Awakening to reality
Available online at www.elixirpublishers.com (Elixir International Journal)
Agriculture
Elixir Agriculture 67 (2014) 21669-21675
Elixir ISSN: 2229-712X

Effects of N and K fertilization of sugarcane *(Saccharum oficinarum)* on acrisols in western Kenya

Mutonyi, J[1,4], Shibairo S.I[2], Chemining'wa, G.N[2], Olubayo, F.O[2], Nyongesa, H.W[3] and Konje, M. M[3]
[1]Mumias Sugar Company Limited, Department of Agriculture, P.O. Private Bag 50137, Mumias.
[2]University of Nairobi, College of Agriculture & Veterinary Sciences, Department of Plant Science and Crop Protection, P.O Box 29053-00625, Kangemi.
[3]Masinde Muliro University of Science and Technology, P.O. Box 190-50100, Kakamega.

ARTICLE INFO
Article history:
Received: 4 December 2013;
Received in revised form:
1 February 2014;
Accepted: 11 February 2014;

Keywords
Sugarcane,
Potassium,
Nitrogen,
Acrisols,
Variety CO 945.

ABSTRACT
Sugarcane fertilization in Kenyan plantations is largely concentrated on Nitrogen and Phosphorus. Use of Potassium, secondary nutrients and micronutrients is altogether missing. Recent soil analysis results indicate that soils in the Mumias Sugar zone of western Kenya that accounts for 50-60 % of national production are K- deficient. In examining the quality factor in sugarcane payment systems as envisaged in recent legislation, adoption of balanced nutrition by inclusion of K would help improve sugar cane productivity and enhance sugar recovery. This paper reports the effect of K, N and their interaction on sugarcane yield and juice quality on acrisols. Four experiments were established in several locations from 2009-2011. The treatments included a factorial combination of four rates of K at 0, 60, 120 and 180 kg/ha K_2O and four rates of N at 0, 46, 92 and 138 kg/ha N. Recommended basal phosphate was included in every plot at 92 kg/ha P_2O_5. Each experiment was harvested after 18 months of growth. Results showed significant responses to K and N. Agronomic efficiency was higher in plots supplied with K along with N. Nitrogen and K_2O application rates that produced optimum cane yields were: N = 46kg/ha and K_2O = 60 kg/ha; however, economically profitable rates were N = 46-92 kg/ha and K_2O at 60 kg/ha. Productivity gains did not offset costs when rates were higher than 120 kg/ha of K_2O and 138 kg/ha of N. The results imply that the inclusion of K in the sugar cane fertilization regime at Mumias will be beneficial. An initial rate of 60kg/ha K_2O (2 bags of 50 kg muriate of potash is recommended on soils with K-deficiency. There were strong indications that with K fertilization the current N recommendation of 120 – 150 kg N/ha could be reduced to only 78-92 kg/ha due to better N utilization from the interaction with K.

Introduction

A major challenge facing the sugar industry in Kenya is declining crop yields over the last two decades. Sugar production in the year 2012 totaled 502,563 metric tons (Mt) against 741,152 Mt required for consumption creating a deficit of 238,589 Mt that was met by importation (KSB, 2012). The sugar deficit was caused by among other factors, low cane yields with fluctuating quality in virtually all sugarcane growing zones. In the Mumias Sugar Zone of Western Kenya that contributes 50-60 % of national sugar production, mean sugarcane yields declined from a high of 110 tons/ha in 1996 to a low of only 55 t/ha in 2012 (Figure 1). Average Pol in cane was 11.16% compared with the industry target of 13.50 % (KSB, 2012).

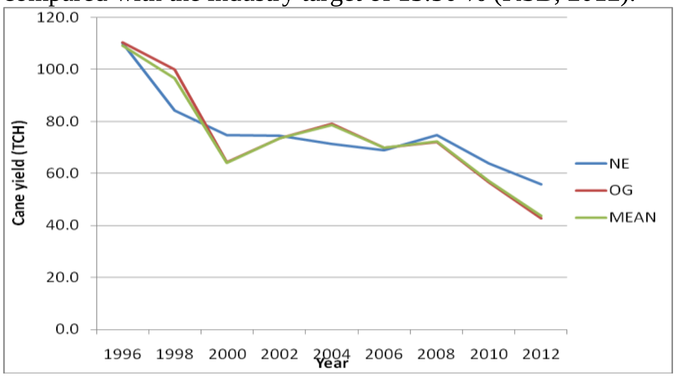

Figure 1: Average sugarcane yields in MSZ (1996-2012)

NE – Nucleus Estate (miller owned); OG- Out growers (farmer owned)

The sugarcane production practices in the Mumias sugar zone (MSZ) are thought to have led to serious deterioration of the soil physical and chemical quality parameters which appears to be the main contributory factor to the sharp yield decline over the years. Growing of sugarcane on the same land is a common practice with no well defined breaks, rotations or fallow periods between the previous crop and re-plant (Wawire *et al.*, 2007). Sugarcane fertilization in the plantations is largely concentrated on nitrogen (N) and phosphorus (P) with N and P sources being Urea and DAP respectively. The current recommendation for sugarcane is 120-150 kg/ha N and 80-95 kg/ha P_2O_5. Balanced nutrition through use of potassium (K), secondary nutrients and micronutrients is altogether missing as K was thought to be adequate in the soils (Wawire *et al.*, 2007). However, recent laboratory analysis results indicate that soils in MSZ are characterized by low pH ($\leq$ 5.5), low P ($\leq$ 10 ppm), low to moderate K (0.1-0.7 m.e), low Ca and Mg (1-2 m.e.) and low CEC (< 9 m.e.) (MSC, 2012).

Sugarcane is capable of rapidly depleting soil of nutrients, particularly potassium. In South Africa, for instance, the aerial parts of an adequately fertilized 12 months old rain fed plant cane crop have been reported to contain 214 kg K ha–1 (Wood, 1990). Under irrigation, a cane crop of similar age and variety may remove as much as 790 kg K ha–1. In the Histosols of

Tele:
E-mail addresses: konjemartha@gmail.com

Florida, an average of 343 kg K ha–1 was removed from the field at harvest of the sugarcane (Coale *et al.*,1993). In Mauritius, more than 250 kg K ha–1 was recovered by sugarcane from soils high in available K even when no K was applied (Cavalot *et al.*,1990). In Australia the average kg K ha–1 in the aboveground biomass of a crop of 84 tonnes cane ha–1 was 198 kg K ha–1 (Chapman, 1996). It is thus clear that for the long term and sustainable use of sugarcane lands, the removal of such large quantities of K needs to be balanced by adequate K inputs if a decline in soil fertility is to be avoided – hence the importance of K manuring in sugarcane cultivation (Ng Kee Kwong, 1994).

Jaetzold *et al*. (2005) reported low and declining soil fertility in the densely populated Western Kenya with deficiencies of N, P and K wide spread leading to low and declining crop yields. Krauss (2004) reported that K depleted soils have in-efficient N fertilizer use even if recommended doses are applied. Potassium plays a key role in N metabolism, and plants inadequately supplied with K fail to transport nitrate efficiently to the shoots (Krauss, 2004). Yadav *et al*. (2009) observed that adoption of balanced and judicious use of all nutrients can help improve cane productivity and enhance sugar recovery by enhancing resistance against biotic and abiotic stresses, and better synthesis and storage of sugar. Gupta and Shukla (1973) observed that K and N need to be in balance; that while N responses can be small, use of K alongside N ensures better yields of cane. Yara (2011) have observed that it is important to have sufficient potassium available to utilize the assimilated nitrogen in the cane to bring about good crop maturity. Kolln *et al*. (2013) observed that increases in soil K content increased sugarcane productivity in Brazil. In S.E Asia, Haerdter and Fairhurst (2003) reported a 16% N recovery when traditional N and P were applied to maize. The crop's N recovery improved to 76% in plots treated with N, P and K as K is involved in N metabolism. Phosphorous and K recoveries also improved respectively from 1 to 22 % in P and from 13 to 61 % in balanced N, P and K application.

Nitrogen is essential in sugarcane metabolism affecting essential physiological processes. It is one of the main building blocks of proteins and essential for photosynthesis and sugar production (MSIRI, 2000). Correct N nutrition not only increases cane yield, but also improves the sucrose content in the harvested cane. However, excessive N use can reduce sugar quality, leading to lower sucrose contents and discolouration of sugar crystals (Meyer and Wood, 2001). This response to N rate varies with variety. It is important though to balance N use with K, so as to maximize sugar conversion, content and juice quality (Meyer and Wood, 2001). In Australia's dry sunny region of Burkedin, N application significantly raised yields compared to other rain fed regions. However, used in excess, N prolonged vegetative growth, delaying maturity and ripening. Late N also reduced sugar quality characteristics, including sugar purity, colour and clarification (Yara, 2011).

In examining the quality factor in sugarcane payment systems, K and N fertilization become a key consideration because they affect yield and sucrose accumulation. Potassium is not included in the current fertilizer regime at Mumias. Whether K can improve sugarcane quality (high sucrose content) is an aspect that warrants investigation and documentation. The objective of this study, therefore, was to determine the effects of K, N and their interaction on sugarcane growth, yield and quality.

Materials and methods

Four experiments were conducted in 2009-2011 in different locations on the miller owned Nucleus estate (NE) and out growers (OG) fields of the Mumias sugar zone (0^o21'N and 34^o 30'E at 1314 m above sea level). The zone receives bi-modal rainfall ranging from 1500-2000 mm per annum with long rains peaking in April-May and short rains in September-October each year. The dominant soil type in the zone is orthic Acrisol (60%) followed by Ferralsol, Nitosol, Cambisol and Planosol (40%) (Jaetzold et. al.,2005). According to Jaetzold et. al., 2005), acrisols are acidic soils with low base status; they are strongly leached and are rich in Aluminum (Al) and Iron (Fe) Oxide elements that are responsible for nutrient fixation at low pH thus making the nutrients unavailable to plants. This is an aspect that demands special crop management practices in sugarcane grown on these soils.

The soil chemical and physical characteristics are shown in Tables 1 and 2 below. All experiments assessed the plant crop data over 18 months growth period in two seasons. The experimental design was RCBD with a 4×4 factorial arrangement of the treatments and three replications. Treatments included four rates of K (0, 60, 120 and 180 kg/ha K_2O) and four rates of N (0, 46, 92 and 138 kg/ha N). Fertilizers Urea (46 % N) and Muriate of potash MOP (60 % KCl) were used as N and K source respectively. Recommended basal P at 92 kg/ha P_2O_5 was supplied from single superphosphate (SSP) in plots where no N was applied or diammonium phosphate (DAP) where N was applied at 46, 92 or 138 kg/ha N. The rate of N applicable was adjusted based on the content in DAP. Gross plot size was 1.5 m x 6 rows x 10 m = 90 m^2 in NE and 1.2 m x 6 rows x 10 m = 72 m^2 in OG based on the standard practice for spacing in the two sectors. The net plot size for data collection was 1.5 m x 4 rows x 10 m= 60 m^2 in NE and 1.2 m x 4 rows x 10 m= 48 m^2 in OG. Other necessary agronomic practices like weed management, top dressing with N, pest and disease observation were carried out as per (KESREF, 2002) recommendations. Predominantly grown sugarcane variety CO 945 was used in the study as a test crop. Variety CO 945 is a medium maturing sugarcane cultivar harvested between 17 and 20 months. Apparent sucrose content at maturity is estimated at 12-14 % with fibre at 15-18 % (Jagathesan *et al*.,1990).

Data was collected on sugarcane emergence and tillering, foliar N, P and K content, stalk number, height and inter-node length, cane yield, sugar yield, juice quality and fibre %, diseases and pests. Agronomic efficiency (AE) and economic evaluation was also done. The data collected were subjected to analysis of variance using GenStat Release 13.2 (PC/Windows 7) Copyright 2010, VSN International Limited and means compared by Fischer's Least Significant Difference (LSD) procedure at 5 % level of significance (Steel and Torrie, 1987).

Results and Discussion

Cane yield, juice quality, sugar yield, agronomic efficiency and economic evalution results are presented in Tables 3-7 and illustrated in Figures 2-5 for sugarcane yield.

Sugarcane yield

Application of K and N significantly increased sugarcane yields. It was also evident that with K application, the rate of N applied could be reduced to modest levels of 46-92 kg/ha N. This finding appeared to confirm that K plays a key role in N metabolism, and that plants inadequately supplied with K fail to transport nitrate efficiently to the shoots (Krauss, 2004). It also agreed with several others studies. Kolln *et al*. (2013) observed that increases in soil K content increased sugarcane productivity in Brazil. In S.E Asia, Haerdter and Fairhurst (2003) reported a

16% N recovery when traditional N and P were applied to maize. The crop's N recovery improved to 76% in plots treated with N, P and K as K is involved in N metabolism. Phosphorous and K recoveries also improved respectively from 1 to 22 % in P and from 13 to 61 % in balanced N, P and K application. Gupta and Shukla (1973) observed that K and N need to be in balance; that while N responses can be small, use of K alongside N ensures better yields of cane. Similarly, Yara (2011) observed that it is important to have sufficient potassium available to utilize the assimilated nitrogen in the cane to bring about good crop maturity. Prasad *et al.* (1996), on the other hand, found in a sandy loam calcareous soil of North Bihar that cane yield was increased from 50 t ha–1 without K fertilization to 74.5 t ha–1 with only 60 kg K ha–1. At 11 locations in Sao Paulo State of Brazil, Korndorfer (1990) indicated that raising application of K to 150 kg K ha–1 progressively increased cane yield. Rabindra *et al.* (1993) demonstrated that sugarcane grown continuously from 1971 on a red sandy loam soil at Karnataka in India gave cane yield of 63 t ha–1 in 1971 with and without fertilizers, but in 1988 while the cane yield with N alone (250 kg N ha–1) was 30-34 t ha–1, application of NPK with K at 125 kg K ha–1 gave cane yield of 130-136 t ha–1.

However, the results of this study did not agree with those of others. In South Africa, spectacular cane and sugar yield response to K has been reported where K was not previously applied (Meyer, 2013 pers. comm.). In India Lakholine *et al.* (1979) showed in a 3-year study under Vidarbha conditions in India that there was no response K applied at 50-100 kg K ha–1. Similarly Olalla *et al.* (1986) showed that at 0-300 kg K ha–1, there were no differences in cane and sugar yields at Malaga during the first 2 years of K fertilizer use and during the next 2 years when K fertilization was withheld. Sachan *et al.* (1993) also observed that plant cane crop did not respond to fertilizer K application while the first ratoon crop only did so slightly in a mollisol of Uttar Pradesh. Paneque *et al.* (1992) in Brazil reported that neither plant cane nor the first ratoon responded to K but cane yields increased by 23 and 39 t ha–1 at the end of the second and third ratoons, respectively. Yang and Chen (1991) reported that only 33% of the sites studied in Fiji showed a response to K fertilization.

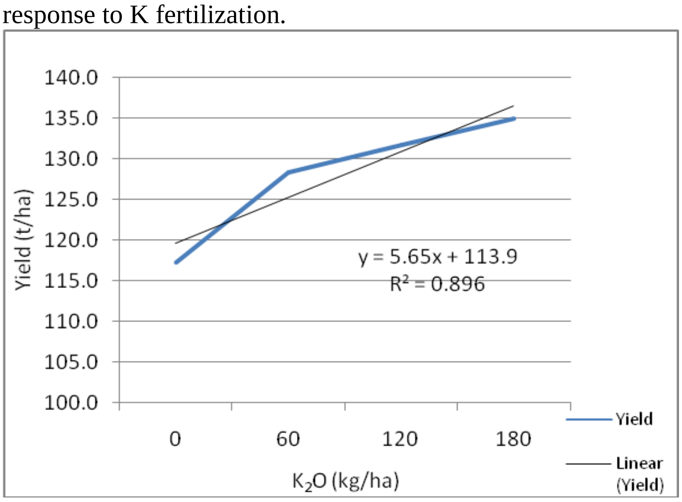

Figure 2: Effect of K on sugarcane yield in NE

Sugar yield, juice quality and fibre % cane

Sugar yield per hectare generally increased with K and N application (Table 4). However, yield due to K application was attributed to improved juice quality (Pol % cane) since K is known to promote sugar synthesis and its translocation to the storage tissue. The improvement in juice quality is thought to be due to an increase in activity of sucrose synthesizing enzymes which also help increase the sucrose yield (Kumar *et al.*, 2002).

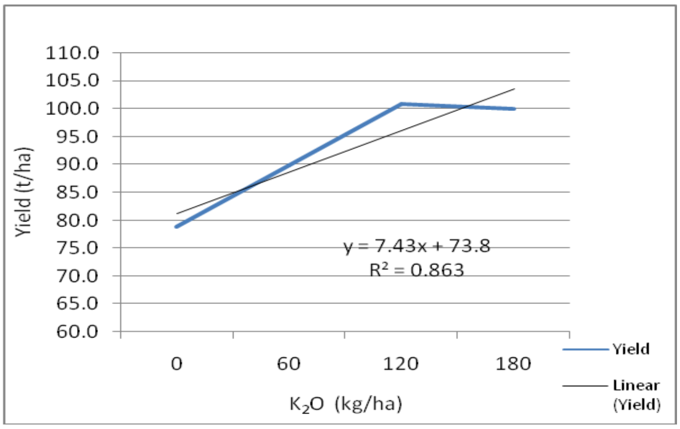

Figure 3: Effect of K on sugarcane yield in OG

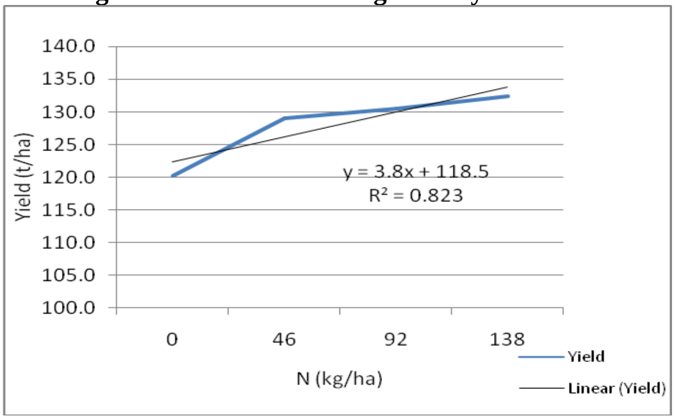

Figure 4: Effect of Non sugarcane yield in NE

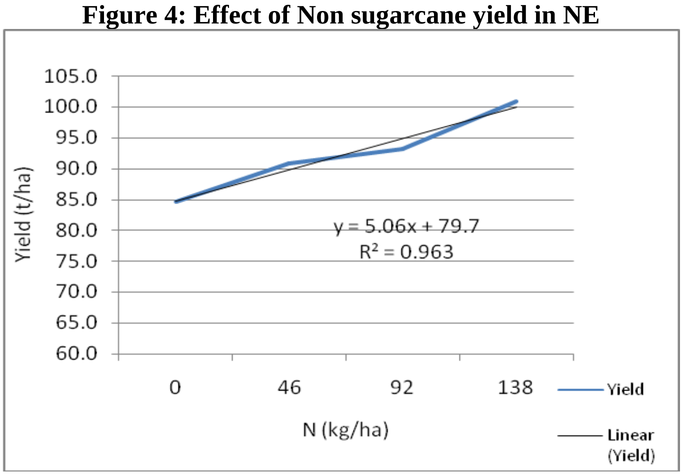

Figure 5: Effect of N on sugarcane yield in OG

Application of N resulted in higher cane yields hence the high overall sugar yield per ha recorded. A significant drop in juice quality was noted with N application at 138 kg/ha in the absence of K or with K application at 60 kg/ha K_2O (Table 5), confirming that excess N application is detrimental to sugarcane juice quality. Fibre % cane was variable with slightly lower levels indicated at higher levels of K application. However, this was considered to be highly a varietal characteristic.

The results of this study agreed with those of Phonde *et al*. (2005) who observed that adequate K supply ensured higher sugar yields and those of Malavolta (1994); Mahamuni *et al.* (1975) and Khosa (2002) showing that K improved juice quality (Pol) and reduced fibre content. In addition, it agreed with those of Yara (2011) who observed that it is important to have sufficient K available to utilize the assimilated N in the cane to bring about good crop maturity and ensure that reducing sugars are converted to sucrose. However, the results were contrary to those of (Perez and Melgar, 2002; Watanabe *et al*., 2013) suggesting that very high levels of K reduced sucrose levels and those by Kawamitsu *et al.* (1997) which showed that K had a highly negative correlation with sucrose contents in the juice of sugarcane in Japan. Results of this study also agreed with the observation that correct N nutrition not only increases cane yield, but also improves the sucrose content in the harvested cane. However, used in excess, N prolongs vegetative growth, delaying maturity and ripening (Meyer and Wood, 2001). Late N also reduced sugar quality characteristics, including sugar purity, colour and clarification (Yara, 2011).

Agronomic efficiency (AE)

In both the NE and OG experiments, highest agronomic efficiencies were obtained with K fertilization at 60-120 kg/ha K_2O and N application at 46-92 kg/ha N. The AEs were greater in plots supplied with K along with N. These results agreed with those of studies from Utta Pradesh, India (Singh *et al*., 2008) which showed that AE was greater in plots with balanced supply of K, S, and Mg along with N and P. The concomitant increase in N use efficiency due to P, K, S and Mg application was in the range of 364 to 557 kg cane/kg nutrient. The increase in efficiency of the individual nutrient was 1,652 to 2,532 kg cane with P_2O5, 692 to 906 kg cane/kg K_2O, 1,615 to 1,857 kg cane/kg S, and 3,687 to 3,713 kg cane/kg Mg. Other studies on sesame (*Sesamum indicum*) in Mubi Region, Adamawa State, Nigeria indicated that balanced nutrition with N, P and K application led to increased dry matter and seed yields. The inclusion of K was desired for balanced nutrition (Shehu *et al*., 2010). These results, therefore, are in agreement with those by Gupta and Shukla (1973) who observed that K and N need to be in balance; that while N responses can be small, use of K alongside N ensures better yields of cane.

Economic Evaluation

Value cost ratios (VCRs) followed the same pattern for AEs where the highest were generally recorded with K application at 60 kg/ha K_2O and N at 46 kg/ha. VCRs were higher on the NE compared with OG due to the higher yields recorded. This finding established the need to invest in fertilizer K as muriate of potash with initial rate of 2 bags (60 kg/ha K_2O).

The current fertilizer regime at Mumias costs Ksh 27,428 per ha. With inclusion of K at 60 kg/ha K_2O this cost would escalate by 25.5% to Ksh 34,428 per ha. However, the increased returns per ha would offset the costs and give profit to the growers. Under the circumstances, application of K at 60 kg/ha K_2O would be feasible for a start and a reduction in the bags/ha Urea necessary to balance the costs to the growers.

Conclusion and Recommendation

The results of this study establish the significance of balanced fertilization with K for higher cane yield, higher sugar yield and higher farmer profit with sugarcane. Although year to year weather and location specific soil fertility variability as well as sugarcane variety greatly influence yield and nutrient use efficiency, this can be minimized through fertilizer best management practices. It is recommended that K be included in the fertilization regime at Mumias initially at 60kg/ha K_2O (2 bags of 50 kg muriate of potash). There were strong indications that with K fertilization the current N recommendation of 120 – 150 kg N/ha could be reduced to only 78-92 kg/ha due to better N utilization from the interaction with K.

Acknowledgement

Professor Solomon I. Shibairo, Dr. George N. Chemining'wa and Prof. Florence M. Olubayo of the University of Nairobi for guiding me through proposal development, project phase and final writing of my PhD thesis. Dr Humphrey W. Nyongesa and Dr. Martha Konje of Masinde Muliro University for editing the manuscript. Mr. Peter Wachira Maina, Ms Risper Amolo and Ms Carolyne Kirungu of Kenya Sugar Research Foundation for scientific literature and data analysis. Mumias sugar company management for permission to carry out the study in the sugarcane zone and for enormous resource input to the project. Kenya sugar board management for the valuable global and national sugar statistics.

References

Bureau of Sugar Experiment Stations (BSES Ltd) 1994. Australian Sugarcane Nutrition Manual. Ed. DV Calcino, CSIRO Davies Laboratory, PMB Aitkenvale, Townsville, QLD 4814, Australia

Cavalot PC, Deville J and Ng Kee Kwong, KF 1990. Potassium fertilization of sugarcane in relation to its availability in soils of Mauritius. *Revue Agricole et Sucrière, Ile Maurice* 69:30-39.

Chapman LS 1996. Australian sugar industry by-products recycle plant nutrients. *In* : Downstream effects of land use (Ed. Hunter, H.M., Eyles, A.G. and Rayment, G.E.). Queensland Department of National Resources, Queensland, Australia.

Coale FJ, Sanchez CA, Izuno FT and Bottcher AB 1993. Nutrient accumulation and removal by sugarcane grown on Everglades Histosols. *Agronomy Journal* 85: 310-315.

Gupta AP and Shukla SP 1973. Further studies on effect of potassium application on yield and quality of sugarcane (Plant crop), 39th Proc. of the STA of India, Kanpur.

Haerdter R and Fairhurst 2003. Nutrient use efficiency in upland cropping systems of Asia. IFA Regional Conference, Cheju Island, Korea 6-8 October, 2003.

Jaetzold R, Schmidt H, Hornetz B and Shisanya C 2005. Ministry of Agriculture. Farm Management Handbook of Kenya Vol. II- Natural Conditions and Farm Management Information 2nd edition. Part A West Kenya (Subpart A1-Western province), pp 36-38

Jagathesan D and Nyang'au AM 1990. Description of four sugarcane varieties. Proc. Kenya Soc. Sugar cane Technol., Nov, 1990.

Kawamitsu Y, Nagae T, Ohmi N, Ueno M, Sun L and Tokashiki Y 1997. Improvement of Sugar Production in Sugarcane with Crop, Soil and System Engineering: I. Relationship between sugar content and elements in Minamidaitou and Ishigaki Islands. Japanese Journal of Crop Science, 66 (1): 262–263.

Kenya Sugar Board (KSB) 2012. Year Book of Statistics pp 8-39

Kenya Sugar Research Foundation (KESREF) 2002. Sugarcane Grower's Guide pp 21

Khosa TM 2002. Effect of different levels and sources of potassium on growth, yield and quality of sugarcane. Better Crops International, Vol. 16, No. 1, pp 14-15.

Kolln OT, Gava GJC, Cantarella HCJ, Franco HCJ, Rhein AFL and Trivelin PCO 2013. Accumulation of nitrogen and biomass in an irrigated ratoon sugarcane crop under varying rates of N. Proc. Int. Soc. Sugar cane Technol., vol. 28, 2013.

Korndorfer, GH 1990. Potassium and sugarcane quality. *Informacoes Agronomicas* 49: 1-3.

Krauss A 2004. Balanced Fertilization, the Key to Improved Fertilizer Use Efficiency. A paper presented to AFA 10th International Annual Conference, Cairo, Egypt 20-22 Jan. 2004

Kumar S, Rana S and Changra R 2002. Effect of phosphorus and potassium doses and their application schedule on yield, juice quality and nutrient use efficiency of sugarcane-ratoon crop sequence. Indian Journals.com

Lakholive BA, Kakde JR, Deshmukh VN and Daterao IH 1979. Nitrogen, phosphorus and potassium requirements of sugarcane (Co 1163) under Vidarbha conditions. *Indian Sugar* 29: 149-151.

Table 1: Soil chemical characteristics at the study sites

Site	pH (1:1)	P Mehlich (ppm)	Ca (m.e.)	Mg (m.e)	Ca/Mg ratio	K (m.e)	CEC (%)	Total N (%)	Org.C (%)
NE field D51	5.0	8.8	5.5	2.27	2.42	0.20	11.3	0.10	0.45
OG Musanda 22	4.7	25.5	1.0	1.07	0.90	0.30	10.1	0.12	1.28
NE field E35	4.9	13.3	6.1	2.58	2.36	0.40	15.8	0.07	0.76
OG Khalaba 49	5.2	27.9	2.1	1.01	2.08	0.30	8.5	0.12	1.39
Recommended for sugarcane*	5.5	> 20	> 4.0	> 2.0	2:1	> 0.7	> 12.0	> 1.0	> 2.0

Source : Mumias Agronomy laboratory ; Key : NE - Nucleus Estate (miller owned) , OG – Outgrowers (farmer owned) ; SCL- sandy clay loam; CL- clay loam; BD - bulk density; MC - moisture content
*BSES, Australia (1994); Okalebo *et al*. (2002)

Table 2: Soil physical characteristics at the study sites

Site	Soil depth (cm)	BD (g/cm^3)	MC (%)	Porosity (%)	Soil texture	Total rainfall (mm)	LTM (mm)
NE field D 51	0 – 30 30 – 60	1.65 1.85	32.96 24.64	37.9 30.3	SCL	2909.2	2756.4
OG Musanda 22	0 – 30 30 – 60	1.46 1.48	35.55 45.32	44.5 44.2	SCL	2397.7	2535.6
NE field E35	0 – 30 30 – 60	1.66 1.67	35.84 29.90	37.4 37.0	SCL	3246.4	2980.3
OG Khalaba 49	0 – 30 30 – 60	1.46 1.69	12.97 16.64	44.9 36.4	SCL	2949.3	2937.0
Recommended for sugarcane*		1.1 – 1.4	< 50	> 50		1800 - 3000	

Source : Mumias Agronomy laboratory ; Key : NE - Nucleus Estate, OG – Outgrowers ;SCL- sandy clay loam;CL- clay loam; BD - bulk density; MC - moisture content;*BSES, Australia (1994); Okalebo *et al*. (2002)

Table 3: Effect of N and K on sugarcane yield (t/ha)

Rates (kg/ha)		Nucleus Estate (Miller owned)		Out growers (Farmer owned)	
N	K	Season 1	Season 2	Season 1	Season 2
0	0 60 120 180	101.7 114.2 114.7 119.7	122.2 123.4 125.8 139.4	88.6 100.9 76.8 111.6	65.1 67.7 68.1 74.2
46	0 60 120 180	111.7 126.8 125.8 134.6	130.1 130.9 142.6 126.4	86.9 102.9 129.0 117.7	65.7 69.3 75.6 68.5
92	0 60 120 180	116.8 125.8 127.7 125.6	123.1 130.8 145.9 148.1	88.7 91.5 125.2 123.9	66.9 79.7 82.9 95.7
138	0 60 120 180	107.0 124.9 121.0 132.0	124.7 149.5 146.7 152.9	103.4 87.8 114.1 128.1	69.9 88.6 85.0 89.0
Mean $LSD_{0.05}$ CV %	(N×K)	120.6 5.7*** 2.8	135.2 3.3*** 3.6	104.8 8.1*** 4.6	75.7 5.2*** 4.2

Table 4: Effect of N and K on sugar yield (t/ha)

Rates (kg/ha)		Nucleus Estate (Miller owned)		Out growers (Farmer owned)	
N	K	Season 1	Season 2	Season 1	Season 2
0	0	15.94	17.67	12.21	8.48
	60	16.31	17.32	14.32	9.14
	120	16.55	18.01	14.11	9.37
	180	17.44	20.36	16.12	10.75
46	0	14.58	17.25	12.70	7.96
	60	18.22	18.17	14.85	9.03
	120	18.00	19.91	18.86	10.37
	180	19.77	17.69	16.63	9.78
92	0	15.72	17.95	12.10	8.24
	60	17.32	17.73	13.27	10.00
	120	18.17	19.93	18.01	11.68
	180	17.35	20.71	17.79	13.54
138	0	14.04	15.60	13.26	8.42
	60	17.34	18.97	12.61	10.88
	120	17.24	19.34	16.46	11.24
	180	18.99	20.26	18.88	12.05
Mean		17.06	18.55	15.14	10.06
$LSD_{0.05}$ (N×K)		1.05*	0.45*	1.18***	0.67***
CV %		3.6	1.5	4.7	4.1

Table 5: Effect of N and K on sugarcane juice quality (Pol % cane)

Rates (kg/ha)		Nucleus Estate (Miller owned)		Out growers (Farmer owned)	
N	K	Season 1	Season 2	Season 1	Season 2
0	0	13.37	13.64	13.78	13.03
	60	14.27	14.03	14.20	13.50
	120	14.43	14.31	14.46	13.77
	180	14.57	14.60	14.45	14.48
46	0	14.33	13.26	13.79	12.91
	60	14.37	13.88	14.13	13.03
	120	14.38	13.96	14.42	13.73
	180	14.70	13.99	14.43	14.27
92	0	13.47	12.55	13.67	12.31
	60	13.77	13.55	14.41	12.55
	120	14.23	13.65	14.39	14.10
	180	13.81	13.98	14.44	14.15
138	0	13.11	12.51	13.47	12.03
	60	13.89	12.64	13.89	12.28
	120	14.25	13.18	13.95	13.21
	180	14.38	13.25	14.38	13.55
Mean		14.15	13.56	14.14	13.31
$LSD_{0.05}$ (N×K)		0.57*	0.04***	0.37*	0.26***
CV %		2.4	0.2	1.5	1.2

Table 6: Effect of N and K on Agronomic efficiency (kg sugarcane/kg nutrient)

Rates (kg/ha)		Nucleus Estate (Miller owned)						Out growers (Farmer owned)					
N	K	Season1			Season 2			Season 1			Season 2		
		YI	%	AE	YI	%	AE	YI	%	AE	YI	%	AE
0	0												
	60	12.5	12.3	82.2	1.2	1.0	7.9	12.3	13.9	80.9	18.0	36.2	118.4
	120	13.0	12.8	61.3	3.6	2.9	17.0	28.2	31.8	133.0	18.4	37.0	86.8
	180	18.0	17.7	66.2	17.2	14.1	63.2	23.0	26.0	84.6	24.5	49.3	90.1
46	0	10.0	9.8	72.5	7.9	6.5	57.2	8.3	9.4	60.1	16.0	32.2	115.9
	60	25.1	24.7	126.8	8.7	7.1	43.9	14.3	16.1	72.2	20.6	41.4	104.0
	120	23.5	23.1	91.1	24.4	20.0	94.6	40.4	45.6	156.6	25.9	52.1	100.4
	180	32.9	32.4	103.5	4.2	3.4	13.2	29.1	32.8	91.5	18.8	37.8	59.1
92	0	15.1	14.8	82.1	0.9	0.7	4.9	0.1	0.1	0.5	17.2	34.6	93.5
	60	24.1	23.7	98.8	8.6	7.0	35.2	2.9	3.3	11.9	30.0	60.4	123.0
	120	26.0	25.6	85.5	23.7	19.4	78.0	36.6	41.3	120.4	33.2	66.8	109.2
	180	23.9	23.5	65.7	25.9	21.2	71.2	35.3	39.8	97.0	36.0	72.4	98.4
138	0	5.3	5.2	23.0	2.5	2.0	10.9	14.8	16.7	64.3	20.2	40.6	87.8
	60	23.2	22.8	80.0	27.3	22.3	94.1	29.2	33.0	100.7	38.9	78.3	134.1
	120	19.3	19.0	55.1	24.5	20.0	70.0	35.5	40.1	101.4	35.3	71.0	100.9
	180	30.3	29.8	73.9	30.7	25.1	74.9	39.5	44.6	96.3	39.3	79.1	95.9

Table 7: Economic Evaluation of the N and K treatments

Rates (kg/ha)		Nucleus Estate (Miller owned)				Out growers (Farmer owned)			
N	***K***	***Season1***		***Season 2***		***Season1***		***Season 2***	
		NR (Ksh)	***VCR***	***NR (Ksh)***	***VCR***	***NR (Ksh)***	***VCR***	***NR (Ksh)***	***VCR***
0	0	207,815.90	-	268,158.60	-	155,049.40		43,056.30	-
	60	238,653.40	6.5	264,774.20	7.2	183,461.10	5.0	87,878.30	2.4
	120	233,166.90	5.3	265,005.40	6.1	222,237.20	5.1	82,029.90	1.9
	180	241,301.90	4.8	298,982.20	5.9	200,266.40	4.0	92,591.80	1.8
46	0	246,277.90	-	300,153.30	-	187,137.10		91,554.30	-
	60	284,985.60	10.0	295,563.70	10.4	197,411.10	6.9	103,555.70	3.6
	120	273,142.40	7.7	323,815.80	9.1	265,553.00	7.5	111,814.40	3.1
	180	294,596.20	6.9	268,005.20	6.3	226,020.30	5.3	84,373.50	2.0
92	0	255,795.60	-	273,142.30	-	157,609.30		94,847.10	-
	60	276,038.60	8.0	289,342.40	8.4	158,670.50	4.6	124,698.30	3.6
	120	274,789.90	6.6	327,838.70	7.9	248,692.80	6.0	126,911.10	3.1
	180	261,433.20	5.4	327,467.30	6.8	237,950.10	4.9	127,972.30	2.6
138	0	220,211.00	-	272,043.10	-	194,010.60		97,564.10	-
	60	267,304.30	6.6	339,675.50	8.4	228,378.20	5.6	144,311.40	3.6
	120	248,499.00	5.2	324,239.10	6.8	239,515.90	5.0	126,947.00	2.7
	180	274,886.00	5.1	336,009.70	6.2	244,121.90	4.5	131,553.00	2.4

NR= Net return, VCR= Value cost ratio, Price of SSP= Ksh 3,300, DAP= Ksh 3,897, MOP= Ksh 3,500 Urea= Ksh 2,960 per 50 kg bag; Price of sugarcane= Ksh 3,750 per ton

Mahamuni I, Lakshmanan C and Krishnamoorty KS 1975. Studies on NPK fertilization on yield and juice quality of sugarcane variety CO 658 in the soils of Lalgudi tract in Trichy district. Indian J. Agric. Chemistry 8 (1+2), pp 1-7.

Malavolta, E 1994. Nutrient and fertilizer management in sugarcane. *International Potash Institute Bulletin* No. 14. International Potash Institute, Basel, Switzerland Meyer JH 2013. 28th ISSCT Congress, Brazil, personal communication.

Meyer JH and Wood RA 2001. The effects of soil fertility and nutrition on sugarcane quality – a review. Proc. S Afr. Sugar Technol. Ass. 75, pp 242-247.

Ng Kee Kwong KF, Bholah MA, Cavalot PC, Gauthier J and Deville PJ 1994. Influence of broadcast and split application of potassium on sugarcane yields in Mauritius. *Revue Agricole et Sucrière, Ile Maurice* **73:**29-35.

Olalla L, Jurado F, Navarro E and Mira A 1986. Analysis of the lack of response to fertilizer application in sugar cane grown at Churriana (Malaga). *Sugar Cane* 4: 9-10.

MSC, 2012. Agronomy Annual Report 2000-2012.

Okalebo JR, Gathua KW and PL Woomer KW 2002. Laboratory Methods of Soil and Plant Analysis: A Working Manual (2nd Ed) pp 22-93

Paneque VM, Martinez MA and Gonzalez PJ 1992. Study of potassium levels in three sugarcane varieties grown on compacted red ferralitic soil. *Cultivos Tropicales* 13: 5-8.

Phonde DB, Nerkar YS, Zende NA, Chavan RV and Tiwari KN 2005. Most profitable Sugarcane production in Maharashtra. Better Crops/Vol. 89, No.3.

Perez O and Melgar M 2000. Sugarcane response to potassium fertilization on Andisol, Entisol and Mollisol Soils of Guatemala. Better Crops International. 14, 1, pp 20-22.

Prasad R, Prasad US and Saka, R 1996. Effect of potassium and sulfur on yield and quality of sugar cane grown in calcareous soils. *Journal of Potassium Research* 12: 29-38.

Rabindra S, Swamygowda SN and Devi TG 1993. Long term effect of fertilizers on sugarcane. *Current Research* 22: 6-8.

Sachan RS, Ram N and Gupta RA 1993. Effect of soil and applied nitrogen, phosphorus and potassium on the yield of planted and ratoon crop of sugarcane in a Mollisol of Uttar Pradesh. *Indian Sugar* 42:769-773.

Shehu, HE, Ezekiel, CS, Kwari, JD and Sandabe, MK. 2010. Agronomic Efficiency of N, P and K Fertilization in sesame (*Sesamum indicum*) in Mubi Region, Adamawa State, Nigeria. Nature and Science 2010;8(8):257-260]. (ISSN: 1545-0740).

Singh VK, Shukla, AK, Gill MS, Sharma, SK and Tiwari, KN.2008. Improving Sugarcane Productivity Through Balanced Nutrition with Potassium, Sulphur and Magnesium. Better Crops - India pp 12-14.

Steel Robert GD and Torrie James H 1980. Principles and Procedures of Statistics. New York: Mc Graw.

Watanabe K, Tominaga J, Kojya F, Oshiro M, Suwa R, Ueno M, and Kawamitsu, Y 2013. Effects of potassium fertilizers on sugarcane sucrose content in Japan. Proc. Int. Soc. Sugar Cane Technol., Vol. 28, 2013.

Wawire NO, Nyongesa DP and Kipruto KB 2007. The effect of continuous land sub-division on cane production in Kenya. KESREF-Technical Bulletin 1 (2):54-71.

Wood RA 1990. The roles of nitrogen, phosphorus and potassium in the production of sugarcane in South Africa. *Fertilizer Research* 26: 87-98.

Yadav RL, Yadav DV and Shukla SK 2009. Improving yield and quality of sugarcane through secondary and micronutrients. Indian J. Fert., Vol 5 (4), pp. 99-105

Yang SJ and Chen JM 1991. A review of fertilizer trials carried out by the Fiji Sugar Corporation between 1977 and 1987. *Taiwan Sugar* 38: 19-24

Yara 2011. Review of research papers, unpublished.