10		60	4.27	4.35	4.35	4.33	
	120	5.04	5.02	4.76	4.94		120	4.46	4.39	4.28	4.38	
	180	5.13	4.74	4.92	4.93		180	4.42	4.31	4.15	4.29	
	Mean split	5.13	5.04	5.05			Mean split	4.42	4.40	4.27		
	CV%		7.46				CV%		7.92			
	LSD p≤0.05		NS		0.25	0.18	LSD p≤0.05		NS		NS	0.16

CV-Coefficient of variation, LSD-Least significant difference, NS-Non-significant, N-Nitrogen, Var-Variety, CO421 and D8484- Sugarcane varieties

Effect of nitrogen fertilizer rates on soil pH

The results on the influence of nitrogen fertilizer rates on soil pH are presented in Tables 2 and 3. There was a general decline in soil pH with high rates of nitrogen. There was a higher pH decline at 15-30 cm soil depth (Table 3) compared to 0-15 cm soil depth. Researchers have reported comparable nitrogen rates responses (Koochekzadeh et al., 2009; Walker et al., 2007; Haynes and Hamilton, 1999; Yaduvanshi, 2003) and soil depth (Koochekzadeh et al., 2009), had been witnessed in previous studies. Increased nitrification reactions are attributed to rise in nitrogenous fertilizer rates, which discharge protons, consequently lowering pH

(Graham et al., 2000; Athokpam et al., 2013). Conversely, the results are not in harmony with those published by Abou-Khalifa, (2012) and Muhammad et al., (2010) where a rise in nitrogen rates did not change the level of soil pH. This is possibly due to differences in soil types. On sandy soils, there is generally very fast leaching of nitrogen; consequently, the nitrification process is not significant within the 0-30 cm soil depths. In Kenya, continuous application of high nitrogen rates may reduce soil pH to levels below the suitable range of 4.5-8.5 (Blackburn, 1984) for cane growing. This may reduce productivity in the long run and render the sugarcane lands unsuitable for sugarcane production.

Effect of split application of nitrogen fertilizer rates on soil pH

Splitting nitrogenous fertilizer application did not change the levels of soil pH (Tables 2 and 3). Comparable findings had been reported in a previous research (Muhammad et al., 2010). These were in contrast to the results of Koochekzadeh et al., (2009), Walker et al., (2007) and Yaduvanshi, (2003) in which splitting nitrogen application into smaller doses significantly ($p \leq 0.05$) increased soil acidity. The results revealed that splitting nitrogen application in western Kenya is not a suitable method of controlling the reduction of pH caused by nitrogenous fertilizers.

Variations in soil %N due to sugarcane varieties, fertilizer rates and application mode

Changes in soil nitrogen levels are presented in Tables 4 and 5.

Table 4 Effect of nitrogen fertilizer rates and split applications on soil %N (0-15 cm depth) at start and harvest of ratoon crop

START OF RATOON CROP							HARVEST OF RATOON CROP					
Var	N Rate	N Split			Mean rate	Mean var	N Rate	N Split			Mean rate	Mean var
		S1	S2	S3				S1	S2	S3		
	0	0.36	0.39	0.32	0.36		0	0.79	0.71	0.78	0.76	
	60	0.42	0.55	0.55	0.51		60	0.76	0.95	0.91	0.87	
	120	0.35	0.47	0.44	0.42		120	0.81	0.86	0.95	0.87	
	180	0.60	0.40	0.46	0.48	0.44	180	1.03	0.83	0.84	0.90	0.85
CO421	Mean split	0.43	0.45	0.44			Mean split	0.85	0.84	0.87		
	CV%		21.94				CV%		17.97			
	LSD $p \leq 0.05$		NS		0.10		LSD $p \leq 0.05$		NS		NS	
	0	0.50	0.40	0.47	0.46		0	0.82	0.85	0.97	0.88	
	60	0.53	0.36	0.46	0.45		60	0.70	0.86	0.86	0.81	
	120	0.53	0.58	0.40	0.50		120	0.70	0.71	0.76	0.72	
	180	0.49	0.45	0.53	0.49	0.47	180	0.88	0.80	0.84	0.84	0.81
D8484	Mean split	0.51	0.45	0.46			Mean split	0.78	0.81	0.86		
	CV%		23.01				CV%		19.17			
	LSD $p \leq 0.05$		NS		NS		LSD $p \leq 0.05$		NS		NS	
	0	0.43	0.40	0.39	0.41		0	0.81	0.78	0.88	0.82	
	60	0.48	0.46	0.51	0.48		60	0.73	0.91	0.89	0.84	
	120	0.44	0.52	0.42	0.46		120	0.76	0.79	0.86	0.80	
	180	0.54	0.43	0.49	0.49		180	0.96	0.82	0.84	0.87	
Overall means	Mean split	0.47	0.45	0.45			Mean split	0.81	0.82	0.86		
	CV%		22.53				CV%		18.55			
	LSD $p \leq 0.05$		NS		NS	NS	LSD $p \leq 0.05$		NS		NS	NS

CV-Coefficient of variation, LSD-Least significant difference, NS-Non-significant, N-Nitrogen, Var-Variety, CO421 and D8484-Sugarcane varieties

The varieties did not influence soil nitrogen levels at the beginning and harvest of the ratoon crop (Tables 4 and 5). Comparable findings had been witnessed and reported in other studies in which varieties (Haynes and Hamilton, 1999; Walker et al., 2007) did not influence soil nitrogen levels. On the other hand, other studies showed that varieties (Abou-Khalifa, 2012; Muhammad et al., 2010) significantly ($p \leq 0.05$) increased soil nitrogen levels. Although soil nitrogen level was low where nitrogen had not been applied, this was only significant ($p \leq 0.05$) for CO421 at the start of the ratoon.

Table 5 Effect of nitrogen fertilizer rates and split applications on soil %N (15-30 cm depth) at start and harvest of ratoon crop

START OF RATOON CROP							HARVEST OF RATOON CROP					
Var	N Rate	N Split			Mean rate	Mean var	N Rate	N Split			Mean rate	Mean var
		S1	S2	S3				S1	S2	S3		
CO421	0	0.38	0.33	0.38	0.36	0.36	0	0.56	0.43	0.51	0.50	0.50
	60	0.40	0.35	0.32	0.36		60	0.50	0.45	0.50	0.48	
	120	0.35	0.33	0.33	0.34		120	0.58	0.46	0.43	0.49	
	180	0.35	0.40	0.33	0.36		180	0.47	0.55	0.55	0.52	
	Mean split	0.37	0.35	0.34			Mean split	0.53	0.47	0.50		
	CV%		14.30				CV%		19.34			
	LSD p≤0.05		NS		NS		LSD p≤0.05		NS		NS	
D8484	0	0.31	0.38	0.33	0.34	0.33	0	0.37	0.50	0.50	0.46	0.50
	60	0.31	0.35	0.33	0.33		60	0.47	0.54	0.62	0.54	
	120	0.29	0.33	0.33	0.32		120	0.44	0.50	0.51	0.48	
	180	0.32	0.37	0.34	0.35		180	0.51	0.54	0.45	0.50	
	Mean split	0.31	0.36	0.33			Mean split	0.45	0.52	0.52		
	CV%		16.48				CV%		20.61			
	LSD p≤0.05		0.05		NS		LSD p≤0.05		NS		NS	
Overall means	0	0.35	0.35	0.36	0.35		0	0.47	0.47	0.51	0.48	
	60	0.36	0.35	0.33	0.34		60	0.48	0.49	0.56	0.51	
	120	0.32	0.33	0.33	0.33		120	0.51	0.48	0.47	0.49	
	180	0.33	0.39	0.34	0.35		180	0.47	0.54	0.50	0.51	
	Mean split	0.34	0.36	0.34			Mean split	0.49	0.50	0.51		
	CV%		15.37				CV%		19.98			
	LSD p≤0.05		NS		NS	NS	LSD p≤0.05		NS		NS	NS

CV-Coefficient of variation, LSD-Least significant difference, NS-Non-significant, N-Nitrogen, Var-Variety, CO421 and D8484- Sugarcane varieties

However, in other studies (Haynes and Hamilton, 1999; Walker et al., 2007) significant (p≤0.05) increase in soil nitrogen levels was observed. Splitting nitrogen application recorded a significantly (p≤0.05) lower effect for variety D8484 than CO421 at the start of ratoon at 15-30 cm soil depth. Similar results in which soil nitrogen levels did not significantly (p≤0.05) increase due to split application of nitrogen fertilizer had been observed in other studies (Sadej and Przekwas, 2008). On the contrary, splitting nitrogen application significantly increased soil nitrogen levels (Haynes and Hamilton, 1999; Walker et al., 2007), attributable to varietal and geographical differences. These results imply that despite the sugarcane variety, the soil nitrogen levels will remain unchanged during sugarcane cultivation.

Variations in soil P and K concentrations due to varieties, nitrogen fertilizer rates and split application

The effect of treatments on soil P and K levels at 0-15 cm and 15-30 cm are presented in Tables 6-9. There were no significant effects of the treatments on soil P levels. Only soil K significantly (p≤0.05) declined due to D8484 at 0-15 cm at harvest and both start of ratoon and harvest at 15-30 cm soil depth. This could be due to the ability of the variety to absorb more K (Achieng', 2015), an observation that is in agreement with the report by Schroeder et al., (1993) that variety influences nutrient uptake. The non-significant responses of the soil chemical parameters to the treatments observed in this study had also been observed by researchers in other studies (Schroeder et al., 1993; Abou-Khalifa, 2012; Graham et al., 2000; Das, 2000; Walker et al., 2007). However, these results presented herein are at variance to those of Muhammad et al., (2010), Walker et al., (2007) and Debiprasad et al., (2010) in which they found significant (p≤0.05) increase and decrease in the soil chemical parameters due to the treatments. These results demonstrate that generally, the soil chemical parameters did not change much. It can therefore be concluded that apart from K the other soil chemical parameters were not affected by varieties, nitrogen fertilizer and splitting of the doses in one crop. The effects could manifest after long-term studies.

Table 6 Effect of nitrogen fertilizer rates and split applications on soil P (mg/kg) at 0-15 cm depth at start and harvest of ratoon crop

START OF RATOON CROP							HARVEST OF RATOON CROP					
Var	N Rate	N Split			Mean rate	Mean var	N Rate	N Split			Mean rate	Mean var
		S1	S2	S3				S1	S2	S3		
	0	6.16	6.54	5.68	6.13		0	5.52	5.79	4.73	5.35	
	60	7.60	7.29	5.97	6.95		60	6.65	5.08	5.35	5.69	
	120	6.53	6.88	8.16	7.19		120	5.59	6.05	6.26	5.97	
	180	6.15	6.53	7.96	6.88	6.79	180	4.89	5.32	7.01	5.74	5.69
CO421	Mean split	6.61	6.81	6.94			Mean split	5.66	5.56	5.84		
	CV%		21.80				CV%		31.57			
	LSD p≤0.05		NS		NS		LSD p≤0.05		NS		NS	
	0	5.61	8.83	7.13	7.19		0	3.66	5.52	5.07	4.75	
	60	7.85	8.09	6.63	7.52		60	5.50	5.83	7.55	6.29	
	120	7.40	8.49	9.34	8.41		120	5.88	5.74	7.22	6.28	
	180	8.01	7.41	5.83	7.08	7.55	180	4.68	4.72	4.95	4.78	5.53
D8484	Mean split	7.22	8.21	7.23			Mean split	4.93	5.46	6.20		
	CV%		36.97				CV%		30.74			
	LSD p≤0.05		NS		NS		LSD p≤0.05		NS		NS	
	0	5.89	7.69	6.41	6.66		0	4.59	5.66	4.90	5.05	
	60	7.73	7.69	6.30	7.24		60	6.07	5.46	6.45	5.99	
	120	6.97	7.69	8.75	7.80		120	5.74	5.90	6.74	6.13	
	180	7.08	6.97	6.89	6.98		180	4.79	5.02	5.98	5.26	
Overall means	Mean split	6.91	7.51	7.09			Mean split	5.30	5.51	6.02		
	CV%		31.16				CV%		31.17			
	LSD p≤0.05		NS		NS	NS	LSD p≤0.05		NS		NS	NS

CV-Coefficient of variation, LSD-Least significant difference, NS-Non-significant, N-Nitrogen, Var-Variety, CO421 and D8484- Sugarcane varieties

Table 7 Effect of nitrogen fertilizer rates and split applications on soil P (mg/kg) at 15-30 cm depth at start and harvest of ratoon crop

START OF RATOON CROP							HARVEST OF RATOON CROP					
Var	N Rate	N Split			Mean rate	Mean var	N Rate	N Split			Mean rate	Mean var
		S1	S2	S3				S1	S2	S3		
	0	5.10	6.57	6.27	5.98		0	4.45	5.82	5.32	5.20	
	60	5.04	7.15	411	5.43		60	4.09	7.87	3.49	5.15	
	120	5.41	5.22	5.49	5.37	5.84	120	4.47	4.38	3.60	4.15	4.98
	180	5.93	6.26	7.51	6.57		180	4.67	5.05	6.56	5.43	
CO421	Mean split	5.37	6.30	5.85			Mean Split	4.42	5.78	4.74		
	CV%		35.50				CV%		34.80			
	LSD p≤0.05		NS		NS		LSD p≤0.05		NS		NS	
	0	7.00	7.63	7.27	7.30		0	6.83	4.32	5.21	5.45	
	60	7.05	7.22	4.30	6.19		60	4.70	4.97	5.22	4.96	
	120	5.00	4.71	5.60	5.10	6.17	120	3.47	6.89	3.49	4.62	5.00
	180	6.14	6.18	5.92	6.08		180	4.46	5.49	4.94	4.97	
D8484	Mean split	6.30	6.44	5.77			Mean Split	4.87	5.42	4.72		
	CV%		34.28				CV%		39.05			
	LSD p≤0.05		1.79		NS		LSD p≤0.05		NS		NS	
	0	6.05	7.10	6.77	6.64		0	5.64	5.07	5.27	5.33	

	60	6.05	7.19	4.20	5.81		60	4.39	6.41	4.36	5.06	
Overall means	120	5.20	4.96	5.55	5.24		120	3.97	5.63	3.55	4.38	
	180	6.03	6.22	6.72	6.32		180	4.57	5.27	5.75	5.20	
	Mean split	5.83	6.37	5.81			Mean Split	4.64	5.60	4.73		
	CV%		34.87				CV%		36.99			
	LSD p≤0.05		NS		NS	NS	LSD p≤0.05		NS		NS	NS

CV-Coefficient of variation, LSD-Least significant difference, NS-Non-significant, N-Nitrogen, Var-Variety, CO421 and D8484- Sugarcane varieties

Table 8 Effect of nitrogen fertilizer rates and split applications on soil K (mg/kg) at 0-15 cm depth at start and harvest of ratoon crop

START OF RATOON CROP							HARVEST OF RATOON CROP					
Var	N Rate	N Split			Mean rate	Mean var	N Rate	N Split			Mean rate	Mean var
		S1	S2	S3				S1	S2	S3		
CO421	0	27.52	44.73	38.53	36.93		0	29.75	35.50	28.10	31.12	
	60	34.96	25.16	39.01	33.04		60	29.30	22.24	23.38	24.97	
	120	42.37	20.41	26.81	29.86		120	28.12	21.41	22.51	24.01	
	180	32.34	26.74	32.31	30.46	32.59	180	23.82	20.35	26.91	23.69	25.95
	Mean split	34.30	29.26	34.17			Mean split	27.75	24.88	25.22		
	CV%		30.95				CV%		22.62			
	LSD p≤0.05		NS		NS		LSD p≤0.05		NS		5.74	
D8484	0	30.51	32.66	40.95	34.71		0	25.59	28.53	34.14	29.42	
	60	41.82	46.93	22.56	37.10		60	35.01	40.86	26.08	33.98	
	120	18.82	22.46	29.18	23.49		120	27.76	26.41	29.88	28.02	
	180	22.27	26.28	25.47	24.67	29.99	180	25.30	28.08	29.79	27.72	29.79
	Mean split	28.36	32.08	29.54			Mean split	28.41	30.97	29.97		
	CV%		36.81				CV%		27.75			
	LSD p≤0.05		NS		10.79		LSD p≤0.05		NS		NS	
Overall Means	0	29.02	38.70	39.74	35.82		0	27.67	32.02	31.12	30.27	
	60	38.39	36.04	30.79	35.07		60	32.16	31.55	24.73	29.48	
	120	30.59	21.43	28.00	26.67		120	27.94	23.91	26.19	26.01	
	180	27.31	26.51	28.89	27.57		180	24.56	24.22	28.35	25.71	
	Mean split	31.33	30.67	31.85			Mean split	28.08	27.92	27.60		
	CV%		33.79				CV%		25.73			
	LSD p≤0.05		NS		7.10	NS	LSD p≤0.05		NS		NS	3.41

CV-Coefficient of variation, LSD-Least significant difference, NS-Non-significant, N-Nitrogen, Var-Variety, CO421 and D8484- Sugarcane varieties

Table 9 Effect of nitrogen fertilizer rates and split applications on soil K (mg/kg) at 15-30 cm depth at start and harvest of ratoon crop

START OF RATOON CROP							HARVEST OF RATOON CROP					
Var	N Rate	N Split			Mean rate	Mean var	N Rate	N Split			Mean rate	Mean var
		S1	S2	S3				S1	S2	S3		
CO421	0	22.49	34.75	31.98	29.74		0	24.71	25.52	21.55	23.93	
	60	30.07	23.93	33.71	29.24		60	24.42	21.01	18.07	21.17	
	120	30.37	20.61	25.43	25.47		120	16.12	21.62	21.13	19.62	
	180	28.90	25.58	25.58	26.69	27.78	180	20.37	19.20	20.18	19.91	21.16
	Mean split	27.96	26.22	29.18			Mean Split	21.40	21.84	20.23		
	CV%		30.76				CV%		24.36			
	LSD p≤0.05		NS		NS		LSD p≤0.05		NS		NS	
	0	34.54	25.97	32.90	31.14		0	29.61	21.84	26.09	25.85	

	60	29.61	24.55	19.74	24.63		60	22.79	18.48	23.25	21.51	
	120	18.02	19.45	19.97	19.15	24.48	120	26.96	23.40	20.67	23.68	24.27
D8484	180	18.98	24.67	25.36	23.01		180	22.01	26.47	29.68	26.05	
	Mean split	25.29	23.66	24.49			Mean Split	25.34	22.55	24.92		
	CV%		24.49				CV%		19.39			
	LSD p≤0.05		NS		5.83		LSD p≤0.05		NS		NS	
	0	28.51	30.36	32.44	30.44		0	27.16	23.68	23.82	24.89	
	60	29.84	24.24	26.72	26.94		60	23.60	19.75	20.66	21.34	
	120	24.19	20.03	22.70	22.31		120	21.54	22.51	20.90	21.65	
	180	23.94	25.13	25.47	24.85		180	21.19	22.83	24.93	22.98	
Overall Means	Mean split	26.62	24.94	26.84			Mean Split	23.37	22.19	22.58		
	CV%		28.24				CV%		21.73			
	LSD p≤0.05		NS		4.56	3.22	LSD p≤0.05		NS		NS	2.39

CV-Coefficient of variation, LSD-Least significant difference, NS-Non-significant, N-Nitrogen, Var-Variety, CO421 and D8484- Sugarcane varieties

4. CONCLUSION AND RECOMMENDATION

Variety D8484 acidified the soil more than CO421; however, the pH remained within the range suitable for sugarcane growing, both at the start and at harvest of ratooning. Current agronomic practices did not lead to much change in the soil N, P and K levels. Soil K levels significantly declined due to variety D8484 at 0-15 cm at harvest and both start of ratoon and harvest at 15-30 cm soil depth. Soil sampling and testing should not be frequently done since the treatment effects on soil physico-chemical parameters could manifest after long period.

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Appendices

Appendix 1 Details of replications showing randomization at the study site

REP 1					REP 2					REP 3				
	1 R_1S_1	2 R_2S_1	3 R_3S_1	4 R_4S_1		1 R_1S_1	2 R_2S_1	3 R_3S_1	4 R_4S_1		1 R_1S_1	2 R_2S_1	3 R_3S_1	4 R_4S_1
V_1	5 R_1S_2	6 R_2S_2	7 R_3S_2	8 R_4S_2		5 R_1S_2	6 R_2S_2	7 R_3S_2	8 R_4S_2		5 R_1S_2	6 R_2S_2	7 R_3S_2	8 R_4S_2
	9 R_1S_3	10 R_2S_3	11 R_3S_3	12 R_4S_4	V_2	9 R_1S_3	10 R_2S_3	11 R_3S_3	12 R_4S_4	V_1	9 R_1S_3	10 R_2S_3	11 R_3S_3	12 R_4S_4
	13 R_1S_1	14 R_2S_1	15 R_3S_1	16 R_4S_1		13 R_1S_1	14 R_2S_1	15 R_3S_1	16 R_4S_1		13 R_1S_1	14 R_2S_1	15 R_3S_1	16 R_4S_1
	17 R_1S_2	18 R_2S_2	19 R_3S_2	20 R_4S_2		17 R_1S_2	18 R_2S_2	19 R_3S_2	20 R_4S_2		17 R_1S_2	18 R_2S_2	19 R_3S_2	20 R_4S_2
V_2	21 R_1S_3	22 R_2S_3	23 R_3S_3	24 R_4S_4	V_1	21 R_1S_3	22 R_2S_3	23 R_3S_3	24 R_4S_4	V_2	21 R_1S_3	22 R_2S_3	23 R_3S_3	24 R_4S_4

50.4 m

120.0 m

Ethical approval

Not applicable.

Informed consent

Not applicable.

Conflicts of interests

The authors declare that there are no conflicts of interests.

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Data and materials availability

All data associated with this study are present in the paper.

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