DISCOVERY

58(318), June 2022

Changes in foliar nitrogen, phosphorus and potassium levels of sugarcane varieties due to rates and split applications of nitrogen fertilizer

Oindo Achieng G[1*], Okinda Owuor P[1], Crispin O Omondi[2], Gordon O Abayo[2]

To Cite:
Achieng GO, Owuor PO, Omondi CO, Abayo GO. Changes in foliar nitrogen, phosphorus and potassium levels of sugarcane varieties due to rates and split applications of nitrogen fertilizer. *Discovery*, 2022, 58(318), 559-578

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:**
Email: georgeoindoachieng@gmail.com

Peer-Review History
Received: 02 April 2022
Reviewed & Revised: 03/April/2022 to 11/May/2022
Accepted: 14 May 2022
Published: June 2022

Peer-Review Model
External peer-review was done through double-blind method.

DISCOVERY
SCIENTIFIC SOCIETY

ABSTRACT

Leaf analysis is widely used for diagnostic purposes, as a means to formulate fertilizer recommendations and to ascertain nutrient trends. Whereas various parts of the plant can be used for tissue sampling, the third top-visible dewlap leaf without its midrib is usually the tissue of choice for assessing the nutrient status of sugarcane. Sample collection is based on the right period and satisfactory age of the cane. This study was aimed at determining the effect of nitrogen fertilizer applied either in single or split to ratoon crop of new (D8484) and old (CO421) varieties on leaf N, P and K levels. The experimental design was a 2x4x3 split split-plot at the Sugar Research Institute, Opapo, situated in the western part of Kenya. Standard methods were applied to examine the levels of leaf nutrients. The results showed significant differences ($p \leq 0.05$) in leaf %N levels as a function of sugarcane varieties from the 5th to 10th month after ratooning (MAR). Leaf %N in both varieties reached their peak at the 5th MAR thereafter decreased. In the 3rd and 4th MAR, the levels of nitrogen in the two varieties were similar. In CO421, except for 6th MAR, there were significant ($p \leq 0.05$) responses in leaf nitrogen to nitrogen fertilizer application rates. The 120 kgN/ha had high ($p \leq 0.05$) leaf nitrogen in this variety than other rates. Indeed, except in the 5th MAR, other rates did not record significant responses. In D8484, significant ($p \leq 0.05$) responses in leaf nitrogen to rates of nitrogen were recorded in the 3rd, 5th and 9th MAR. There was no clear pattern of the responses to nitrogen rates in this variety. For the mean, conflicting response patterns observed in the two varieties caused lack of response in leaf nitrogen to nitrogen rates in most months. Sporadic significant ($p \leq 0.05$) effects were observed due to split application in the two varieties at some sampling dates. Except in CO421, splitting nitrogen application generally had no effect on leaf nitrogen levels. There were no varietal differences in leaf P up to the 7th MAR. In both varieties, significant ($p \leq 0.05$) variations were observed in leaf P due to rates of nitrogen fertilizer. However, the order was sporadic and did not follow any pattern. Peak leaf P levels were observed at the 4th MAR with the levels falling after this period. Generally, split application of nitrogen fertilizer rates only sporadically influenced leaf P levels. Apart from the 7th and 10th MAR, there were significant ($p \leq 0.05$) differences in leaf K levels due to varieties. In general, variety D8484 had higher leaf K levels than CO421. Significant ($p \leq 0.05$) variations were only observed from 3rd to 5th MAR. Similarly, for the mean, the significant variations were observed in the 3rd, 4th and 5th MAR. Peak leaf K levels were recorded at 5th MAR. Generally, nitrogen rates of 0 and 120 kgN/ha caused decline in the leaf K levels. The responses in leaf K levels due to splitting nitrogen fertilizer application appeared to be sporadic though significant ($p \leq 0.05$) especially in the early MAR in both varieties. The pattern appeared clearer in D8484 from 3rd to 5th MAR in which leaf K was higher where nitrogen had been split into two. It is concluded that leaf sampling and nutrients analysis should be done before 5th MAR.

Key words: Leaf nutrients, month after ratooning, fertilizer rate, split application

1. INTRODUCTION

Sugarcane (*Saccharum officinarum L.*) is a commercial crop cultivated in humid and sub-humid areas for sugar production in environments ranging from hot dry near sea level to cool and moist at high altitudes (Plaut *et al*., 2000). Apart from main product, sugar, it yields valuable co-products such as alcohol used in pharmaceutical industry and as fuel, bagasse for manufacturing paper and chip board, and press mud as a rich source of organic nutrients for crop production (Kumar *et al*., 1996; Lingle *et al*., 2000). In Kenya, sugarcane industry is a major employer and a contributor to the national economy, supporting approximately 250,000 small-scale farmers that supply 92% of cane. The crop saves Kenya in excess of Kshs. 19.3 billion in foreign exchange annually and contributes tax revenues to the exchanger (Kenya Sugar Board, 2010-2014). New sugarcane varieties have been introduced in Kenya sugar industry. These include KEN82-216, KEN82-219, KEN82-247, KEN82-401, KEN82-808 and KEN83-737 in 2002 (Wawire *et al*., 2006), KEN82-472, KEN82-62, EAK73-335 and D8484 in 2007 and KEN82-121, KEN82-601 and KEN82-249 in 2009 (GOK, 2009) under rain fed conditions (Wawire *et al*., 2006; Kenya Sugar Board, 2010). Most of the soils where sugarcane is grown in Kenya are low in soil nitrogen (Jaetzold *et al*., 2005). Nitrogen fertilizer application in sugarcane farming is therefore mandatory (Sreewarome *et al.,* 2007; Ali et al., 2019). The range of nitrogen fertilizer rates currently in use is 100-120 kg N/ha applied in a single dose. These rates were developed and recommended in 1980s for plant and ratoon crops of the old and late maturing varieties (KESREF, 2010). In North America, early maturing varieties need different fertilizer rates (Snyder and Bruulsema, 2007). The new varieties have not been assessed to establish if they require similar rates as the old late maturing varieties. Again, nitrogen fertilizer is costly and haphazard application such as inappropriate rate, time and placement method may lead to low ratoon crop performance and nitrogen fertilizer loss through nitrate leaching, nitrate de-nitrification and ammonia volatilization (Dalal and Meyer, 1986). Thus, exhaustion of plant available soil nitrogen over time justifies the need for split application of total rate per hectare (Wiedenfeld, 1997). Nevertheless, application of nitrogen fertilizer in intensive sugarcane farming raises N losses to the environment, consequently, causing potential negative environmental impacts (Eickhout *et al*., 2006).

Leaf nutrient analysis has been widely used as a diagnostic tool to complement soil testing in sugarcane production and to predict possible deficiencies (Gascho and Elwali, 1979; Rice *et al.*, 2002). Previous studies have considered foliar sampling dates of between 3rd and 10th months (Ambachew *et al*., 2012; Madhuri *et al*., 2011; Mucovej and Newman, 2004a, 2004b; Schroeder *et al*., 1999) since this is the period of active growth in sugarcane crop (Malavolta, 1994; Rice *et al*., 2002; Okalebo *et al*., 2002). However, in this study, nitrogen fertilizer rates and method of application for intervention on leaf nutrients deficiency was done at 3rd, 6th and 9th months after ratooning. Moreover, data to develop leaf analysis nutrient guide is lacking for Kenya sugar industry, especially on early maturing varieties. Indeed, it is not known how leaf nutrients levels of early and late maturing sugarcane varieties are influenced by the agronomic inputs under Kenya sugarcane growing conditions.

Leaf nutrients can foretell insufficiency that influences sugarcane yields (Gascho, 1983). The foliar examination is commonly used for problem-solving as a means to formulate fertilizer recommendations and to ascertain nutrient tendencies (Malavolta, 1994; Meyer *et al*., 1989). Though various parts of the plant may be used for matter sampling, the third top-visible dewlap (TVD) leaf minus its midrib is mostly the tissue of choice for evaluating the nutrient status of sugarcane (Ezenwa *et al*., 2005). Sample collection is centred on the correct period (precisely, when the plant has received sufficient and well distributed rain or irrigation to stop any moisture stress) and suitable age (six weeks after any fertilizer application) of the cane (Schroeder *et al*., 1999). Based on experiences elsewhere, it was suggested that sampling ages of 3 to 5 and 4 to 7 months be used in Queensland and New South Wales respectively (Schroeder *et al*., 1999). These recommendations were based on agronomic conditions in temperate conditions, where growth and agronomic conditions are very different from those realised in the tropical areas, especially along the equator, such as in Kenya. However, optimal sampling time has not been established in Kenya. Nutrient uptake is dependent on cane variety and leaf nutrient (Schroeder *et al*., 1993). The phosphorus and potassium critical values for sugarcane varieties were suggested from South Africa (Schroeder *et al*., 1993). The critical green leaf nitrogen concentration for photosynthesis in sugarcane ranges from 1.2% N at emergence to 0.5% at flowering (Keating *et al*., 1999). The recommended nutrients levels for sugarcane and levels observed in different countries are presented in Table 1 (McCray and Mylavarapu, 2010; Ambachew *et al*., 2012; Madhuri *et al*., 2011).

Table 1 Sugarcane Leaf Nutrient critical values and optimum ranges

	Country			
	Florida (recommended levels)		Ethiopia	India
Nutrient	Critical Value	Optimum Range	Five months	Six months
N	1.80%	2.00-2.60%	1.53%-1.73%	1.99%-2.38%
P	0.19%	0.22-0.30%	0.17%-0.20%	0.10%-0.25%
K	0.90%	1.00-1.60%	1.22%-1.64%	1.23%-1.93%

Source: McCray and Mylavarapu (2010), Ambachew *et al*. (2012) and Madhuri *et al*. (2011)

For the sugarcane varieties in Ethiopia, Ambachew *et al*. (2012) observed that at the 5th month variety B41-227 had higher leaf N, P and K levels and CO449 had the lowest levels while B52-298, CO421 and Nco334 had in-between contents in both plant cane and ratoon crop. The lower leaf N content was attributed to lower nitrogen use efficiency (Hunsigi, 1993). The leaf nutrient contents of CO421 and D8484 ratoon crop under Kenya sugarcane growing soils are not known.

Changes in nitrogen fertilizer rates normally influence foliar nutrient levels of sugarcane in the development regime, though the levels vary transversely within the sampling period (Muchovej and Newman, 2004a). For instance, leaf potassium concentrations increased with time during the first ratoon crop. But leaf macro and micro-nutrient levels remained unaffected by the investigated nitrogen fertilizer rates. Fast sugarcane development and buildup of dry matter contribute to low foliar nitrogen level (Jarrell and Beverly, 1981). Adequate nitrogen fertilizer rates notwithstanding, sugarcane foliar nitrogen levels decline during the second half of sugarcane development (Muchovej and Newman, 2004a). A significant rise in foliar levels of nitrogen and potassium in the TVD plant tissues occur with rising rates of nitrogen fertilizer (Singh and Jha, 1994; Ahmed *et al*., 2009). However, they only studied the effect of single application of nitrogen fertilizer rates on foliar nitrogen and potassium levels. Kumar and Verma (1997) investigated the nutrient contents of the index leaf of eleven sugarcane varieties. Leaf N, P and K contents were significantly correlated with cane yield (TC/Ha) (Kumar and Verma, 1997). However, leaf nutrient contents were analyzed once at maximum growth stage. Furthermore, no report was made on the effects of nitrogen fertilizer rate and split application on leaf nutrients of the sugarcane varieties studied. It is not known how leaf nutrients levels of early and late maturing sugarcane varieties are influenced by different rates and split application of nitrogen fertilizer in the Kenya Sugar Industry and if there is a relationship between leaf nutrients and yields of ratoon sugar crops. This study was aimed at comparing N, P, and K foliar levels of early and late maturing sugarcane varieties as influenced by rates and split application of nitrogen fertilizer with months after ratooning and establish the appropriate time for sampling leaf for nutrients analysis.

2. MATERIALS AND METHODS

Description of the study site

The experiment was a continuation of research project conducted in Sugar Research Institute Opapo, whose features as described by Jaetzold *et al.* (2007) are listed in Table 2.

Table 2: Description of the study site

Parameter	Values
Position	25 km west of Rongo town
Altitude	1454 m above sea level
Latitude	0° 30′ S
Longitude	34° 30′ E

ISSN 2278–5469 EISSN 2278–5450 I OPEN ACCESS

Mean annual rainfall (av. Of 12 years, 2001-2013)	1770 mm
Mean monthly temperature	23 ^{o}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	LM_1

Source: Jaetzold *et al.* (2007)

Experimental design and treatments

The experimental design was a 2x4x3 split split-plot (72 plots) where the sugarcane varieties CO421 and D8484 were the main plots while nitrogen (N) rates and number of splits were the sub plot and sub sub-plot factors, respectively, with three replications. Each sub-plot comprised of 7 rows of sugarcane and measured 1.2 m wide x 10 m long (84 m^2) (Appendix 1). Nitrogenous fertilizer (urea) was applied in each plot based on the assigned levels and splitting schedule. The levels were 0, 60, 120 and 180 kgN/ha per crop (R_1, R_2, R_3 and R_4, respectively) which were applied once (S_1) at the 3rd MAR, split into two halves (S_2) and each half applied at the 3rd and 6th MARs and split (S_3) in the ratio of 4:3:3 and applied at the 3rd, 6th and 9th MARs, respectively.

Sugarcane leaf sampling and preparation for N, P and K determination

Twenty (20), third top-visible dewlap (TVD) sugarcane leaves were randomly sampled starting from the 3rd to 10th MAR on a monthly basis. Sample preparation and analysis was done according to Okalebo *et al*. (2002) procedures. The leaves were oven dried at 70 ^{o}C for 72 hours; ground and 0.3 g of oven dried leaf sample was weighed on an analytical balance (Shimadzu AUW220, Japan) and digested in 100 ml tube with 2.5 ml of digestion mixture (3.2 g of salicylic acid in 100 ml of conc. H_2SO_4-Se mixture) and the blank reagent. The tube was placed in a block digester (VELP DK20, Europe) set at 110 ^{o}C for 1 hr, removed and cooled before adding 3 successive 1 ml portions of 30 % H_2O_2. The tube contents were thoroughly agitated and placed back on the block digester and temperature increased gradually up to 330 ^{o}C until a colourless solution formed. The tube was removed, cooled and plant digest filtered through Whatman No. 91 filter paper. The filtrate was collected into a 50 ml volumetric flask, diluted to the mark with de-ionized H_2O and allowed to settle to a clear solution.

Total nitrogen

Five milliliter (5 ml) of the aliquot was mixed with 10 ml of 40% NaOH then distilled for 3 minutes followed by standardization with N/70 HCl using a mixed indicator until color changed from pink to magenta at end-point. A 5 ml of laboratory blank sample was also subjected to the same procedure (Okalebo *et al*., 2002).

Total phosphorus

Five milliliters (5 ml) of the aliquot and laboratory blanks were each put into 50 ml volumetric flasks, 5 ml of ammonium-vanadomolybdate reagent added and diluted to the mark with de-ionized water for the development of a yellow color. For the calibration curve, volumes of 0, 1, 2, 3, 4 and 5 ml standard stock solutions were measured and 10 ml of ammonium-vanadomolybdate reagent added into 100 ml volumetric flasks and the procedure repeated (Okalebo *et al*., 2002).

Potassium

Five milliliters of the aliquot stock and laboratory blanks were filtered into 50 ml volumetric flasks and diluted to the mark with de-ionized water and run through the flame photometer (Jenway PFP7, UK) under the calibration curve of standards 0, 25, 50 and 100 ppm (Okalebo *et al*., 2002).

Data analysis

The data obtained from this study were statistically analysed using Statistical Analysis System (SAS) Version 9.2 (SAS Inc., 2002) as a 2x4x3 split split plot design. An analysis of variance (ANOVA) using general linear models (GLM) procedure was executed on the various parameters to determine any significant ($p \leq 0.05$) treatment effects. In addition, quadratic graphs were drawn using Microsoft Office Excel to elaborate on the ANOVA tables.

ISSN 2278–5469 EISSN 2278–5450 I OPEN ACCESS

3. RESULTS AND DISCUSSION

Leaf Nitrogen

Leaf nitrogen (%N) of CO421 and D8484 sugarcane varieties

Nitrogen is the main nutrient for sugarcane (Sreewarome *et al*., 2007). The results for leaf nitrogen levels of CO421 and D8484 in different months after ratooning (MAR) are highlighted in Figure 1 and Tables 3-6.

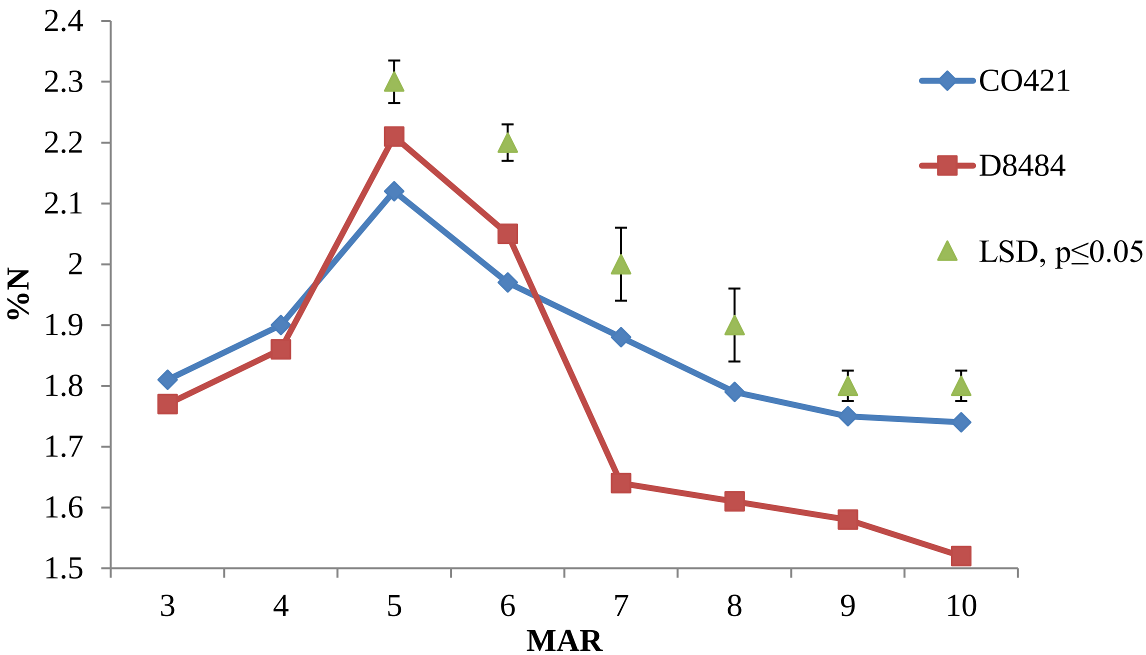

Figure 1 Changes in leaf nitrogen levels of CO421 and D8484 sugarcane varieties in different months after ratooning

Significantly different ($p \leq 0.05$) foliar %N levels were recorded due to sugarcane varieties from 5 to 10 MAR. Leaf nitrogen contents in both varieties reached their peak values at 5 MAR, thereafter the concentrations decreased. The foliar N levels in the two varieties were at par the 3rd and 4th MAR. The witnessed decline in leaf nitrogen levels in the second half of sugarcane growth had also been observed by Muchovej and Newman, 2004a) and (Ochola, 2013). Varietal differences in nutrient uptake and subsequent leaf nutrient levels had also been witnessed in other studies (Schroeder *et al*., 1993; Ambachew *et al*., 2012; Ochola *et al*., 2014). Results presented herein are in agreement with other studies and suggest that leaf sampling for estimation of levels of nitrogen should be done in Kenya before 5 MAR when the levels have not started responding to varietal differences. Although in the 5th and 6th MARs variety D8484 had higher ($p \leq 0.05$) levels of leaf nitrogen than CO421, the converse was observed from 7th MAR onwards. Significant differences imply that from the 5th MAR onwards, individual varieties require variety specific recommendations on rates of nitrogen if these were to be used in fertilizer advisory system. More data needs to be accumulated on nitrogen levels of ratoon crops for many varieties so that guide lines on recommended levels can be formulated.

Table 3 Effect of rates and split applications of nitrogen fertilizer on %N at 3 MAR and 4 MAR

3 MAR							4 MAR					
Var	N Rate	N Split			Mean rate	Mean var	N Rate	N Split			Mean rate	Mean var
		S1	S2	S3				S1	S2	S3		
	0	1.73	1.95	1.72	1.80		0	1.87	1.85	1.94	1.89	
	60	1.77	1.73	1.78	1.76		60	1.66	2.03	1.98	1.89	
	120	1.93	1.90	1.79	1.87	1.81	120	1.93	1.96	2.01	1.97	
	180	1.75	1.82	1.84	1.80		180	1.83	1.89	1.86	1.86	1.90
CO421	Mean split	1.79	1.85	1.78			Mean split	1.82	1.93	1.95		
	CV%		6.94				CV%		10.96			

	LSD p≤0.05		0.05		0.02		LSD p≤0.05		0.10		0.02	
D8484	0	1.69	1.72	1.71	1.70		0	1.92	1.94	1.92	1.93	
	60	1.77	1.94	1.84	1.85		60	1.90	1.78	1.71	1.80	
	120	1.78	1.81	1.83	1.81		120	1.93	1.79	1.91	1.87	
	180	1.78	1.69	1.72	1.73	1.77	180	1.88	1.84	1.83	1.85	1.86
	Mean split	1.76	1.79	1.77			Mean split	1.91	1.84	1.84		
	CV%		5.60				CV%		7.00			
	LSD p≤0.05		NS		0.10		LSD p≤0.05		0.03		NS	
Overall means	0	1.71	1.83	1.71	1.75		0	1.89	1.90	1.93	1.91	
	60	1.77	1.84	1.81	1.81		60	1.78	1.91	1.84	1.84	
	120	1.86	1.85	1.81	1.84		120	1.93	1.87	1.96	1.92	
	180	1.77	1.75	1.78	1.77		180	1.86	1.87	1.85	1.86	
	Mean split	1.78	1.82	1.78			Mean split	1.86	1.88	1.90		
	CV%		6.27				CV%		8.98			
	LSD p≤0.05		NS		0.02	NS	LSD p≤0.05		0.02		NS	NS

Table 4 Effect of rates and split applications of nitrogen fertilizer on %N at 5 MAR and 6 MAR

5 MAR							6 MAR					
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	2.23	2.19	2.05	2.16		0	1.94	1.92	2.01	1.96	
	60	1.94	2.05	2.22	2.07		60	1.73	2.10	2.05	1.96	
	120	2.13	2.16	2.16	2.15		120	2.00	2.03	2.08	2.03	
	180	2.07	2.22	1.98	2.09	2.12	180	1.90	1.96	1.93	1.93	1.97
	Mean split	2.09	2.15	2.10			Mean split	1.89	2.00	2.02		
	CV%		8.33				CV%		10.62			
	LSD p≤0.05		NS		0.02		LSD p≤0.05		0.11		NS	
D8484	0	2.09	2.27	2.14	2.20		0	2.10	2.12	2.10	2.11	
	60	2.03	2.32	2.32	2.20		60	2.08	1.97	1.89	1.98	
	120	2.26	2.30	2.11	2.30		120	2.11	1.97	2.09	2.06	
	180	2.11	2.21	2.08	2.14	2.21	180	2.06	2.02	2.02	2.03	2.05
	Mean split	2.21	2.16	2.26			Mean split	2.09	2.02	2.03		
	CV%		11.87				CV%		6.26			
	LSD p≤0.05		NS		0.11		LSD p≤0.05		NS		NS	
Overall means	0	2.24	2.14	2.16	2.18		0	2.02	2.02	2.06	2.03	
	60	2.04	2.03	2.33	2.13		60	1.90	2.03	1.97	1.97	
	120	2.23	2.21	2.23	2.22		120	2.05	2.00	2.08	2.05	
	180	2.09	2.20	2.06	2.12		180	1.98	1.99	1.97	1.98	
	Mean split	2.15	2.16	2.18			Mean split	1.99	2.01	2.02		
	CV%		10.10				CV%		8.44			
	LSD p≤0.05		NS		0.03	0.07	LSD p≤0.05		NS		NS	NS

Table 5 Effect of rates and split applications of nitrogen fertilizer on %N at 7 MAR and 8 MAR

7 MAR							8 MAR					
Var	N Rate	N Split			Mean rate	Mean var	N Rate	N Split			Mean rate	Mean var
		S1	S2	S3				S1	S2	S3		

ISSN 2278–5469 EISSN 2278–5450 I OPEN ACCESS

	0	1.82	1.76	1.93	1.84		0	1.73	1.67	1.84	1.75	
	60	1.77	1.99	1.81	1.86		60	1.68	1.90	1.72	1.77	
CO421	120	2.06	1.87	2.04	1.99	1.88	120	1.97	1.78	1.95	1.90	1.79
	180	1.87	2.01	1.62	1.83		180	1.78	192	1.53	1.74	
	Mean split	1.88	1.91	1.85			Mean split	1.79	1.82	1.76		
	CV%		14.01				CV%		14.74			
	LSD p≤0.05		NS		0.03		LSD p≤0.05		NS		0.03	
	0	1.81	1.62	1.57	1.66		0	1.78	1.59	1.54	1.63	
	60	1.90	1.52	1.48	1.64		60	1.87	1.49	1.45	1.61	
	120	1.82	1.53	1.57	1.64	1.64	120	1.79	1.50	1.54	1.61	1.61
	180	1.79	1.55	1.54	1.63		180	1.76	1.52	1.51	1.60	
D8484	Mean split	1.83	1.55	1.54			Mean split	1.80	1.52	1.51		
	CV%		14.83				CV%		15.15			
	LSD p≤0.05		0.21		NS		LSD p≤0.05		0.21		NS	
	0	1.81	1.69	1.75	1.75		0	1.75	163	1.69	1.69	
	60	1.84	1.76	1.65	1.75		60	1.78	1.70	1.59	1.69	
	120	1.94	1.70	1.81	1.81		120	1.88	1.64	1.74	1.75	
	180	1.83	1.78	1.58	1.73		180	1.77	1.72	1.52	1.67	
Overall means	Mean split	1.85	1.73	1.70			Mean split	1.79	1.67	1.63		
	CV%		14.42				CV%		14.95			
	LSD p≤0.05		0.05		0.01	0.12	LSD p≤0.05		0.05		NS	0.12

Table 6 Effect of rates and split applications of nitrogen fertilizer on %N at 9 MAR and 10 MAR

9 MAR							10 MAR					
Var	N Rate	N Split			Mean rate	Mean var	N Rate	N Split			Mean rate	Mean var
		S1	S2	S3				S1	S2	S3		
	0	1.67	1.89	1.66	1.74		0	1.66	1.75	1.65	1.68	
	60	1.71	1.67	1.72	1.70		60	1.66	1.69	1.78	1.71	
	120	1.87	1.84	1.73	1.81	1.75	120	1.82	1.79	1.87	1.83	1.74
	180	1.69	1.76	1.80	1.75		180	1.75	1.79	1.68	1.74	
CO421	Mean split	1.73	1.79	1.73			Mean split	1.72	1.76	1.75		
	CV%		7.25				CV%		6.18			
	LSD p≤0.05		0.05		0.11		LSD p≤0.05		NS		0.10	
	0	1.50	1.53	1.52	1.51		0	1.46	1.63	1.54	1.54	
	60	1.58	1.75	1.65	1.66		60	1.50	1.54	1.46	1.50	
	120	1.59	1.62	1.64	1.62	1.58	120	1.44	1.55	1.42	1.47	1.52
	180	1.59	1.50	1.53	1.54		180	1.64	1.49	1.57	1.57	
	Mean split	1.57	1.60	1.58			Mean split	1.41	1.45	1.40		
D8484	CV%		6.03				CV%		7.94			
	LSD p≤0.05		NS		0.12		LSD p≤0.05		NS		NS	
	0	1.58	1.71	1.59	1.63		0	1.56	1.69	1.60	1.61	
	60	1.65	1.71	1.69	1.68		60	1.58	1.61	1.62	1.60	
	120	1.73	1.73	1.69	1.71		120	1.63	1.67	1.65	1.65	
	180	1.64	1.63	1.67	1.65		180	1.70	1.64	1.63	1.66	
Overall means	Mean split	1.65	1.69	1.66			Mean split	1.62	1.65	1.62		
	CV%		6.64				CV%		7.06			
	LSD p≤0.05		NS		NS	0.05	LSD p≤0.05		NS		NS	0.05

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Leaf N variations with nitrogen fertilizer rates

The influence of nitrogen fertilizer rates on leaf nitrogen levels are presented in Figure 2 and Tables 3-6.

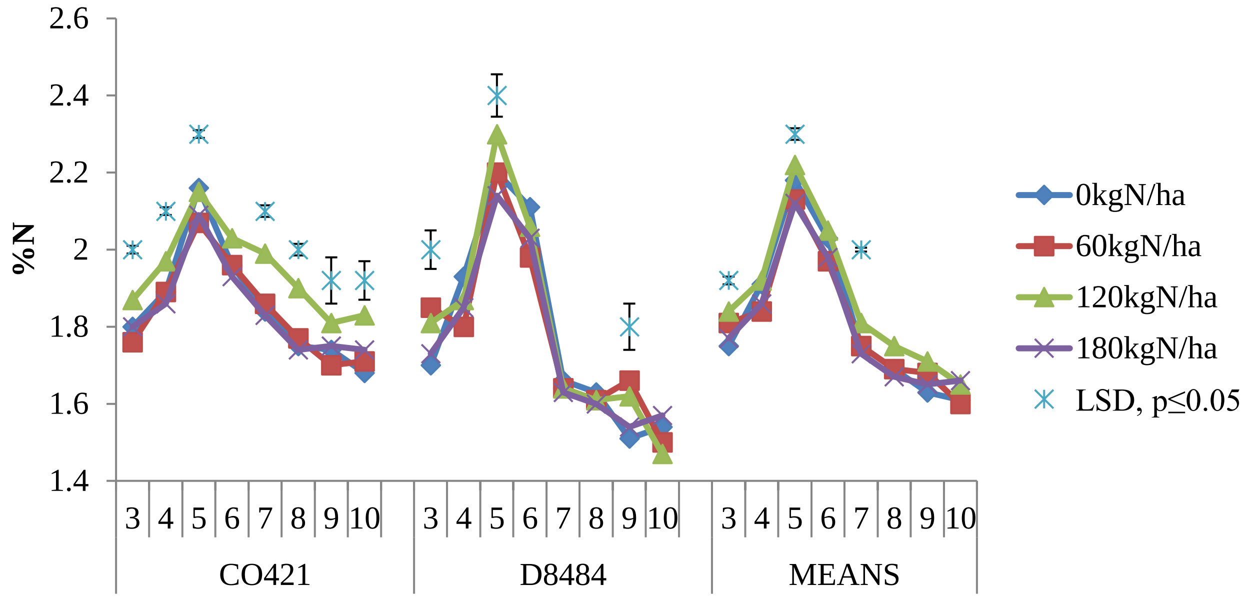

Figure 2 Effect of nitrogen fertilizer rates on leaf %N of CO421 and D8484

The response in the 3rd MAR was however sporadic since fertilizer had been applied two weeks before sampling. For overall mean data, nitrogen fertilizer rate only influenced ($p \leq 0.05$) leaf nitrogen levels in the 3rd, 5th and 7th MAR. This was however, different from the responses in individual varieties. In CO421, except for 6th MAR, there were significant ($p \leq 0.05$) responses in leaf nitrogen to nitrogen fertilizer application rates. The 120kgN/ha had high ($p \leq 0.05$) leaf nitrogen in this variety than other rates. Indeed, except in the 5th MAR, other rates did not record significant responses. In D8484, significant ($p \leq 0.05$) responses in leaf nitrogen to rates of nitrogen were recorded in the 3rd, 5th and 9th MAR. There were no clear patterns in the responses to nitrogen rates in this variety. For the mean, conflicting response patterns observed in the two varieties caused lack of response in leaf nitrogen to nitrogen rates in most months. Similar results had been observed in other studies in Florida (Muchovej and Newman, 2004a, 2004b), India (Madhuri *et al*., 2011), Ethiopia (Ambachew *et al*., 2012) and Kenya (Wawire *et al*., 2006). These results contrast with findings in India in which there was a striking rise in nitrogen levels in TVD plant tissues with increase in nitrogen fertilizer rates (Singh and Jha, 1994; Stranack and Miles, 2011; Ahmed *et al*., 2009). The variances could be attributed to differences in varieties used and differences in environmental conditions of growth. The results suggest that use of leaf nitrogen to predict deficiency in the nutrient may be less successful in Kenya, except when there is deficiency.

Effect of splitting nitrogen fertilizer on leaf nitrogen

The influence of splitting application of nitrogen fertilizer rates on leaf nitrogen of CO421 and D8484 are shown in Figure 3 and Tables 3-6.

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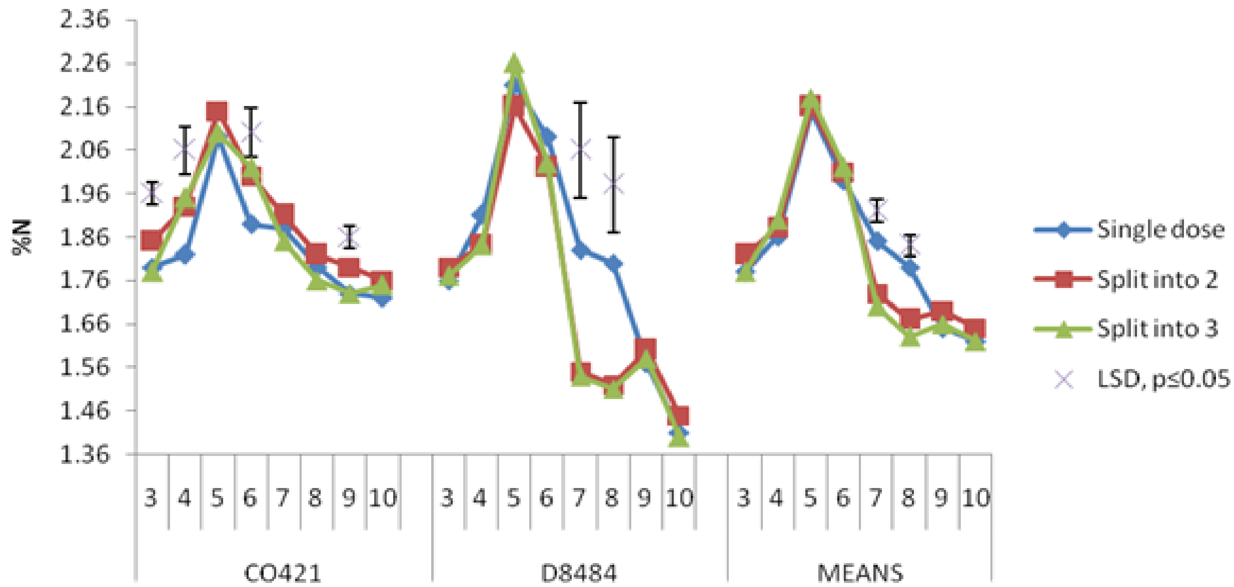

Figure 3 Effect of split applications of nitrogen fertilizer rates on leaf %N of CO421 and D8484

Sporadic significant ($p \leq 0.05$) effects were observed in the two varieties at some sampling dates (Figure 3). Except in CO421, generally splitting nitrogen application had no effect on leaf nitrogen levels. Results similar to these had been observed in other studies (Muchovej and Newman, 2004a, 2004b; Madhuri *et al.*, 2011; Wawire *et al.*, 2006). However these results, contrast with other findings (Stranack and Miles, 2011; Ahmed *et al.*, 2009) where splitting nitrogen application significantly ($p \leq 0.05$) increased leaf nitrogen levels throughout the study period. These results demonstrate that splitting nitrogen doses lead to a significant accumulation of the nutrient in the cane leaves. There was no clear pattern in the response of leaf nitrogen levels due to splitting the application.

Leaf phosphorus

Varietal effect on leaf P

The changes in leaf P levels due to varieties in different months are presented in Figure 4 and Tables 7-10. The leaf P only varied ($p \leq 0.05$) with time in 7th, 9th and 10th MAR.

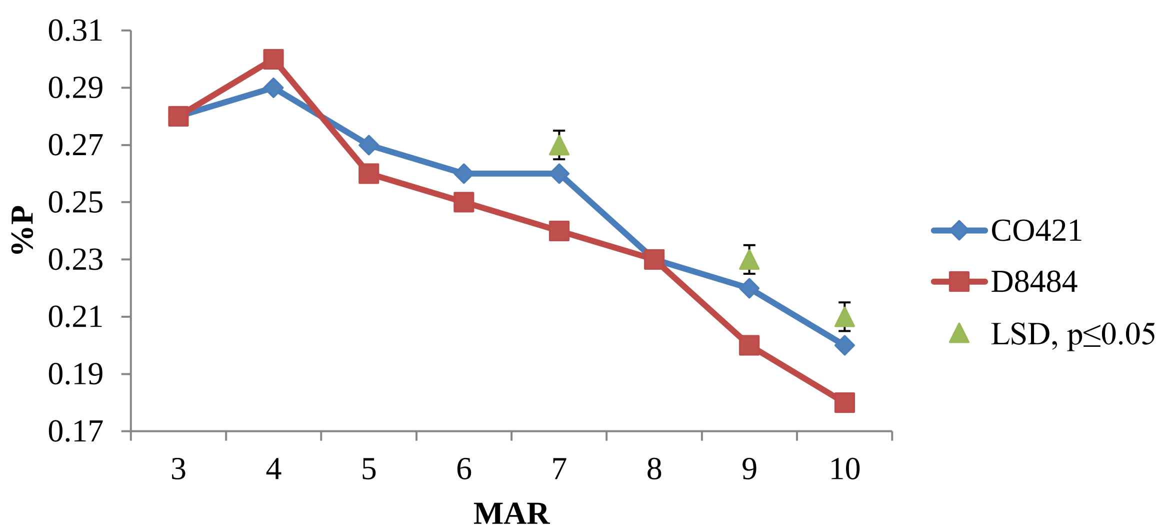

Figure 4 Comparison of leaf %P of CO421 and D8484 sugarcane varieties

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Although nutrients uptake generally change with varieties (Schroeder *et al*., 1993; Ambachew *et al*., 2012), there were no varietal differences in leaf P upto the 7 MAR. The results demonstrate that in use of leaf analysis to predict nutrient requirements, sampling should be done in the early stages of ratoon crop growth.

Table 7 Effect of rates and split applications of nitrogen fertilizer on %P at 3 MAR and 4 MAR

3 MAR							4 MAR					
Var	N Rate	N Split			Mean rate	Mean var	N Rate	N Split			Mean rate	Mean var
		S1	S2	S3				S1	S2	S3		
	0	0.30	0.28	0.26	0.28		0	0.29	0.29	0.28	0.29	
	60	0.27	0.28	0.27	0.27		60	0.28	0.29	0.29	0.29	
	120	0.28	0.28	0.30	0.29		120	0.28	0.30	0.28	0.29	
	180	0.27	0.28	0.27	028	0.28	180	0.31	0.28	0.30	0.30	0.29
CO421	Mean split	0.28	0.28	0.27			Mean split	0.29	0.29	0.29		
	CV%		9.56				CV%		7.66			
	LSD p≤0.05		0.003		0.01		LSD p≤0.05		NS		NS	
	0	0.28	0.28	0.31	0.29		0	0.32	0.31	0.30	0.31	
	60	0.30	0.27	0.26	0.28		60	0.30	0.29	0.30	0.30	
	120	0.30	0.25	0.26	0.27		120	0.32	0.29	0.30	0.30	
	180	0.26	0.29	0.27	0.27	0.28	180	0.31	0.31	0.27	0.30	0.30
D8484	Mean split	0.29	0.27	0.28			Mean split	0.31	0.30	0.30		
	CV%		11.92				CV%		8.88			
	LSD p≤0.05		0.003		0.01		LSD p≤0.05		NS		NS	
	0	0.29	0.28	0.29	0.28		0	0.30	0.30	0.29	0.30	
	60	0.29	0.28	0.27	0.28		60	0.29	0.29	0.30	0.29	
	120	0.29	0.27	0.28	0.28		120	0.30	0.29	0.31	0.29	
	180	0.27	0.29	0.27	0.27		180	0.31	0.29	0.28	0.30	
Overall Means	Mean split	0.28	0.28	0.27			Mean split	0.30	0.29	0.29		
	CV%		10.74				CV%		8.27			
	LSD p≤0.05		NS		0.01	NS	LSD p≤0.05		NS		NS	NS

Table 8 Effect of rates and split applications of nitrogen fertilizer on %P at 5 MAR and 6 MAR

5 MAR							6 MAR					
Var	N Rate	N Split			Mean rate	Mean var	N Rate	N Split			Mean rate	Mean var
		S1	S2	S3				S1	S2	S3		
	0	0.27	0.26	0.26	0.26		0	0.29	0.27	0.27	0.28	
	60	0.27	0.27	0.26	0.27		60	0.25	0.27	0.26	0.26	
	120	0.27	0.29	0.27	0.27		120	0.28	0.25	0.27	0.26	
	180	0.29	0.27	0.28	0.28	0.27	180	0.25	0.25	0.26	0.26	0.26
CO421	Mean split	0.27	0.27	0.27			Mean split	0.27	0.26	0.27		
	CV%		9.39				CV%		10.70			
	LSD p≤0.05		NS		NS		LSD p≤0.05		NS		0.01	
	0	0.28	0.26	0.26	0.26		0	0.27	0.27	0.24	0.26	
	60	0.25	0.23	0.25	0.25		60	0.25	0.23	0.24	0.24	
	120	0.27	0.25	0.26	0.26		120	0.28	0.23	0.25	0.25	
	180	0.26	0.27	0.25	0.26	0.26	180	0.28	0.25	0.21	0.25	
D8484	Mean split	0.26	0.25	0.25			Mean split	0.27	0.25	0.24		0.25

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	CV%		6.39				CV%		10.52			
	LSD p≤0.05		NS		NS		LSD p≤0.05		0.01		0.01	
	0	0.27	0.26	0.26	0.26		0	0.28	0.27	0.26	0.27	
	60	0.26	0.25	0.26	0.26		60	0.25	0.25	0.25	0.25	
	120	0.27	0.27	026	0.27		120	0.28	0.24	0.26	0.26	
	180	0.27	0.27	0.26	0.27		180	0.27	0.25	0.24	0.25	
Overall Means	Mean split	0.27	0.26	0.26			Mean split	0.27	0.25	0.25		
	CV%		7.89				CV%		10.61			
	LSD p≤0.05		NS		NS	NS	LSD p≤0.05		0.01		0.01	NS

Table 9 Effect of rates and split applications of nitrogen fertilizer on %P at 7 MAR and 8 MAR

7 MAR							8 MAR					
Var	N Rate	N Split			Mean rate	Mean var	N Rate	N Split			Mean rate	Mean var
		S1	S2	S3				S1	S2	S3		
	0	0.27	0.27	0.26	0.26		0	0.24	0.24	0.23	0.23	
	60	0.26	0.27	0.25	0.26		60	0.23	0.24	0.22	0.23	
	120	0.24	0.27	0.26	0.25		120	0.21	0.24	0.23	0.22	
	180	0.27	0.25	0.29	0.27		180	0.24	0.22	0.26	0.24	
CO421	Mean split	0.26	0.26	0.26		0.26	Mean split	0.23	0.23	0.23		0.23
	CV%		9.37				CV%		10.59			
	LSD p≤0.05		NS		0.01		LSD p≤0.05		NS		NS	
	0	0.25	0.24	0.25	0.25		0	0.24	0.23	0.24	0.24	
	60	0.24	0.23	0.24	0.24		60	0.23	0.22	0.23	0.23	
	120	0.23	0.23	0.23	0.23		120	0.22	0.22	0.22	0.22	
	180	0.22	0.22	0.26	0.23		180	0.21	0.21	0.25	0.22	
D8484	Mean split	0.24	0.23	0.24		0.24	Mean split	0.23	0.22	0.24		0.23
	CV%		8.41				CV%		8.73			
	LSD p≤0.05		NS		0.01		LSD p≤0.05		0.01		NS	
	0	0.26	0.25	0.26	0.26		0	0.24	0.23	0.24	0.24	
	60	0.25	0.25	0.24	0.25		60	0.23	0.23	0.22	0.23	
	120	0.24	0.25	0.25	0.24		120	0.22	0.23	0.23	0.22	
	180	0.24	0.23	0.27	0.25		180	0.22	0.21	0.25	0.23	
Overall Means	Mean split	0.25	0.25	0.25			Mean split	0.23	0.23	0.23		
	CV%		8.89				CV%		9.66			
	LSD p≤0.05		NS		0.01	0.01	LSD p≤0.05		NS		NS	NS

Table 10 Effect of rates and split applications of nitrogen fertilizer on %P at 9 MAR and 10 MAR

9 MAR							10 MAR					
Var	N Rate	N Split			Mean rate	Mean var	N Rate	N Split			Mean rate	Mean var
		S1	S2	S3				S1	S2	S3		
	0	0.25	0.23	0.23	0.24		0	0.21	0.20	0.21	0.21	
	60	0.21	0.23	0.22	0.22		60	0.18	0.18	0.20	0.19	
	120	0.24	0.21	0.23	0.22		120	0.20	0.18	0.20	0.19	
	180	0.21	0.21	0.22	0.22		180	0.21	0.18	0.21	0.20	
CO421	Mean split	0.23	0.22	0.23		0.22	Mean split	0.20	0.19	0.21		0.20
	CV%		11.07				CV%		16.89			

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	LSD p≤0.05		NS		0.006		LSD p≤0.05		0.01		0.01	
D8484	0	0.20	0.19	0.20	0.20	0.20	0	0.20	0.16	0.18	0.18	0.18
	60	0.19	0.20	0.21	0.20		60	0.17	0.21	0.16	0.18	
	120	0.22	0.18	0.21	0.20		120	0.17	0.19	0.21	0.19	
	180	0.24	017	0.21	0.20		180	0.17	0.16	0.20	0.18	
	Mean split	0.21	0.18	0.20			Mean split	0.18	0.18	0.19		
	CV%		16.47				CV%		14.25			
	LSD p≤0.05		0.003		NS		LSD p≤0.05		NS		NS	
Overall Means	0	0.23	0.21	0.22	0.22		0	0.21	0.18	0.20	0.20	
	60	0.20	0.21	0.22	0.21		60	0.18	0.20	0.18	0.19	
	120	0.23	0.19	0.22	0.21		120	0.19	0.18	0.21	0.19	
	180	0.23	0.19	0.22	0.21		180	0.19	0.17	0.21	0.19	
	Mean split	0.22	0.20	0.22			Mean split	0.19	0.18	0.20		
	CV%		13.77				CV%		15.57			
	LSD p≤0.05		0.01		NS	0.01	LSD p≤0.05		0.01		NS	0.01

Changes in leaf P due to N rates

The changes in leaf phosphorus due to rates of nitrogen are presented in Figure 5 and Tables 7-10. In both varieties and on the mean of varieties, significant (p≤0.05) variations were observed in leaf P due to rates of nitrogen. However, the order was sporadic and did not follow any pattern.

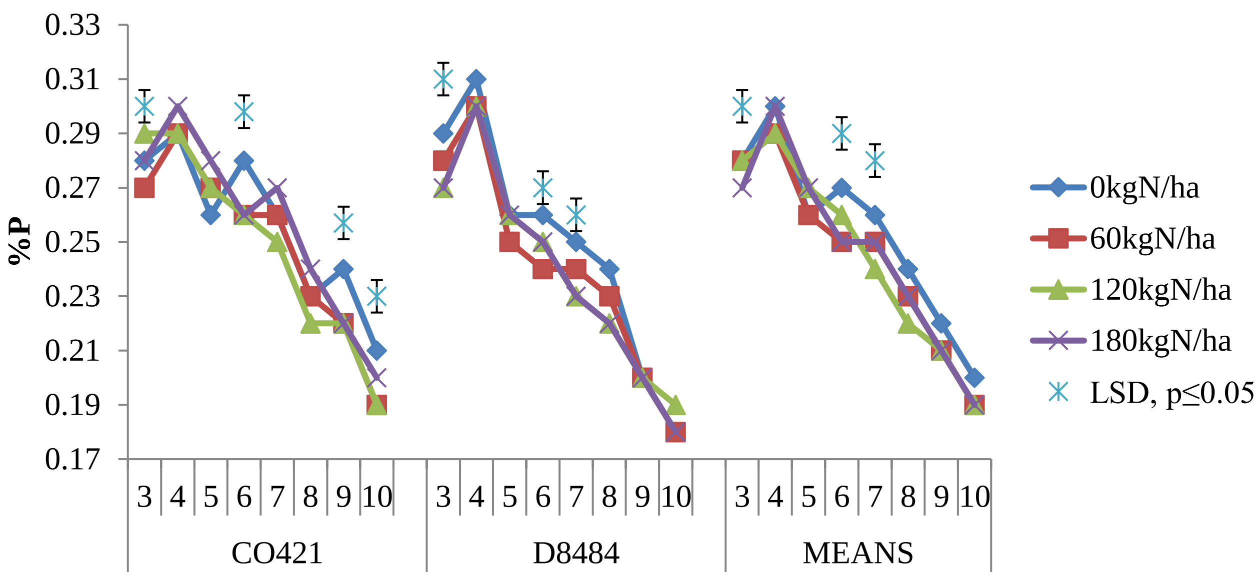

Figure 5 Effect of nitrogen fertilizer rates on leaf %P of CO421 and D8484

Peak leaf P levels were observed at the 4 MAR with the levels declining after this period. Similar results showing lack of a clear pattern (Muchovej and Newman, 2004a, 2004b; McCray and Mylavarapu, 2010; Ambachew *et al.*, 2012), and non-response of leaf P to rates of nitrogen had also been observed (Muchovej and Newman, 2004a, 2004b; Ambachew *et al.*, 2012) in other studies. In other studies using inorganic nitrogenous fertilizer (Madhuri *et al.*, 2011; Stranack and Miles, 2011), significant decrease in leaf P levels with the nitrogen fertilizer rates was observed. It can be concluded that leaf P levels decreased with the age of the plant at any rate of nitrogen fertilizer used and can be attributed to partitioning process in the sugarcane plant (Whittaker and Botha, 1997).

Effect split applications of nitrogen fertilizer rates on leaf %P

Figure 6 and Tables 7-10 indicate the results for the effect of split application nitrogen fertilizer rates on leaf %P of CO421 and D8484.

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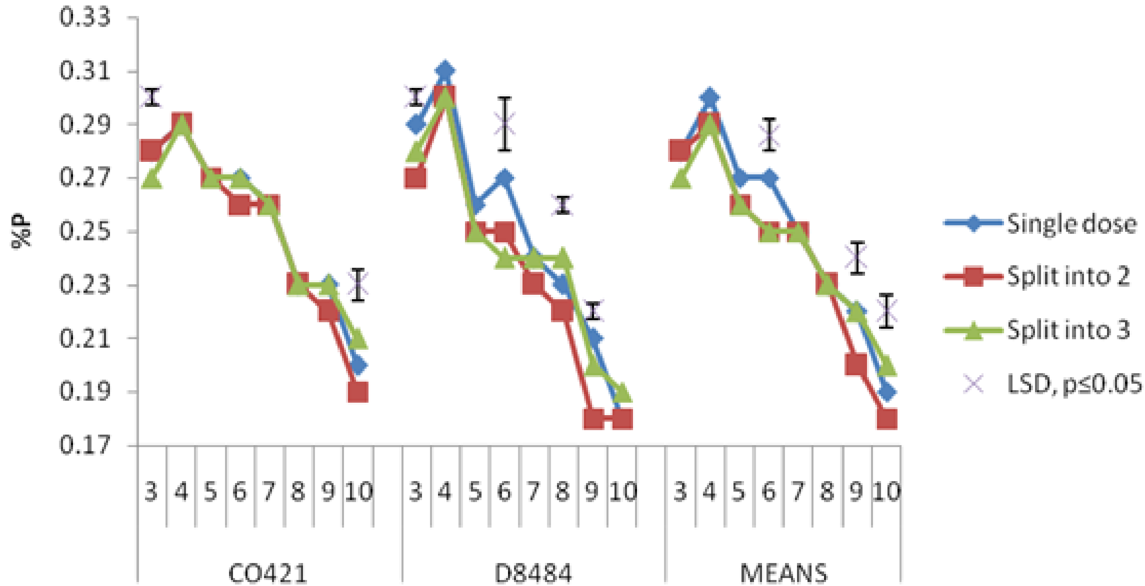

Figure 6 Effect of split applications of nitrogen fertilizer rates on leaf %P of CO421 and D8484

Generally, split application of nitrogen fertilizer rates (Figure 6 and Tables 7-10) only sporadically influenced leaf P levels. Similar outcome where irregular decline in leaf P levels with splitting nitrogen fertilizer over time had been observed in other studies in Florida (Muchovej and Newman, 2004a, 2004b) and Ethiopia (Ambachew *et al.*, 2012). Splitting nitrogen fertilizer application did not influence leaf phosphorus levels in predictable manner under Kenya sugarcane growing conditions.

Leaf %K

Variations in leaf %K due to varieties CO421 and D8484

The changes in leaf K levels with varieties are presented in Figure 7 and Tables 11-14. Except for the 7th and 10th MAR, there were significant (p≤0.05) differences in leaf K levels due to varieties in all other months.

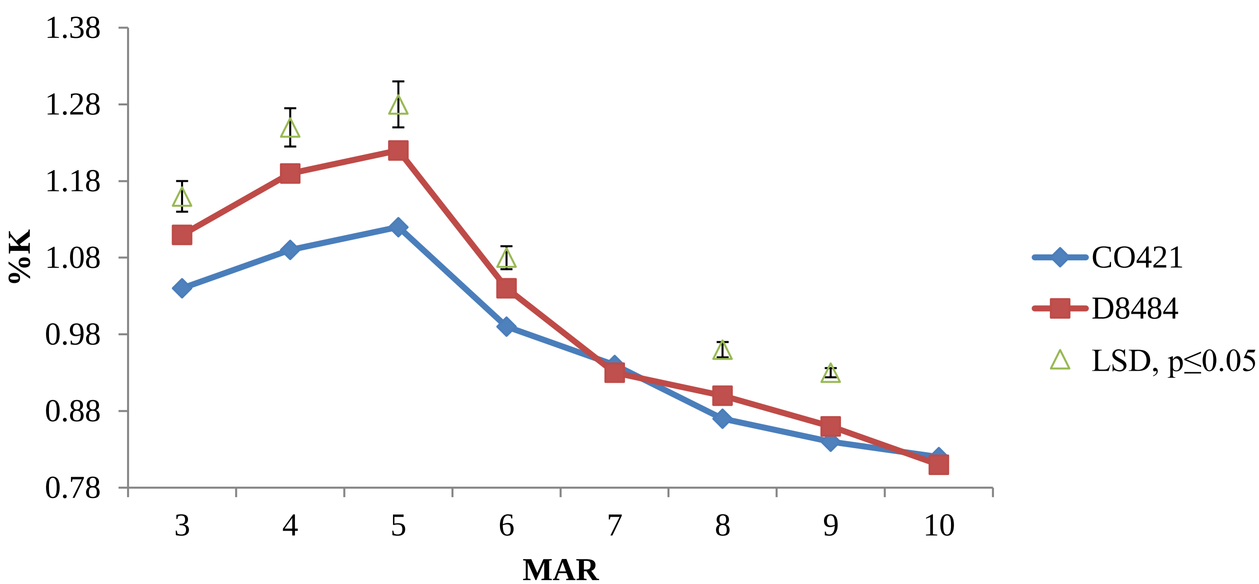

Figure 7 Variations in leaf %K due to varieties CO421 and D8484

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Peak leaf K levels were recorded at 5 MAR. The peak period observed was much later than those observed elsewhere (Wilkinson *et al*., 2000; Whitehead, 2000). Possibly this was due to variations in the environmental conditions of growth. It had been expected that an early maturing sugarcane variety like D8484 could show a peak at a different MAR from a late maturing variety like CO421. Generally D8484 had higher leaf K levels than CO421 in the early months. In a recent study (Ochola *et al*., 2014), yield response was observed in plant crop of new early maturing variety like D8484, but not CO421. The results presented herein demonstrate that indeed the early maturing D8484 is a more efficient absorber of K than old variety CO421. This may explain the observed yield difference (Ochola *et al*., 2014). The varieties manifested higher differences (Achieng', 2015) before 6th MAR. Sampling ages of 3 to 5 and 4 to 7 months were suggested as suitable in Queensland and New South Wales respectively (Schroeder *et al*., 1999) for leaf K diagnosis. The sampling time, therefore, varies with geographical area of production. The variation in leaf K levels with varieties is not unique. Schroeder *et al*. (1993) in South Africa and Ambachew *et al*. (2012) in Ethiopia had observed similar variations. Potassium is important to sugarcane as it regulates water and nutrients movement in the plant (Mengel and Kirby, 2001). There was general decline in leaf K level with age as had also been observed in other studies (Stranack and Miles, 2011). These results imply that unlike N and P, leaf sampling in the early months after ratooning may be problematic as the levels are varietal dependent. For such sampling, there will be need to set variety specific levels to guide advisory/fertilizer requirements guidelines.

Table 11 Effect of rates and split applications of nitrogen fertilizer on %K at 3 MAR and 4 MAR

3 MAR							4 MAR					
Var	N Rate	N Split			Mean rate	Mean var	N Rate	N Split			Mean rate	Mean var
		S1	S2	S3				S1	S2	S3		
	0	1.16	0.94	1.08	1.06		0	1.06	1.07	1.27	1.13	
	60	1.02	1.06	0.93	1.00		60	1.13	1.12	1.07	1.11	
	120	1.21	1.09	1.05	1.12		120	1.02	1.08	1.04	1.05	
	180	0.97	1.02	0.92	0.97	1.04	180	1.04	1.14	1.06	1.07	1.09
CO421	Mean split	1.09	1.03	0.99			Mean split	1.06	1.10	1.11		
	CV%		14.89				CV%		10.74			
	LSD p≤0.05		0.05		0.05		LSD p≤0.05		0.05		0.05	
	0	1.02	1.22	1.00	1.08		0	1.27	1.17	1.23	1.22	
	60	1.21	1.24	1.18	1.21		60	1.16	1.23	1.09	1.16	
	120	1.19	1.13	1.00	1.11		120	1.12	1.22	1.16	1.17	
	180	1.07	1.02	1.04	1.04	1.11	180	1.24	1.21	1.17	1.21	1.19
	Mean split	1.12	1.15	1.05			Mean split	1.20	1.21	1.16		
D8484	CV%		14.91				CV%		7.86			
	LSD p≤0.05		0.05		0.08		LSD p≤0.05		0.05		0.06	
	0	1.09	1.08	1.04	1.07		0	1.16	1.12	1.25	1.18	
	60	1.11	1.15	1.05	1.11		60	1.14	1.18	1.08	1.13	
	120	1.20	1.11	1.03	1.11		120	1.07	1.15	1.10	1.11	
	180	1.02	1.02	0.98	1.01		180	1.14	1.18	1.11	1.14	
Overall means	Mean split	1.11	1.09	1.02			Mean split	1.13	1.16	1.14		
	CV%		14.95				CV%		9.30			
	LSD p≤0.05		0.05		0.08	0.04	LSD p≤0.05		0.05		0.06	0.05

Table 12 Effect of rates and split applications of nitrogen fertilizer on %K at 5 MAR and 6 MAR

5 MAR							6 MAR					
Var	N Rate	N Split			Mean rate	Mean var	N Rate	N Split			Mean rate	Mean var
		S1	S2	S3				S1	S2	S3		
	0	1.06	1.09	1.30	1.15		0	0.97	1.01	1.03	1.00	

	60	1.14	1.18	1.06	1.13		60	0.99	0.95	1.01	0.98	
CO421	120	1.09	1.14	1.06	1.10	1.12	120	0.96	1.00	0.96	0.97	0.99
	180	1.07	1.15	1.14	1.12		180	1.01	1.05	0.93	1.00	
	Mean split	1.09	1.14	1.14			Mean split	0.98	1.00	0.99		
	CV%		12.87				CV%		6.98			
	LSD p≤0.05		0.02		0.02		LSD p≤0.05		NS		NS	
	0	1.26	1.19	1.24	1.23		0	1.09	0.99	1.09	1.06	
	60	1.21	1.17	1.19	1.19		60	1.07	1.03	0.97	1.02	
	120	1.18	1.23	1.17	1.19		120	0.96	1.08	1.01	1.02	
	180	1.22	1.31	1.19	1.25	1.22	180	1.09	1.04	1.02	1.05	1.04
D8484	Mean split	1.22	1.24	1.20			Mean split	1.05	1.03	1.02		
	CV%		16.29				CV%		6.21			
	LSD p≤0.05		0.02		0.02		LSD p≤0.05		NS		NS	
	0	1.16	1.14	1.27	1.19		0	1.03	1.00	1.06	1.03	
	60	1.18	1.12	1.18	1.16		60	1.03	0.99	0.99	1.00	
	120	1.13	1.19	1.12	1.15		120	0.96	1.04	0.99	0.99	
Overall means	180	1.14	1.20	1.22	1.19		180	1.05	1.04	0.98	1.02	
	Mean split	1.15	1.19	1.17			Mean split	1.02	1.02	1.00		
	CV%		14.58				CV%		6.59			
	LSD p≤0.05		0.02		0.03	0.06	LSD p≤0.05		NS		NS	0.03

Table 13 Effect of rates and split applications of nitrogen fertilizer on %K at 7 MAR and 8 MAR

7 MAR							8 MAR					
Var	N Rate	N Split			Mean rate	Mean var	N Rate	N Split			Mean rate	Mean var
		S1	S2	S3				S1	S2	S3		
	0	0.95	0.92	0.94	0.94		0	0.88	0.85	0.87	0.87	
	60	0.94	0.96	0.94	0.95		60	0.87	0.89	0.87	0.88	
	120	0.94	0.91	0.96	0.93	0.94	120	0.87	0.84	0.89	0.86	0.87
	180	0.94	0.90	0.98	0.94		180	0.87	0.83	0.91	0.87	
CO421	Mean split	0.94	0.92	0.96			Mean split	0.87	0.85	0.88		
	CV%		5.62				CV%		5.95			
	LSD p≤0.05		NS		NS		LSD p≤0.05		0.01		NS	
	0	0.93	0.94	0.95	0.94		0	0.90	0.91	0.92	0.91	
	60	0.90	0.94	0.93	0.92		60	0.87	0.91	0.90	0.89	
	120	0.89	0.91	0.94	0.91	0.93	120	0.86	0.88	0.91	0.88	0.90
	180	0.94	0.94	0.94	0.94		180	0.91	0.91	0.92	0.91	
D8484	Mean split	0.92	0.93	0.94			Mean split	0.89	0.90	0.91		
	CV%		4.52				CV%		4.63			
	LSD p≤0.05		NS		NS		LSD p≤0.05		NS		NS	
	0	0.94	0.93	0.94	0.94		0	0.89	0.88	0.90	0.89	
	60	0.92	0.95	0.94	0.94		60	0.87	0.90	0.88	0.88	
	120	0.92	0.91	0.95	0.92		120	0.87	0.86	0.90	0.87	
Overall means	180	0.94	0.92	0.96	0.94		180	0.89	0.87	0.91	0.89	
	Mean split	0.93	0.93	0.95			Mean split	0.88	0.88	0.89		
	CV%		5.07				CV%		5.29			
	LSD p≤0.05		NS		NS	NS	LSD p≤0.05		0.01		NS	0.02

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Table 14 Effect of rates and split applications of nitrogen fertilizer on %K at 9 MAR and 10 MAR

	9 MAR						10 MAR					
Var	N Rate	N Split			Mean rate	Mean var	N Rate	N Split			Mean rate	Mean var
		S1	S2	S3				S1	S2	S3		
	0	0.85	0.82	0.84	0.84		0	0.80	0.84	0.84	0.83	
	60	0.84	0.86	0.84	0.85	0.84	60	0.81	0.79	0.83	0.81	0.82
CO421	120	0.84	0.81	0.86	0.83		120	0.77	0.80	0.86	0.81	
	180	0.84	0.80	0.88	0.84		180	0.76	0.85	0.84	0.82	
	Mean split	0.84	0.82	0.86			Mean split	0.79	0.82	0.84		
	CV%		6.29				CV%		5.25			
	LSD p≤0.05		0.01		NS		LSD p≤0.05		0.01		NS	
	0	0.84	0.88	0.88	0.87		0	0.85	0.84	0.83	0.84	
	60	0.83	0.85	0.87	0.85	0.86	60	0.83	0.77	0.83	0.81	0.81
	120	0.88	0.88	0.85	0.87		120	0.82	0.86	0.83	0.84	
D8484	180	0.83	0.87	0.87	0.86		180	0.82	0.75	0.76	0.78	
	Mean split	0.85	0.87	0.87			Mean split	0.83	0.80	0.81		
	CV%		4.43				CV%		4.95			
	LSD p≤0.05		NS		NS		LSD p≤0.05		0.01		0.02	
	0	0.85	0.85	0.86	0.85		0	0.83	0.84	0.84	0.83	
	60	0.84	0.86	0.86	0.85		60	0.82	0.78	0.83	0.81	
Overall	120	0.86	0.84	0.86	0.85		120	0.80	0.83	0.84	0.82	
means	180	0.84	0.84	0.87	0.85		180	0.79	0.80	0.80	0.80	
	Mean split	0.84	0.85	0.86			Mean split	0.81	0.81	0.83		
	CV%		5.36				CV%		5.10			
	LSD p≤0.05		NS		NS	0.01	LSD p≤0.05		0.01		NS	NS

Effect of N rates on leaf %K

Variations in leaf K levels due to nitrogen rates in different sugarcane varieties are presented in Figure 8 and Tables 11-14. Significant ($p \leq 0.05$) variations were only observed from 3 to 5 MAR. Similarly, for the mean, the significant variations were observed in the 3rd, 4th and 5th MAR.

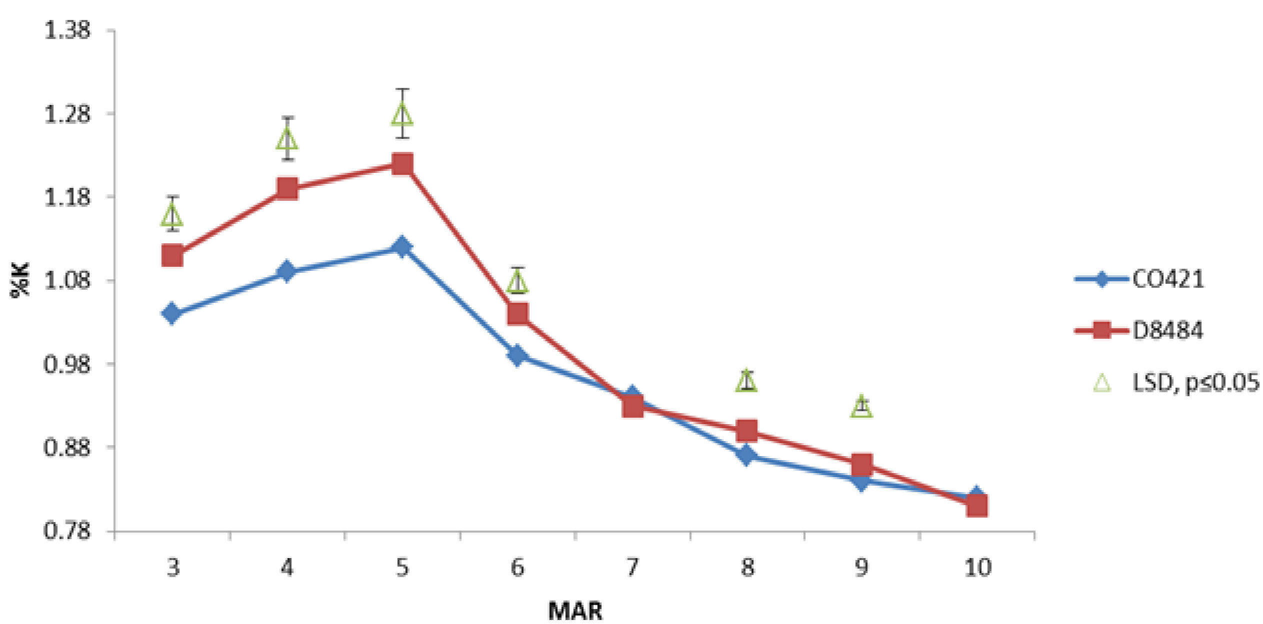

Figure 8 Effect of nitrogen fertilizer rates on leaf %K of CO421 and D8484

ISSN 2278–5469 EISSN 2278–5450 I OPEN ACCESS

Generally nitrogen rate of 0 and 120 kgN/ha caused decline in the leaf K levels. These results compare well with previous studies in Florida, South Africa and Pakistan (Muchovej and Newman, 2004a; 2004b; Stranack and Miles, 2011; Ahmed *et al*., 2009) where significant increase in leaf K levels was recorded in the early stages of the plant. However, the results are of variance with other studies in India (Singh and Jha, 1994; Madhuri *et al*., 2011) and Ethiopia (Ambachew *et al*., 2012) where there was no response of leaf K levels to nitrogenous fertilizer application. The results demonstrate that K levels in sugarcane are best tested for adequacy/deficiency within 5 MAR. In subsequent months, sugarcane leaf K levels in Kenya do not respond to nitrogenous fertilizer application. Results presented here demonstrate that both peaking time and response to nitrogen were not influenced by nitrogen fertilizer application. Furthermore, optimal leaf sampling time for K levels diagnosis is independent of variety under Kenya sugarcane growing conditions. Thus, sampling for foliar K levels analysis can be done within 5 MAR where both varieties did respond to the nitrogen rates.

Responses in leaf K levels due to splitting N rates

Although there were significant (p≤0.05) responses in leaf K levels due to splitting nitrogen fertilizer application especially in the early MAR (Figure 9 and Tables 11-14) in both varieties and means, the responses appeared to be sporadic.

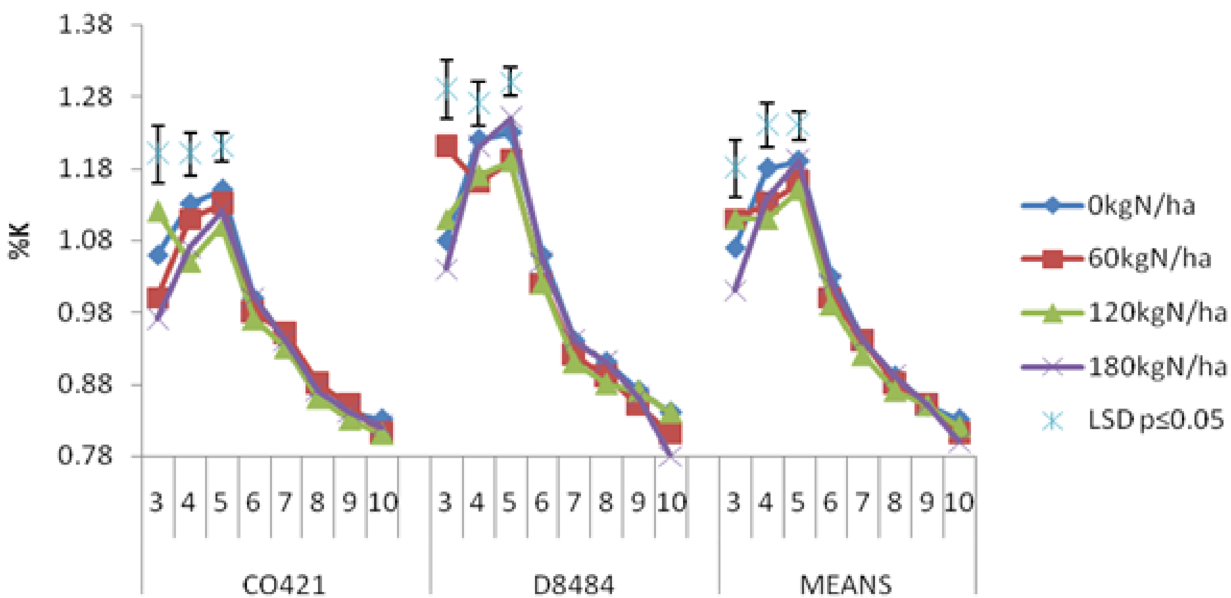

Figure 9 Effect of split applications of nitrogen fertilizer rates on leaf %K of CO421 and D8484

However, the pattern was clearer in D8484 from 3rd to 5th MAR (Figure 9) in which leaf K was higher where nitrogen had been split into two. It is important to note that during the period of response, the plant had only received the first dose for both split into two and split into three treatments. Application of other doses later in the 6th and/or 9th MAR caused significant (p≤0.05) responses of K levels in the leaf with K levels rising due to the late applications. Similar findings had been observed in other studies in South Africa (Muchovej and Newman, 2004a, 2004b). However, other researchers (Wilkinson *et al*., 2000; Whitehead 2000) showed significant (p≤0.05) response of leaf K levels due to splitting nitrogen application where there was a regular increase in K levels from 3rd to 5th and a decrease from 5th to 10th MAR.

Acknowledgement

We thank Sugar Research Institute formerly Foundation (KESREF) and National Council for Science and Technology (NCST) for financial support.

ISSN 2278–5469 EISSN 2278–5450 I OPEN ACCESS

APPENDICES

Appendix 1: Details of replications showing randomization at the 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	V_2	5 R_1S_2	6 R_2S_2	7 R_3S_2	8 R_4S_2	V_1	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		9 R_1S_3	10 R_2S_3	11 R_3S_3	12 R_4S_4		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
V_2	17 R_1S_2	18 R_2S_2	19 R_3S_2	20 R_4S_2	V_1	17 R_1S_2	18 R_2S_2	19 R_3S_2	20 R_4S_2	V_2	17 R_1S_2	18 R_2S_2	19 R_3S_2	20 R_4S_2
	21 R_1S_3	22 R_2S_3	23 R_3S_3	24 R_4S_4		21 R_1S_3	22 R_2S_3	23 R_3S_3	24 R_4S_4		21 R_1S_3	22 R_2S_3	23 R_3S_3	24 R_4S_4

50.4 m

120.0 m

Funding

This study has received external funding from Sugar Research Institute formerly Foundation (KESREF) and National Council for Science and Technology (NCST).

Conflicts of interests

The authors declare that there are no conflicts of interests.

Data and materials availability

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

REFERENCES AND NOTES

1. Achieng', G.O. (2015). MSc. Thesis "Effects of rates and split applications of nitrogen fertilizer on soil and leaf nutrients levels, quality and harvesting age of ratoon crop of two sugarcane varieties in western Kenya" in the Chemistry department, School of Biological and Physical Sciences, Maseno University, pp 193.
2. Ahmed, M.A.; Ferweez, H.; Saher, M.A. (2009). The optimum yield and quality properties of sugarcane under different organic, nitrogen and potassium fertilizers levels. *Journal of Agricultural Research, Kafer El-Sheikh University*, 35(3):879-896.
3. Akhtar, M.M.; Ehsan, M.A.; Bashir, K.; Rafiq, S.C. (2000). Agronomic Characters, Productivity and Nutrient Content of Sugarcane (*Saccharum Officinarum* L.) Affected by Nitrogen. *Pakistan Journal of Biological Sciences*, 3(11):1877-1879.
4. Ali A, Zafar M, Rahman A.U, Gill A, Ismail S, Mushtaq F, Ali M.A, Hadi A, Zafar M.M. (2019). Impacts of soil amendments practices on growth and yield attributes of spring planted sugarcane under water deficit conditions. *Discovery*, 55(277), 8-19
5. Ambachew, D.; Abiy, F.; Zeleke, T. (2012). Correlation of Foliar Nutrient Status with Yield of Sugarcane Varieties at Different Crop Stages and Nitrogen Levels at Wonji-Shoa and Finchaa Sugarcane Plantations of Ethiopia. *Ethiopian Journal of Applied Science and Technology*, 3(1):9-22.

6. Bouwman, A.F.; Bouwmans, L.J.M.; Batjes, N.H. (2002). Emissions of N_2O and NO from fertilized fields-summary of available measurement data. *Global Biogeochemical Cycles,* 16:1050
7. Breaux, R.D. (1972). Selecting commercial sugarcane varieties from large seedling and clonal populations. *Journal of American Society of Sugar Cane Technology*, 2:60-61.
8. BSES (1991). Bureau of Sugar Experiment Station. The standard laboratory manual for Australian sugar mills, *Analytical Methods and Tables,* Vol. 2, Brisbane, Australia.
9. Dalal, R.C. and Meyer, R.J. (1986). Long term trends in fertility of soils under continuous cultivation and cereal cropping in Southern Queensland. I. Overall changes in soil properties and trends in winter cereal yields. *Australian Journal of Soil Research,* 36:873-881.
10. Das, D. K. (2000). Micronutrients: Their Behaviour in Soils and Plants. Kalyani Publishers, New Delhi-110002. 14-07-2013.
11. Duhan, B.S.; Singh, M. (2002). Effect of green manuring and nitrogen on yield and uptake of micronutrients by rice. *Journal of the Indian Society of Soil Science,* 50(1):178-180.
12. Eickhout, B.; Bouwman, A.F.; van Zeijts, H. (2006). The role of nitrogen in world food production and environmental sustainability. *Agricultural Ecosystem Environment,* 116:4-14.
13. Ezenwa, I.V.; Mc Cray, J.M.; Newman, P.R.; Rice, R.W. (2005). Sugarcane leaf tissue sample preparation for diagnostic analysis. *Macmillian/CTA, United Kingdom.*
14. Gana, A.K. (2008). Determination of optimal rate of nitrogen for chewing sugarcane production in the Southern Guinea Savanna of Nigeria. *Sugarcane Technology*, 10:278-279.
15. Gascho, G.J. (1983). The effect of nitrogen rate on four sugarcane varieties grown on sandy soil.
16. Gascho, G.J.; Elwali, A.M.O. (1979). Tissue testing of Florida sugarcane. *Sugarcane Journal*, 42:15-16.
17. GOK (2009). Kenya Gazette Notice No 2070., Government Printer, Nairobi.
18. Hunsigi, G. (1993). Production of sugarcane, Theory and Practice. *Springer-Verlag,* NewYork, pp19-23.
19. Jaetzold, R.; Schmidt, H.; Hornetz, B.; Shisanya, C. (2005). Natural Conditions and Farm Management Information, Part A. West Kenya, Subpart A1 (2nd Ed.): Western province in: Farm Management Handbook of Kenya Vol. II. Ministry of Agriculture. Nairobi.
20. Jarrell, W.M.; Beverly, R.B. (1981). The dilution effect in plant nutrition studies. *Advance Agronomy Journal,* 34:197-224.
21. *Journal of American Society of Sugar Cane Technology,* 2:84.
22. Keating, B.A.; Robertson, M. J.; Muchow, R.C.; Huth, N.I. (1999). Modelling sugarcane production systems I. Development and performance of the sugarcane module. *Field Crops Research,* 61:253-271.
23. KESREF (2010). Kenya Sugar Research Foundation. Strategic Plan 2009-2014.
24. KESREF (2010). Kenya Sugar Research Foundation. Sugarcane Growers' Guide.
25. KSB (2010-2014). Kenya Sugar Board. Enhancing Industry competitiveness: Kenya Sugar Industry Strategic Plan, 2010-2014, Kenya Sugar Board, Nairobi.
26. Kumar, M.D.; Channabasappa, K.S.; Patil, S.G. (1996). Effect of integrated application of pressmud and paddy husk with fertilizer on yield and quality of sugarcane (*Saccharum officinarum* L.). *Indian Journal of Agronomy,* 41:301-305.
27. Lingle, S.E.; Wiedenfeld, R.P.; Irvine, J.E. (2000). Sugarcane response to saline irrigation water. *Journal of Plant Nutrition,* 23:469-486.
28. Madhuri, N.K.V; Hemanth Kumar, M.; Subba Rao, M.; Sarala, N.V.; Giridhar, V. (2011). Response of promising mid-late maturing sugarcane varieties to different doses of nitrogen fertilizer. *Journal of Sugarcane Research*, 1(1):49-54.
29. Malavolta, E. (1994). Fertilizing for high yield sugarcane. *International Potash Institute. Basel.*
30. Mandal, K.G.; Baral, U.; Padhi, J.; Majhi, P.; Chakraborty, H.; Kumar, A. (2012) Effects of cropping on soil properties and organic carbon stock in Deras region, India. *Regional Environmental Change,* 12:899-912.
31. McCray, J.M.; Mylavarapu, R. (2010). Sugarcane nutrient management using leaf analysis. Florida Cooperative Extension Service Pub.SS-AGR-335. 16-08-2014.
32. Mengel, K.; Kirkby, E.A. (1981). Principles of Plant Nutrition. Published by International
33. Meyer, J.H.; Wood, R.A.; Harding, R.L. (1989). Fertility trends in the South African sugar industry. *Proceedings of South African Sugarcane Technology Association,* 63:159-163.
34. Muchovej, R.M.; Newman, P.R. (2004a). Nitrogen fertilization of sugarcane on a sandy soil II soil and groundwater analyses. *Journal of American Society of Sugarcane Technologists,* 24:225-240.
35. Muchovej, R.M.; Newman, P.R. (2004b). Nitrogen fertilization of sugarcane on a sandy soil: Yield and leaf nutrient composition. *Journal of American Society of Sugarcane Technologists,* 24:210-224.
36. Ochola, P.; Owuor, P.O.; Abayo, G.; Manguro, L.O.A. (2014). Yields and growth parameters responses of different sugarcane varieties to nitrogen and potash fertilizers in Nyando Sugar Belt, Kenya. *East Africa Agriculture and Forestry Journal*, 80(4):363-273
37. Okalebo, J.R.; Gathua, K.W.; Woomer, P.L. (2002). Laboratory Methods of Soil and Plant Analysis: A Working Manual. 2nd Edition. TSBF-CIAT and SACRED Africa, Nairobi, Kenya, 2002. pp128.
38. Othieno, C.O. (1988). Summary of Recommendations and Observations from TRFK. *Tea*, 9(2):50-65.

39. Plaut, Z.; Meinzer, F.C.; Federman, E. (2000). Leaf development, transpiration and ion uptake and distribution in sugarcane cultivars grown under salinity. *Plant Soil*, 218:59-69.
40. Potash Institute, 3rd Edition, Worblaufen-Bern/Switzerland.
41. Rice, R.W.; Gilbert, R.A.; Lentini, R.S. (2002). Nutritional requirements for Florida sugarcane. *Florida Cooperative Extension Service Pub.*SS-AGR-228
42. Sadej, W.; Przekwas, K. (2008). Fluctuations of nitrogen levels in soil profile under conditions of a long-term fertilization experiment. *Plant and Soil Environment*, 54(5):197-203
43. Schroeder, B.L.; Wood, A.W; Kingston, G.; Meyer, J.H.; Barnard, R.O. (1999). Leaf analysis-What does it offer the Australian sugar industry? *Poceedings of Australian Society of Sugar Cane Technology*, 21:122-130.
44. Schroeder, B.L.; Wood, R.A.; Meyer, J.H. (1993). Foliar analysis in the South African sugar industry for diagnostic and nutrient trend purposes. In N.J. Barrow (ed.). Plant nutrition from genetic engineering to field practice: 299-302. Kluwer Academic Publishers, Dordrecht, The Netherlands.
45. Singh, K.D.; Jha, B.K. (1994). Transformation and availability of applied potassium to sugar cane in Calciorthent. *Journal Indian Society of Soil & Science*, 42(1):72-76.
46. Snyder, C.S.; Bruulsema, T.W. (2007). Nutrient use efficiency and effectiveness in North America: Indices of agronomic and environmental benefits. *International Plant Nutrition Institute. Ref. No.07076.*
47. Sreewarome, A.; Seansupo, S.; Prammanee, P.; Weerathworn, P. (2007). Effect of rate and split application of nitrogen on agronomic characteristics, cane yield and juice quality. *Proceedings of International Society of Sugar Cane Technology*, 26:465-469.
48. Stranack, R.A.; Miles, N. (2011). Nitrogen nutrition of sugarcane on an alluvial soil on the Kwazulu-Natal North Coast: effects on yield and leaf nutrient concentrations. *Proceedings of the South African Sugar Technologists Association*, 84:198-209.
49. Walker, T.W.; Kingery, W.L.; Street, J.E.; Cox, M.S.; Gerard, P.D.; Oldham, J.L. (2007). Soil chemical properties and rice yield response to nitrogen rate and timing after precision leveling. Online Crop Management doi:10.1094/CM-2007-0119-02-RS. 12-03-2014.
50. Wawire, N.W.; Kahora, F.W.; Wachira, P.M.; Kipruto, K.B. (2006). Technology adoption study in Kenya sugar industry. *Kenya Sugar Research Foundation, Technical Bulletin*, 1:51-77.
51. Whitehead, D.C. (2000). *Nutrient Elements in Grassland*. Soil-Plant-Animal Relationships. CABI Publishing, Cambridge. 369 pp.
52. Whittaker, A.; Botha, F. C. (1997). Carbon partitioning during sucrose accumulation in sugarcane internodaltissue. *Plant Physiology*, 115:1651-1659.
53. Wiedenfeld, R. (1997). Sugarcane responses to N fertilizer application on clay soil. *Journal American Society of Sugarcane Technology*, 17:14-27.
54. Wilkinson, S.R.; Grunes, D.L.; Sumner, M.E. (2000). Nutrient interactions in soil and plant nutrition. In: ME Sumner (Ed) *Handbook of Soil Science*, CRC Press, New York. pp D89-D112.

ISSN 2278–5469 EISSN 2278–5450 I OPEN ACCESS