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Abstract

Low sugarcane yields in Muhoroni sugar zone are due to low soil phosphorus, aggravated by lack of P replenishment and continuous growing of single dominant variety. The on-farm study, was conducted at Fort-ternan and Kaitui on a Chronic Vertisol and Humic Cambisol respectively, evaluated the effect of P rates (0, 40, 80 and 120kg P_2O_5 ha^{-1}) and response of three sugarcane varieties in terms of growth, yield and quality attributes for plant cane crop. The sites are located in Kericho District and are under Muhoroni sugar zone. Variety CO617 and N14 were check crops in Fort-ternan and Kaitui respectively while KEN83-737 and KEN82-808 were test crops. The trial was laid out as a RCBD of two factor, variety and P rate involving 12 treatments. The varieties responded positively to application of P in of Kaitui, moderate in soil P and medium acidity unlike Fort-ternan where there was adequate soil P and near neutral soil pH. Sugarcane varieties performed differently in both sites with KEN83-737 was superior to CO617, N14 and KEN82-808. Application of P increased yield compared to the control (0kg P_2O_5 ha^{-1}). The highest yield was recorded when P applied was 80kg P_2O_5 ha^{-1}, the trend being 80>40>120>0kg P_2O_5 ha^{-1}. It was concluded that P nutrition and suitable variety for a given area is essential for increased yield in plant cane harvest. KEN83-737 and 80kg P_2O_5 ha^{-1} are recommended for increased yield of plant cane harvest in the study sites. The study shows that soil testing is critical in assessing soil fertility for judicious fertilizer use recommendation.

Key words: Phosphorus, Rates, Sugarcane, Yield, On-farm

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Introduction

Sugarcane is a crop of great agro-economic importance in the Muhoroni sugar zone. Sugarcane cultivation is undertaken by Muhoroni Sugar Company in the nucleus estate and also by local farmers as outgrowers. Sugarcane contributed by the miller companies is about 10% while 90% is from the outgrower farmers (Wawire *et al*., 2006a). The harvested cane is delivered to Muhoroni Sugar Company for processing into sugar and co-products (KSB, 2003; Wawire *et al*., 2006a). The current sugar status in Kenya is deficit at about 200,000tons annually which has to be met through importation (KSB, 2006). There has also been increased interest in co-product utilization as value addition in sugarcane – sugar chain. This has fuelled demand for sugarcane by Muhoroni Sugar Company, leading to increased area under cane especially in out-growers land. The area under cane increased from 9,073ha in 1994 to 13,196ha in 2005 (KSB, 2006). However, this has not translated to increased cane but a declined yield has been recorded.

Some of the causal factors to declined yields are declined levels of essential plant nutrients such as phosphorus in the soil and also growing of single cane variety such as CO617, introduced in the 1970's (Wawire *et al*., 2006b). The depleted or low plant nutrients in the soil are aggravated by lack of or inadequate fertilizer application. Phosphorus role in cane is to stimulate early root formation and development. Phosphorus deficiency leads to reduced metabolic rate and photosynthesis which then leads to reduced cane yield and quality (Blackburn, 1984; Anderson and Bowen, 1990). Therefore, to replenish plant nutrients especially, phosphorus in the soil, it is imperative to apply P fertilizers to supplement nutrients taken up by cane so as to increase and sustain yield (Anderson and Bowen, 1990; Malavolta, 1994). Since the fertilizers are costly, judicious application is paramount and therefore the rate of application needs to be determined which takes into consideration the soil conditions of a given area and the suitable varieties recommended for the particular areas.

The current rate of P application has been largely a blanket recommendation where the humid conditions receive 80-90kg P_2O_5 ha^{-1} while sub humid receive 40-60kg P_2O_5 ha^{-1}. These rates were based on studies conducted in the 1970's where few introduced varieties were available. To date, more locally released varieties such as KEN82-808, KEN83-737 high in vigor, yields and quality have been developed and availed for commercial production in the industry (KESREF, 2002a).

Considering the importance of P nutrition in sugarcane performance and availability of high yielding locally released varieties, the present study was undertaken to determine the appropriate P rate and the response of some locally released sugarcane varieties.

Materials and Methods

The field experiment was established on farm at Fort-ternan and Kaitui, Kericho district. Fort-ternan is located in agro-ecological zone, UM 2-3, marginal coffee zone. The soil at Fort-ternan is classified as Chromic Vertisol according to FAO soil classification system (FAO, 1988). The top soil is dark grey, sandy clay loam to cracking clay and perfectly drained (MoA-NARL, 1987). These soils are near neutral pH, adequate in P, Ca, Mg and low in Mn (Table 1).

Kaitui is located in agro-ecological zone, LM 2, marginal sugarcane zone. The soil at Kaitui on-farm site is classified as Humic Cambisol. The top soil is dark reddish brown, gravelly clay, moderately deep and well drained. These soils are medium acid, moderate in P and Mn and low in Ca/Mg (Table 1).

The experiment was established as a Randomized Complete Block Design (RCBD) with two factors involving 12 treatments and two replications. The 12 treatments were a factorial combination of three varieties and four rates of phosphorus as 0, 40, 80 and 120kg P_2O_5 ha^{-1}.

Table 1: Some soil chemical properties of the experimental site

	On-farm site	Fort-ternan		Kaitui	
	Soil depth (cms)	Levels	Description*	Levels	Description*
Soil pH	0 – 15	6.4	Slight acid	5.9	Medium acid
	15 – 30	6.7	Near neutral	5.9	Medium acid
Available P (mg/kg)	0 – 15	563	High	16	Moderate
	15 – 30	566	High	15.5	Moderate
Exchangeable cations (cmol(+)/kg)					
Mn	0 – 15	0.15	Low	0.69	Moderate
	15 – 30	0.15	Low	0.68	Moderate
Ca	0 – 15	52.4	Very high	25	Very high
	15 – 30	51.4	Very high	23.5	Very high
Mg	0 – 15	Trace	Low	18.3	Very high
	15 – 30	Trace	Low	20	Very high
Ca/Mg	0 – 15	52.4	High	1.37	Low
	15 – 30	51.4	High	1.18	Low

* (Euroconsult, 1989; Landon, 1991; Okalebo, *et al*., 2002)

The three sugarcane varieties for each site were CO617, KEN83-737 and KEN82-808 used at Fort-ternan while N14, KEN83-737 and KEN82-808 at Kaitui site. The gross plots measured 10 m x 1.2 m x 6 rows or 72 m^2 while the net plots measured 10 m x 1.2 m x 4 rows or 48 m^2 excluding the two outer rows (guard rows). Certified seed cane was planted on 20th April 2005 at Fort-ternan site and 21st April 2005 at Kaitui site. Phosphorus treatments using single super phosphate (SSP) fertilizer was applied at the time of planting in the planting furrows. Nitrogen fertilizer (urea) was applied at a uniform rate of 100kg N ha^{-1} in all experimental units. It was top dressed when the cane was 3 and

6months after Planting (MAP) in two equal splits. Weed control and other management practices were undertaken as recommended by Kenya Sugar Research Foundation(KESREF, 2002b).

Growth attributes, germination and tiller count were recorded twice each in both sites. Germination count in Fort-ternan was on 25th May 2005 (34days after planting - DAP) and 16th June 2005 (56DAP) while in Kaitui this was done on 31st May 2005 (40DAP) and 22nd July 2005 (62DAP). Tiller count in Fort-ternan was on 20th December 2005 (8months after planting - MAP) and 19th January 2006 (9MAP) while in Kaitui site was on 21st December2005 (8MAP) and 20th January2006 (9MAP). Plant cane harvest was undertaken on October 2006 (19MAP). Data collected at harvest were yield attributes; number of stalks (population), stalk height (m), cane yield (TCH). Quality attributes were cane juice quality with respect to brix percent juice, pol percent juice and purity.

The data were analysed statistically using Fisher's Analysis of Variance (ANOVA) technique and treatment means were compared using the least significance difference test at $P \leq 0.05$ P as described by (Gomez and Gomez, 1984).

Results and Discussion

Effect of P rates on sugarcane growth attributes for plant crop cycle

The varieties differed significantly in terms of germination and tiller counts in Fort-ternan (Table 2) and Kaitui (Table 3) sites. Phosphorus treatments significantly influenced germination and tiller count in both sites however positive effect of P application was not observed in Fort-ternan as control (0kg P_2O_5 ha^{-1}) plots gave high readings compared to P applied plots (Table 2).

Sugarcane variety CO617 showed high germination followed by KEN83-737 and KEN82-808. However KEN83-737 developed more tillers followed by CO617 and KEN82-808 in Fort-ternan (Table 2). Results in Kaitui showed KEN83-737 was more superior to N14 and KEN82-808 both in germination and tiller count (Table 3). These results support those reported by Sreewarome *et al.*, (2005) who recorded significant response among varieties upon phosphorus application.

Table 2: Effect of phosphorus rates on sugarcane germination, tiller counts and yield attributes for plant crop cycle at Fort-ternan

	Germination count		**Tiller count**		**No. of stalks per ha (Population)**	**Stalk height (m)**	**Cane yield (TCH)**
	34DAP	56DAP	8MAP	9MAP	19MAP	19MAP	19MAP
Variety							
CO617	125[a]	225[a]	861[a]	879[ab]	95 417	2.8[a]	106.8
KEN83-737	71[b]	146[b]	803[ab]	885[a]	106 042	2.9[a]	105
KEN82-808	91[b]	169[b]	766[b]	796[b]	96 042	2.4[b]	89.5
LSD $_{(P \leq 0.05)}$	*	*	*	*	Ns	*	Ns
P Rates (kg P_2O_5 ha^{-1})							
0	107[a]	192[a]	804[b]	849	95 417	2.68	95.7
40	68[b]	143[b]	748[b]	819	105 208	2.7	104.4
80	94[ab]	183[ab]	884[a]	903	103 125	2.82	101.8
120	113[a]	202[a]	804[b]	842	92 917	2.77	99.8
LSD $_{(P \leq 0.05)}$	*	*	*	Ns	Ns	Ns	Ns
CV (%)	27.22	19	7.59	9.39	15.26	7.17	19.96
R^2	0.62	0.66	0.6	0.4	0.24	0.62	0.25

Any two means not sharing a common letter differ significantly at $P \leq 0.05$

DAP: Days after planting; MAP: Months after planting; *: Significantly different at $P \leq 0.05$

Ns: Not significantly different

Table 3: Effect of phosphorus rates on sugarcane germination, tiller counts and yield attributes for plant crop cycle at Kaitui

	Germination Count		**Tiller count**		**No. of stalks per ha (Population)**	**Stalk height (m)**	**Cane yield (TCH)**
	40DAP	62DAP	8MAP	9MAP	19MAP	19MAP	19MAP
Variety							
N14	35[b]	59[c]	349[b]	414[c]	33 750[c]	2.6[b]	38.3[b]
KEN83-737	59[a]	159[a]	676[a]	699[a]	73 958[a]	3.2[a]	75.4[a]
KEN82-808	45[ab]	104[b]	593[a]	563[b]	51 250[b]	2.6[b]	58.3[ab]
LSD $_{(P \leq 0.05)}$	*	*	*	*	*	*	*
P Rates (kg P_2O_5 ha^{-1})							
0	35	91[b]	507	523	41 667[b]	2.7	43.7[b]
40	49	108[a]	536	557	51 042[ab]	2.8	57.5[ab]
80	52	111[a]	538	555	65 000[a]	2.8	71.5[a]
120	51	121[a]	575	599	54 167[ab]	2.8	56.6[ab]
LSD $_{(P \leq 0.05)}$	Ns	*	Ns	Ns	80.42	Ns	*
CV (%)	29.86	12.13	22.14	18.37	25.91	10.99	37.16
R^2	0.5	0.93	0.72	0.67	0.76	0.57	0.63

Any two means not sharing a common letter differ significantly at $P \leq 0.05$

DAP: Days after planting; MAP: Months after planting; *: Significantly different at $P \leq 0.05$

Ns: Not significantly different

Results in Kaitui site showed positive effect of P application as significant effect was recorded in germination count (62DAP). Although statistically similar, germination and tillering in P applied plots were high compared to control (0kg P_2O_5 ha^{-1}) (Table 3). The positive response of cane to P application in Kaitui site is attributed to the moderate levels of P and medium acid soil conditions (Table 1).

Effect of P rates on sugarcane yield attributes for plant crop harvest

The records on yield parameters varied between the sites with high values recorded in Fort-ternan site (Table 2) than in Kaitui site (Table 3). The varieties significantly differed among each other in terms of all the yield parameters at Kaitui site unlike Fort-ternan site where only stalk height varied significantly (Table 2).

Variety KEN83-737 was superior to CO617, N14 and KEN82-808 in all the yield parameters at Kaitui site and also in stalk height at Fort-ternan. Cane yield of 75.4TCH was the highest recorded for KEN83-737 while the lowest 38.3TCH recorded for N 14 at Kaitui site. Although statistically similar, stalk population for KEN83-737 in Fort-ternan was high at 106, 042 number of stalks per ha. The cane yield recorded of 105.0TCH was comparable to CO617 yield of 106.8TCH.

Sugarcane at Fort-ternan (Table 2) showed no significant difference in yield parameters among treatments upon P application unlike Kaitui site where significant difference was recorded. P application had a positive effect on population and yield (TCH) as P applied treatments recorded high values compared to the control (0 kg $P_2O_5ha^{-1}$) (Table 3). P application rate of 80kg P_2O_5 ha^{-1} recorded the highest population and yield at 65, 000stalks per ha and 71.5TCH respectively while the lowest was recorded in control (0kg P_2O_5 ha^{-1}) the trend being 80>40>120>0kg P_2O_5 ha^{-1}.

These results are similar to those reported by (Rahman *et al*., 1992; Perez and Melgar, 1998; Sreewarome *et al*., 2005; Omollo and Abayo, 2007). They observed enhanced stalk number upon phosphorus application.

The positive response to phosphorus application in Kaitui site is attributed to the moderate levels of P, medium acid soil conditions unlike Fort-ternan site where P was adequate and near neutral soil condition. The superiority of KEN83-737 to other varieties tested suggests suitability of the variety to the agro – ecological conditions of Fort-ternan and Kaitui sites.

Effect of P rates on sugarcane quality attributes for plant crop harvest

There was no significant difference in terms of the quality attributes among the cane varieties (Table 4). P application also had no influence on quality attributes.

Table 4: Effect of P rates on sugarcane quality attributes for plant cane harvest at Fort-ternan

	Brix % juice	Pol % juice	Purity
Variety			
CO617	17.48	13.44	77.04
KEN83-737	18.3	14.67	80.21
KEN82-808	17.26	13.33	77.18
LSD $_{(P \leq 0.05)}$	Ns	Ns	Ns
P Rates (kg P_2O_5 ha^{-1})			
0	17.88	14.39	80.47
40	17	12.87	75.68
80	17.8	13.87	77.97
120	18.05	14.09	78.62
LSD $_{(P \leq 0.05)}$	Ns	Ns	Ns
CV (%)	5.63	11.56	7.84
R^2	0.52	0.28	0.25

Any two means not sharing a common letter differ significantly at $P \leq 0.05$

Ns: Not significantly different

This suggests the quality attributes are inherent attributes of the varieties and can not be altered by application of nutrients such as P. These results are similar to those observed by (Omollo and Abayo, 2007).

Conclusions

Sugarcane varieties respond differently in terms of growth and yield attributes in a given agro-ecological environment and soil conditions. Variety KEN83-737 was superior in performance to KEN82-808 and N14 and compared well to CO617 at Fort-ternan and Kaitui site.

Soil conditions in terms of pH and available nutrients have an effect on the response of applied P for sugarcane performance. Cane grown in Kaitui site responded positively to P applied compared to those grown in Fort-ternan. Soils of Kaitui are medium acidic, moderate P and low Ca/Mg while those in Fort-ternan are near alkaline and adequate in P.

Application of P enhances sugarcane nutrition which then leads to increased yields. Application rate of 80kg P_2O_5 ha^{-1} recorded highest yield and population of millable stalks in both sites while lowest yield was recorded in no P (0 $kgP_2O_5ha^{-1}$). Application of P did not influence the quality attributes in the Fort-ternan site.

Recommendations

In view of the results, it is recommended;

1. Soil tests to determine the soil condition in terms of pH and available nutrients is paramount before planting. Therefore soil conditions adequate in available nutrients do not require P application.
2. Choice of variety suitable for a given area is essential so as to optimize the benefits of the variety suitability. KEN 83-837 is suitable for the conditions in Fort-ternan and Kaitui.
3. Sugarcane nutrition plays a positive role in increased yield. It is therefore necessary to undertake studies of other essential nutrients N, K and Si and their interaction for increased sugarcane yield.
4. The results are based on plant cane harvest and therefore follow up of the ratoon performance is necessary.

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