Kenya Sugar Research Foundation

(KESREF)

Technical Bulletin

Number 1

KESREF Technical Bulletin No. 1 (December 2006)

KESREF Technical Bulletin (Number 1)

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ISBN: 9966-7179-1-9

TABLE OF CONTENTS

FORWARD

Introducing KESREF Technical Bulletin

ASSESSMENT OF YIELD LOSS DUE TO SUGARCANE SMUT (*Ustilago Scitaminea*) INFECTION IN KENYA

H.S. Nzioki and J.E. Jamoza

Abstract

Sugarcane smut caused by the fungus Ustilago scitaminea is considered the most important disease of sugarcane in Kenya. The disease was first reported in Kenya in 1958 necessitating compulsory planting of smut-resistant cultivars in 1963. No reliable information on yield loss caused by this disease is available in Kenya. Studies were started at KESREF, Kibos in year 2004 to assess yield loss caused by sugarcane smut infection in inoculated and uninoculated cultivars. Preliminary plant cane results indicate yield losses of 38% on the susceptible, 17% on intermediate tolerant and 20-33% on resistant and immune cultivars. The results suggest that smut infection results to yield reduction not only on susceptible cultivars, but also on resistant and immune cultivars hence the importance of hot water treatment in seed cane to eliminate seedborne smut infection. The reduction in plant cane yield positively correlated with sugarcane smut incidence in inoculated treatments, and negatively with smut incidence in uninoculated treatments.

Introduction

Sugarcane smut is caused by *Ustilago scitaminea* H & P. Sydow., a basidiomycete's fungus (Rott *et al* 2000). It was first reported in Natal in South Africa in 1877 and has since been reported in all other countries that lie between 20^{o} N and 20^{o} S of equator (Martin *et al*., 1961). The disease was first reported in Kenya in 1958 in Nyanza and Coastal provinces (Robinson, 1959). As a result, planting of smut resistant varieties was made compulsory in Kenya in 1963 (Early, 1970b). Presently, sugarcane smut occurs in all sugarcane growing areas of Kenya (Ochieng, 1982, Wawire *et al.,* 1987, KESREF, 2002).

Symptoms of sugarcane smut include black whip like structures from terminal meristem or meristems of lateral buds of infected stalks (Ferreira and Comstock, 1989). The whips reduce the yield and quality of sugarcane and jaggery (James, 1973; Bachchlav *et al*., 1979, Mukerjee *et al*., 1979). The reduction in yield and quality of sugarcane varies widely in different sugarcane growing areas of the world and is dependent mainly on the races of the pathogen present, the sugarcane varieties and the prevailing environmental conditions (Lee-Lovick, 1978). Estimates of economic losses have ranged from negligible to levels serious enough to threaten the agricultural economy of the area (Lee – Lovick, 1978). The disease may not cause any losses for many years and reappear to cause extensive crop damage (Ferreira and Comstock, 1989).

Primary transmission of the smut fungus occurs through planting diseased seed cane. Secondary spread is through windblown spores. Spores in or on soil are carried to different fields via rain or irrigation water where they can cause new infections to cane (Agnhotri, 1983, Rott, *et al*., 2000).

Smut is controlled by an integration of several methods. Planting resistant or tolerant cultivars is the most practical as it is cheap and reliable. Hot water treatment of seed cane for 20 minutes at 52-54^{o}C or 30 minutes at 50^{o}C gets rid of seedborne smut spores or dormant smut infection. Rouging affected plants as and when noticed is another control measure. As the disease is systemic, it is necessary to remove the whole clump during rouging before the emergence of the whip but if the whips have already emerged, they should first be covered with a gunny/plastic bag, removed and burned. Scattering of spores should be avoided during the rouging operation. Reduction of the number of ratoons is recommended in susceptible cultivars. Any plant crop which has over 10% smut infection should not be kept for ratoon (Agnihotri, 1983). According to Kenya Legal Notice No. 390 of the Plant Protection Ordinance, cultivars which show more than 21% stools smutted in the ratoons are not considered for commercial production and it is illegal to grow such a cultivar. Seed protectant fungicides are effective in ridding seed cane of dormant smut spores and/or dormant smut infections. (Agnohorti, 1983; Fauconnier, 1993; Rot *et al*., 2000).

Various studies have been carried out worldwide to quantify yield loss due to sugarcane smut. Whittle (1982) reported maximum potential loss of 12.4% to 25.6% in inoculated and healthy plots. James (1973) found significant losses in yields of healthy and smutted canes. Sandhu *et al* (1969) reported yield losses of 70.7% to 75.3% in CO 312, CO 313 and CO 129.

The importance of smut in the sugar industry cannot be ignored as it raises the costs of sugar production through monitoring of fields, rouging, hot water treatment, and breeding/selection programs, replacing susceptible cultivars, and application of protectant fungicides to seed cane.

Attempts have been made in Kenya to estimate yield loss caused by sugarcane smut disease. Early (1970a) estimated losses of 3% on CO 331 (PC, R1, R2) in Ramisi, 15% on CO 617 (R2) in Miwani, 4.5% on CO 331 (R2) in Songhor, 2.5% on CO 421 (R1, R2) in Chemelil, 1.5% on CO 421 (PC, R1) in Nyando Sugar Estate based on field observatons. Estimated mean yield losses of 1.7% based on healthy and smut inoculated plots of CO 421, CO 331, EAK 69-41 and CO 617 in plant crop and ratoon crop II were also reported (KARI, 1992). However, the results were not confirmed. Hence, reliable and up-to-date information on yield loss caused by sugarcane smut in the Kenya sugar industry is inadequate.

The aim of this experiment was to assess yield loss caused by *U. scitaminea* in smut inoculated and uninoculated plant cane, ratoon crop 1 and ratoon crop II. This paper presents preliminary plant cane results.

Materials and Methods

Six commercial cultivars were evaluated. The **c**ultivars were chosen to represent a wide range of smut reaction present among commercially grown cultivars in Kenya based on past field smut screening results under natural and artificial inoculations. The following cultivars were selected: CO 421, CO 617, CO 945, N14 and CO 1148. EAK 70 97 is immune (smut rating 0) (KESREF 2003; 2005). Cultivar N14 is very hghly resistant (smut rating 1), CO1148 is resistant (smut rating 2) and CO 945 is intermediate resistant (smut rating 4) . CO. 617 is intermediate and tolerant (smut rating 5) (KESREF 2001, 2003). CO 421 is susceptible (smut rating 6 and above) (KESREF 2003; 2005). The description of smut rating is presented on Table 9. However, the smut ranking of the cultivars can vary significantly from year to year since host reaction to smut is dependent on the environment and probably races of the pathogen present (Lee-Lovick, 1978).

Dry smut spores were freshly collected from the field in Kibos from cultivars and breeding lines showing smut whips. The varieties included CO 421, N14, CO 617, CO 945, breeding lines and pre-released varieties. The spores were bulked and stored in size 5 khaki envelopes under dry conditions in the laboratory.

Ninety six three budded setts of each cultivar were hot water treated in batches of 12 setts at 52^{o}C for 20 minutes (Fauconnier, 1993) in a simple water bath , cooled and stored in polythene sacks.

Forty eight (48) 3-budded setts of each cultivar were dipped in a concentration of smut spores (0.3gm per liter of water) for 30 minutes and then held overnight in polythene sacks (Nasr, 1977). In the uninoculated treatment, the procedure was as for inoculated treatment except that the remaining 48 setts were dipped in distilled water.

Forty eight (48) 3-budded setts of each cultivar were planted in 5 m long double row plots per treatment in the field at KESREF, Kibos in April 2004 in sand clay loam soils. Each treatment comprised 48 inoculated and 48 uninoculated setts per cultivar.

The trial was conducted in a completely randomized split plot design replicated four times. The cultivars were placed in main plots, and inoculated and uninoculated treatments in sub-plots.

Germination data was collected on inoculated and uninoculated treatments 30 days after planting. The data was then converted into percent germination. Tillers were counted 60 days after planting with the help of a tally counter on all treatments. Smut incidence was determined by counting the

number of stalks infected per treatment for six (6) months starting three (3) months after planting. These data was then converted into smut incidence per cultivar per treatment. Data on pol % cane and fibre % cane was determined in the laboratory from samples collected from inoculated and uninoculated treatments.

The trial was harvested 18 months after planting. This was the time when sucrose accumulation on the cultivars was optimal as determined from pol% cane results from the laboratory (data not shown). Plant height and plant girth (cm) were determined from an average of 10 plants selected at random from each treatment at harvest (18 months after planting). Plant height was measured by a metre rule while plant girth was measured by vernier calipers from the medium internodes of each plant. The total numbers of millable stalks were visually counted per treatment at harvest, and then converted into millable stalks per hectare (MSHa). All stalks per treatment were weighed by a scale balance to give the net stalk weight in kilograms. The resulting figure was then converted into tons cane per hectare (TCHa).

The data collected (except pol% cane and fibre % cane) were subjected to analysis of variance (ANOVA). Treatment means were separated using Fisher's least significant difference (LSD) test ($P \leq 0.05$). In addition, correlation between TCHa and smut incidence in inoculated and uninoculated treatments was evaluated.

Results and Discussion

Germination

Smut reduced % germination in the susceptible (CO 421) and tolerant (CO 617) cultivars relative to the control (Table 1). However, no significant differences in mean % germination were noted in the inoculated treatment. The cultivars interacted significantly in the control treatment. On average, the susceptible and intermediate cultivars had relatively higher % germination than immune and resistant cultivars (Table 1).

Table 1: Effects of smut inoculation on germination

	% Germination		
Variety	**inoculated**	**control**	**Mean**
N14	49	44.5c[s]	46.8c
EAK7097	54.8	50.3bc	52.5bc
CO1148	53.3	50.8bc	52bc
CO945	61	51.3bc	56.1bc
CO421	60.8	62.0ab	61.4ab
CO617	63	66.3a	64.6ab
Mean	**57.0a**	**54.2a**	
CV %	**22**	**17**	**19**
LSD (P≤0.05)	**ns**	**13.6**	**11**

[s] Means within a column followed by the same letter do not differ significantly ($P \leq 0.05$)

Tillering

Significant differences were noted in control and inoculated treatments in tiller numbers (Table 2). Smut inoculation significantly increased the tillering capacity in all cultivars except in the susceptible cultivar (CO421) (Table 2). It is suspected that some tillers in CO421 were killed by the smut pathogen before the counts could be taken. Tiller proliferation is among the symptoms induced by the smut pathogen in the host (Agnihotri, 1983). Significant differences in the control treatment could be attributed to varietal differences.

Table 2: Effect of smut inoculation on tiller counts

Varieties	Tiller Counts		
	Inoculated	control	Mean
EAK7097	169.5c[t]	157.0b	163.3d
CO617	211.5bc	210.3ab	210.9c
CO421	228.8abc	247.5a	238.1c
N14	270.1ab	253.5a	262.0ab
CO945	274.3ab	262.5a	268.4ab
CO1148	305.8a	284.8a	295.3a
Mean	**243.4a**	**235.9a**	
CV %	**21.2**	**22.2**	**23.5**
LSD (p≤0.05)	**77.9**	**79.1**	**47.1**

[t] *Means within a column followed by the same letter do not differ significantly (P≤0.05)*

Percent Smut Incidence

There were significant differences (p≤0.05) in smut incidence (with no interaction) in the smut inoculated treatment (Table 3). The susceptible cultivar CO 421 had relatively the highest smut incidence while the immune cultivar EAK7097 had the lowest. Only CO 945 and CO 1148 had symptoms of smut infection in the control treatment, suggesting that heat therapy was not 100% effective in control of seedborne smut and/or the varieties probably got infected from windblown smut spores. Agnihotri (1983) reported that the internal dormant infection of buds by smut is not always cured by heat therapy. No significant different differences were noted in the control treatment. High CV's were noted in control and inoculated treatments, suggesting inherent genetic differences to smut reaction among the varieties. The means of control and inoculated treatments were significantly different (p≤0.05) confirming the fact that the varieties differed widely in their smut reaction.

Table 3: Effect of smut inoculation on smut incidence

Variety	% Stalk Infected		
	Inoculated	Control	Mean
CO421	30.0a	0	15a[u]
CO945	9.7b	3.4	6.5b
N14	3.5b	0	1.8c
CO617	2.5b	0	1.2c
CO1148	0.7b	0.7	0.7c
EAK7097	0 b	0	0 c
Mean	**7.7a**	**0.7a**	**4.2**
CV%	**84**	**328**	**125**
LSD (p≤0.05)	**9.8**	**ns**	**4.5**

[u] Means within a column followed by the same letter do not differ significantly (P ≤ 0.05)

Plant Height

Smut inoculation generally reduced plant height in all the varieties (Table 4). However, the varieties did not differ significantly in either treatment. On average, CO 1148 was the tallest, and N14 was the shortest.

Plant Girth

Smut inoculation reduced plant girth (cm) in all varieties except in N14 but the differences were not significant within treatments (Table 5). In the control treatment, the varieties interacted significantly in girth, and EAK 7097 had relatively the biggest girth while CO 617 had the least. N14 led in girth in the inoculated treatment while CO617 and CO 1148 had the least girth. In either treatment, CO 617 had the least girth.

Table 4: Effect of smut inoculation on plant height

	Plant Height (cm)		
Variety	**Inoculated**	**Control**	**Mean**
CO1148	280	284	282 a [v]
EAK7097	265	279	271.9 ab
CO617	260	272	265.9 ab
CO421	255	287	270.9 ab
CO9 45	249	256	252.6 b
N14	247	253	249.5 b
Mean	**259.3b**	**271.7a**	**265.5**
Cv%	**9.2**	**7.9**	**7.2**
LSD (p≤0.05)	**ns**	**ns**	**26.2**

[v] Means within a column followed by the same letter do not differ significantly ($P \leq 0.05$)

Table 5: Effect of smut inoculation on plant girth

	Plant Girth (cm)		
Variety	**Inoculation**	**Control**	**Means**
EAK7098	2.58	2.8 a [w]	2.67 a
CO945	2.63	2.63 ab	2.6 ab
N14	2.7	2.5b	2.6 ab
CO1148	2.35	2.48 b	2.4 c
CO421	2.43	2.48 b	2.45 bc
CO617	2.35	2.43 b	2.39 c
Mean	**2.5**	**2.6**	
CV%	**6.23**	**6**	**5.7**
LSD (P≤0.05)	**ns**	**0.23**	**0.17**

[w] Means within a column followed by the same letter do not differ significantly

Millable Stalks per Hectare (MSHa)

Smut inoculation significantly reduced millable stalks in all varieties irrespective of their smut rating /ranking (Table 6). The immune variety, EAK 7097 had relatively the highest number of MSHa in the inoculated treatment while N14, which is rated highly resistant, had the lowest (Table 6). However, there were no significant differences in the MSHa means in the control treatment.

Table 6: Effect of smut inoculation on millable stalks per ha (MSHa)

Variety	Millable stalks per ha		
	Inoculated	Control	Means
EAK7097	59,100 a[x]	59,167	59,134 a
CO1148	55,338 b	58,500	56,919 ab
CO617	54,500 a	72,833	63,667 a
CO945	36,167 b	59,167	47,667 c
CO421	36,000 b	63,833	49,917 bc
N14	28,167 b	62,000	
Mean	**44,879**	**62,583**	-
CV%	**19.9**	**16**	19.2
LSD (p≤0.05)	**34,055**	**ns**	21,849

[x] *Means within a column followed by the same letter do not differ significantly*

Tons Cane per Hectare (TCHa)

There were no significant differences in varietal yields in the inoculated treatment in contrast to the control treatment, suggesting the differences in yields could be attributed to smut inoculation (Table 7). On average, the control treatment had significantly higher yields than inoculated treatment. Our results indicate that smut inoculation generally reduced yields in all varieties. EAK 7097 had the highest yields in either treatment.

Table 7: Effect of smut inoculation on tons cane per hectare (TCHa)

Variety	Tons Cane per Hectare		
	Inoculated	Control	Means
EAK 7097	91.5 a[z]	3120.3	105.9 a
CO 617	73.2 ab	100.5	86.7 ab
CO 1148	70.7 abc	88.0	79.4 b
CO 945	67.7 abc	100.5	84.1 b
N 14	66.7 abc	89.3	78.0 b
CO 421	49.7 c	80.7	65.2 b
Mean	**69.9**	**96.6**	**83.2**
CV%	**22.7**	**18.2**	**15.4**
LSD	**60.1**	**ns**	**53.4**

[z] *Means within a column followed by the same letter are not significantly different*

Yield loss

Sugarcane variety CO 421 had the highest yield loss (38%) followed by CO 945 (33%). CO 617 had the least yield loss (17%). The other varieties had yield losses of 20-24%). However, the differences in variety mean yield losses were not significant (Table 8). Clear cut varietal differences in yield loss of the respective varieties due to smut infection may be noted in ratoon crops when latent smut infections in buds of underground stubble of plant cane become active in ratoons (Agnhotri, 1983). Correlations analysis indicated that yield loss was positively correlated with smut incidence in the inoculated treatment, and negatively correlated with smut incidence in the control (data not shown). This was because there were more smut whips in the inoculated treatment relative to the uninoculated treatment. Each smut whip is a potential millabe cane stalk. Hence the more the smut whips, the less the millable cane stalks and the less the cane yields.

Table 8: Relationship between % yield loss (rank) and smut rating of varieties.

Variety	%Yield loss (rank)	Smut rating	Smut Description
CO 617	21.0	5.0	Intermediate
CO 1148	20.0	2.0	Highly Resistant
EAK 7097	24.0	0.0	Immune
N 14	25.0	1.0	Very Highly Resistant
CO 945	33.0	4.0	Intermediate Resistant
CO 421	38.0	6.0 and above	Susceptible

Relationship Between Percent Yield Loss (Rank) and Smut Rating of Cultivars

We expected a trend between the smut rating of the cultivars and yield loss i.e. the more resistant a cultivars is to smut, the less the yield loss. Thus from the extremes, we expected the immune cultivar (EAK 70 97) to have the least yield loss, and the susceptible cultivar (CO 421) to have the greatest yield loss. Our results indicate that the highly resistant (CO.1148), intermediate resistant (CO 945) and susceptible (CO 421) cultivars followed our trend with yield losses of 20%, 33% and 38% respectively (Table 9). However, the immune (EAK 7097), very highly resistant (N 14) and intermediate tolerant (CO 617) deviated from the trend and had losses of 22%, 24% and 17% respectively. This suggests that the cultivars are probably wrongly rated, or there was interaction of variety, environment and smut races. In addition, it highlights the problem of selecting for smut resistance and yields during the breeding process. A compromise has to be reached between the two important traits.

Table 9. Smut rating on 0-9 scale[y]

Rating	Smut (No. whips/Ha	Disease Description
0	0	Immune
1	1-60	Very Highly Resistant (VHR)
2	61-120	Highly Resistant (HR)
3	121-240	Resistant (R)
4	241-625	Intermediate Resistant (IR)
5	626-1875	Intermediate (I)
6	1876-5000	Intermediate Susceptible (IS)
7	5001-15000	Susceptible (S)
8	15001-30000	Highly Susceptible (HS)
9	over 30000	Very Highly Susceptible (VHS)

[y](Hutchinson, 1970)

Conclusion

Sugarcane smut reduced germination, plant girth, plant height, millable stalks per ha (MSHa) and tons cane per hectare (TCHa) in the smut- inoculated treatment. Correlation was high between % yield loss and smut infection in the inoculated treatment, and low between % yield loss and smut incidence in the uninoculated treatment. However, the plant cane results show that there were no significant differences in yields in our test cultivars. Significant varietal differences in yield may become apparent in the ratoon crops when the latent smut infection will be expressed inform of smut whips. The trial is now in ratoon crop 1 and yield loss results are expected late next year (2007).

Way Forward

The trial will be continue to ratoon crop 2. Based on results of economic analysis on cane yields in smut-inoculated and control treatments, we will be able to come up with recommendations on profitability of ratooning sugarcane varieties varying in reaction to the smut pathogen.

Acknowledgements

We thank the Director, KESREF for facilitating this research, for reviewing the manuscript and for permitting this paper to be published. Thanks to Paul Agoi (Research Assistant) and Samson Omwango (Research Technician) for assistance in field work.

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EFFECT OF IRRIGATION ON SUGARCANE PRODUCTIVITY IN NYANDO SUGAR ZONE

S.M. Muturi and N. W. Wawire

Abstract

Currently there is no documented information in Kenya on sugarcane irrigation. This study is an effort to fill this void for the benefit of potential investors and users. A yield – water response trial was initiated in Kibos in 2003 with three objectives: a) to determine the cane crop and irrigation water requirements, b) to select varieties that respond best to irrigation and c) to develop yield-water relationships for cane and recommend ways of improving it. This trial was a 3 by 9 split-plot design with 3 water regimes and 9 commercial varieties replicated 3 times. The water regimes were furrow irrigation at 14 days interval, at 28 days interval and rainfed (no irrigation) The data was collected for plant crop (PC) and ratoon 1(R1) in sugar and cane yields, stalk heights, population and girth, irrigation dates and amounts and climate data. Crop water requirements were 2017 and 1780mm while irrigation water requirements were 750 and 700mm for PC and R1, respectively. The corresponding seasonal rainfall was 2568 and 1935mm but only about 50 percent was effectively used. For all varieties yields increased in direct proportion to amount of water applied and irrigation increased yields by an average of 45 percent. CO1148, CB3822, EAK70-97 and CO617 gave the highest yields of 190, 180, 175 and 167 TCHa, respectively. Plant cane responded best to irrigation at 28 days interval while R1 at 14 days interval. Water use efficiency (WUE) varied from 5.2 to 8.9 t/ha/100mm which is considered low. Recommendations for increasing WUE have been given and include improving irrigation and rain water use efficiencies by adopting practices that reduce runoff and maximize infiltration such as trash alignment, deep ploughing, subsoiling and contour furrowing.

Introduction

Sugarcane production in Kenya is heavily dependent on rainfall, a fact that exposes the industry to vagaries of weather. Consequently, there is over production of cane in years after heavy rainfall and shortage in years after drought. For instance between 1983 and 2002 yield in Chemelil Sugar Company (CSC) varied from 35 tch in 1995 to 82.9 tch in 1998 following the El Niño rains of 1997. More recently (2005) CSC had stopped milling operations due to lack of cane following protracted drought of 2005. These interruptions in cane supply lead to unnecessary inefficiencies in sugar mills and impact negatively on the sugar industry's effort to meet local demand

For many years, it has been common knowledge in the Kenya Sugar Industry that irrigation of cane is one sure way of increasing and stabilizing sugarcane yields. This is because the rainfall obtaining in most sugar growing zones especially Nyando and Busia is either inadequate or poorly distributed leading inevitably, to moisture limitation to cane production. Need for irrigation depends more on rainfall distribution than amount. In United Kingdom for instance, irrigation is done in summer in spite of annual rainfall being in excess of 3000mm (Bailey *et al*, 1997). Sugarcane in Mauritius is irrigated in areas with more than 2000mm of rain for similar reasons (Jhoty *et al*, 2001). Irrigation is an essential commodity in subhumid areas if cane yields have to be increased or at least maintained (Jhoty *et al*, 2001). In Mauritius, irrigation has increased yield in sub-humid areas by 40-60 tch (Bachelor and Soopramanien, 1993). Some of the countries where sugarcane irrigation is a success story include Mauritius with 22 percent of cane area irrigated, Australia, Cuba and South Africa.

World-wide sugarcane is irrigated using three conventional irrigation methods viz: furrow, overhead and drip. Countries where irrigation has been practiced for long will usually have all the three irrigation methods but in varying proportions of area. According to a survey done in Mauritius (Jhoty *et al*, 2001), 79% of area irrigated is by overhead systems, 8% by drip and 13% by furrow. Furrow was still considered the best for heavy clay soils where water is cheap and energy cost high

(Soopramanien, 1998). A general trend observed in the recent past is the reduction in area under furrow irrigation and high pressure overhead systems (target master, big gun and hose reel) in favor of the more water efficient irrigation systems such as drip, lateral move and center pivot systems. The mov*e is prompted by the declining water and energy resources and the increasing cost of the same forcing cane growers to go for more water efficient systems. It is noteworthy that research is being done in a number of countries e.g. Australia to find ways of improving efficiency of furrow irrigation. Recent innovations include the "flex flume" (Soopramanien, 1998). This is a lay flat tube made from polyethylene and fitted with adjustable outlets that correspond to irrigation furrows. The advantage of the flex flume is that it will make furrow irrigation efficient and cheap to maintain. This system has attained an application efficiency of 90% for a recycling system. This technology could be tested in CSC where furrow irrigation efficiency is low and in the order of 35% (Muturi *et al,* 2004 unpublished report).

Currently there is no reliable, locally generated information on sugarcane irrigation. At times the information available is negative and misleading, depicting irrigation as expensive and therefore not cost effective. This has scared potential investors and users in irrigation, hence leading to a limited area under sugarcane irrigation in CSC being low at just 500 ha. There is an urgent need therefore to generate accurate information that may be used for improving existing irrigated sugarcane areas and in planning and management of new cane irrigation schemes before the expiry of Common Markets for Eastern and Southern Africa (COMESA) grace period ending in February 2008.

The specific objectives of this trial were: a) to determine the cane crop and irrigation water requirements, b) to select varieties that respond best to irrigation and c) develop yield-water relationships for cane and recommend ways of improving it.

Materials and Methods

Site Characteristics

A sugarcane irrigation response experiment was planted in April 2003 at KESREF Hqs, Kibos at an altitude of 1128m.a.s.l. Kibos has a sub-humid climate characterized by high day temperatures, cool nights and bimodal rainfall pattern. Average temperatures, day lengths, evaporation and radiation vary very little through out the year (Table 1*).*

The main climatic variable is the rainfall that shows the bimodal pattern typical of the latitude. There is the long rain season centered around April and a short rains season extending invariably from August to November. The long term mean (LTM) annual rainfall is around 1364mm against LTM annual Class A pan evaporation of 1783mm giving an LTM annual moisture deficit of 418mm.The bulk of this deficit occurs in the driest months December-March.

Table1: Long term weather data for Kibos

Weather parameter	Months													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Mean
Rainfall mm	97.5	85.5	155.0	207.1	107.0	67.2	74.5	112.7	111.4	101.7	138.3	106.1	1364	113.67
Evaporation mm	179.8	182.0	176.7	141.0	139.5	120.0	130.2	139.5	141.0	148.8	129.0	155.0	1782.5	148.54
Moisture deficit mm	-82.3	-96.5	-21.7	66.1	-32.5	-52.8	-55.7	-26.8	-29.6	-47.1	9.3	-48.9	-418.5	-34.88
Radiation MJ/m^2/month	858.7	910.0	880.4	852.0	756.4	720.0	747.1	771.9	807.0	864.9	801.0	871.1	9840.5	820.04
Sunshine hrs/month	269.7	257.6	226.3	201.0	145.7	183.0	204.6	220.1	195.0	201.5	195.0	241.8	2541.3	211.78
Temp max o C	31.6	30.2	28.2	26.8	28.2	27.4	25.8	25.5	26.6	27.3	27.0	27.1	331.7	27.642
Temp min o C	15.0	16.5	15.9	16.1	17.0	14.1	14.6	14.6	14.7	15.2	15.2	15.3	184.2	15.35
RH % 0900	65.7	60	72.9	74.2	77.4	75.7	64	64.1	58.6	58	68.1	66.3	805	67.083
RH % 1500	41.9	34.5	43.5	50.7	50.4	53.5	42.0	40.1	40.6	40.0	47.7	44.7	529.6	44.133

The soil at the experimental site consists of Eutric vertisols, which occupy over 60% of the total cane area in the Nyando zone (about 30,000ha). These soils are characterised by high clay content (over 60%), high water holding capacity and neglible permiability. Studies on moisture holding capacity has shown that the average water holding capacity for the vertisols in the experimental site is around 213mm/m.

Design and Treatments

The experiment was laid out in a 3 by 9 split plot design with 3 water regimes as the main plot and 9 varieties as the sub- plots and replicated 3 times. The area of sub- plot was $90m^2$ with a net plot of $60m^2$. The 9 commercial varieties used were N14, CO421, CO617, KEN82-808, CB38-22, CO1148, CO945, EAK70-97 and KEN83-737 whereas the 3 irrigation regimes were: T_1 - Irrigation at 14 days interval when about 50% of RAW has been depleted, T_2 - Irrigation at 28 days interval when about 100% of RAW has been depleted, T_3 - No irrigation (control).

Land preparation undertaken was conventional for the Nyando zone and consisted of moulboard ploughing, harrowing (2 passes) and ridging (at 1.5m spacing). Cane setts were planted end-to-end on the ridge shoulder and not in the conventional furrow bottom. This was to facilitate furrow irrigation which was done only during critical dry periods. Tie ridging of furrows was applied to minimize runoff from irrigation and rain. Irrigation water was applied to the furrows using a 75mm diameter PVC pipe locally modified to serve as a gated pipe. The "gated" pipe had 18 orifices spaced at 1.5m and discharging an average of 1.5 l/s of water into the head of the furrows. Other cultural practices e.g. fertilizer and weed management were as recommended for rain fed cane in Nyando zone.

Data on the principal yield components - stalk population, heights, girth, pol and the actual yields were collected for both the plant crop (PC) and ratoon 1 (R1) which were harvested in January 2005 and April 2006, respectively. Also recorded were the weather data, irrigation dates and amounts for each water regime. SAS (Statistical Analysis System) was used in the analysis of data for the yield components. Crop water requirements (CWR) and irrigation water requirements (IWR) were computed using the following relationships (Jensen, 1983):

$CWR = K_c * E_{to}$
$IWR = CW - R_{Reff}$

Where:
CWR = Crop water requirements (mm/day) also called consumptive water use.
IWR = Field/irrigation water requirements
K_c = Crop factor (dimensionless)
E_{to} = Potential evapotranspiration (mm/day)
R_{Reff} = Effective rainfall (mm)

E_{to} was estimated using Pan Evaporation method. Use of this method in estimating E_{to} is popular especially in sugar growing regions because it is cheap, simple and readily available (Teare and Peet, 1983). Penman Monteith, the method of choice due to its high accuracy could not be used as wind speed data was unavailable. Crop factor values were adopted from Tilly and Chapman (2004) while Reff was estimated using USDA (1974) Soil Conservation Service method. The latter uses monthly precipitation and consumptive water use data to estimate R_{Reff}.

Results and Discussion

Sugarcane Irrigation Water Requirements

Table 2 shows the number of irrigation events and the amount of irrigation water applied in the various water regimes. T1 and T2 received an average of 70mm and 100mm of water per irrigation event, respectively. The ratio of volume of water required by the crop to water delivered to the crop

is termed the application efficiency (AE). These are shown in brackets in Table 2 and range from 54.7-92%. Though low, they are within the usual range 30 to 90% for furrow irrigation (Tilly and Chapman, 1999).

Table 2: Irrigation events and amounts of water applied for plant crop and ratoon 1

Crop Cycle	No of irrigation events		Irrigation amounts mm		Total volume added (rain+irrigation) mm & Irrig. Efficiency % (in brackets)		
	T1	T2	T1	T2	T1	T2	T3 (Rain fed)
Plant crop	16	8	1120	700	3688 (54.7)	3268 (61.7)	2568 (78.5)
Ratoon 1	10	5	830	500	2765 (64.4)	2435 (73.1)	1935 (92)

The total amount of water used (rain & irrigation) by each water regime were compared with the estimates of crop water requirements shown in Table 3a and 3b. The CWR for a 20-month PC was 2017mm and 1780mm for a 16-month R1. CWR depends mainly on the length of growth period and environment's evaporative demand and was highest in January at 5.6mm/day for the PC while it was highest in December at 6.2mm/day for R1. As expected, this coincided with the grand growth stage. IWR for PC and R1 were 749mm and 699mm respectively. Irrigation is required most during the critical dry months December-March while some limited irrigation is needed between June and October.

The rainfall, crop and irrigation water requirements results shows that out of 2568mm seasonal rainfall for PC, only about 50% is effective with the rest going to waste as runoff, evaporation and deep percolation. Increasing rain effectiveness would reduce irrigation requirement but the big challenge remains how to achieve this cost-effectively.

Table 3. Computations of crop and irrigation water requirements

a) Plant crop

Year					2003											2004						
Months	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sept.**	**Oct.**	**Nov.**	**Dec.**	**Jan.**	**Feb.**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sept.**	**Oct.**	**Nov.**	**Dec.**	**Total**
Pan evaporation (mm)	128.7	120.9	114	120.7	136.5	154.8	148.1	147.6	150.3	144.4	170.5	186.3	123.4	159.6	146.3	163	146.6	152.2	159.2	153.7	171.3	**3098.1**
ETo mm	103	96.7	91.2	96.6	109.2	123.8	118.5	118.1	120.2	115.5	136.4	149	98.7	127.7	117	130.4	117.3	121.8	127.4	123	137	**2478.5**
Growth stage	**Germination**		**Tillering/establishment**							**Grand Growth**								**Ripening**				
Kc	**0.3**	**0.4**	**0.5**	**0.6**	**0.6**	**0.8**	**0.9**	**1.1**	**1.1**	**1.2**	**1.2**	**1.2**	**1.2**	**1.2**	**1.2**	**0.6**	**0.6**	**0.6**	**0.6**	**0.6**	**0.6**	
CWR (Et) mm	30.9	38.7	45.6	57.9	65.5	99.1	106.6	129.9	132.3	132.8	156.9	171.4	113.5	146.8	134.6	78.2	70.4	73.1	76.4	73.8	82.2	**2016.6**
Rainfall mm	262.4	232.8	80.7	66.6	160.7	90.3	75.8	87.6	67.4	84.7	111.7	103.7	376.5	73.7	41.4	97	127	146.4	64.5	77.4	139.7	**2568**
R eff mm	63	73	33	32	75	56	48	57	40	65	84	76	100	56	32	65	70	72	43	47	80	**1267**
Deficit mm (FWR)	-32.1	-34.3	12.6	25.9	-9.5	43.1	58.6	72.9	92.3	67.8	72.9	95.4	13.5	90.8	102.6	13.2	0.4	1.1	33.4	26.8	2.2	**749.6**

b) Ratoon 1

Year						2005							2006				
Months	**Jan.**	**Feb.**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sept.**	**Oct.**	**Nov.**	**Dec.**	**Jan.**	**Feb.**	**Mar**	**Apr**	**Total**
Pan evaporation (mm)	172.3	182.4	159.4	147.3	125.4	129.7	135.3	148.8	151.8	167.9	137.4	207.6	189.3	178.9	177.3	133.1	**2543.9**
ETo mm	137.8	145.9	127.5	117.8	100.3	103.8	108.2	119	121.4	134.3	109.9	166.1	151.4	143.1	141.8	106.5	**2035.1**
Growth stage	**Tillering/establishment**							**Grand Growth**							**Ripening**		
Kc	0.4	0.5	0.6	0.8	0.9	1.1	1.1	1.2	1.2	1.2	1.2	1.2	1.2	0.6	0.6	0.6	
CWR (Et) mm	55.1	73	76.5	94.3	90.3	114.1	119.1	136.9	139.7	154.5	126.4	191	174.2	85.9	85.1	63.9	**1779.8**
Rainfall mm	111.3	88.8	165.6	157.8	101.6	64.7	129.3	242.3	76.3	75.1	139.8	19.7	164.3	30.5	200.2	168	**1935.3**
R eff mm	55	56	76	92	65	47	90	100	56	58	100	19.7	100	26	80	60	**1080.7**
Deficit mm (FWR)	0.1	17	0.5	2.3	25.3	67.1	29.1	36.9	83.7	96.5	26.4	171.3	74.2	59.9	5.1	3.9	**699.1**

Note:

ET_0 = Potential evaporation
Kc = Crop factor
CWR = Crop water requirement (Et)
R_{eff} = Effective rainfall
Deficit = Irrigation requirement

Effect of Irrigation on Cane Yields

Water has been described as the life blood of sugarcane (Teare and Peet, 1983) and that cane yield is directly proportional to amounts of water applied as long as there is no water logging (Tilly and Chapman, 1999). This behavior is depicted in Table 4a and 4b.

Table 4. Effect of irrigation on sugarcane yields (tons cane/ha-tch)

a) Plant crop

	Varieties									
Water regimes	**N14**	**CO421**	**CO617**	**KEN 82-808**	**CB 38-22**	**CO 1148**	**CO 945**	**EAK 70-97**	**KEN 83-737**	**Means**
T1	168	143	168	137	185	201	121	163	168	161a
T2	153	177	166	149	176	180	159	188	166	168a
T3	115	117	162	98	89	143	109	108	108	116b
Means	145	146	165	128	150	174	130	153	147	148
	bcd	bcd	ab	d	bc	a	cd	ab	bcd	
CV %	**22.1**									

In a row or column, means with the same letter are not significantly different at 0.05 level of significance
T1 and T2: Irrigation at 14 and 28days interval; T3: Rainfed

b) Ratoon 1 crop

Water regimes	Varieties									
	N14	**CO421**	**CO617**	**KEN 82-808**	**CB 38-22**	**CO 1148**	**CO 945**	**EAK 70-97**	**KEN 83-737**	**Means**
T1	104	108	98	96	117	108	122	148	103	111 a
T2	107	93	81	76	94	83	74	113	78	89 b
T3	74	70	74	83	67	96	79	78	77	78 b
Means	95 ab	90 ab	84 b	85 b	93 ab	95 ab	92 ab	113 a	86 b	93
CV %	**24**									

The PC mean yield for irrigated varieties was 168tch which was significantly higher than non-irrigated varieties with a mean yield of 116tch. Irrigated yields were higher than rain fed yields by an average of 45% but some varieties e.g. CB3822 had their yields doubled under irrigation. The four highest yielding varieties were CO1148, CB3822, EAK 7097 and CO 617 with yields 190, 180, 175 and 167tch, respectively.

As expected ratoon yields were lower than PC yields for all water regimes. Gascho (1973) found that there was 33% reduction in ratoon cane yield compared with PC yield due to increased mortality of stalks, reduction in nutrition status of the soil and abundance of pests and diseases in the soil. The yield reduction in this trial was however higher than expected due to severe infestation by smut. It is noted (Table 4b) that the same 4 varieties that performed well in PC out-yielded the rest in R1. This is with an exception of CO617, which performed poorly. As in the case of PC results above, irrigated ratoon yields were significantly higher than rain fed yields for same varieties. EAK 70-97 scored highest yield of 148tch under irrigation followed by CO945, CB3822 with 122 and 117tch, respectively.

In the PC there was no significant difference in yield between T1 and T2 which shows that PC can withstand long irrigation intervals of 28 days. This would be preferred because less irrigation water and labor would be used, leading to greater savings. As for the R1, T1 gave significantly higher yields than T2 and T3 implying that R1 would require high frequency irrigation of 14 days for maximum yields. This tendency is confirmed in a study by Sheu

and Yang (1999) who found that light irrigations at frequent intervals were better for ratoon because water uptake was more concentrated in the top soil.

In this trial, fertilizer regimes suited for rain fed cane was used (2 bags DAP + 4 bags urea). This appeared inadequate judging from the yellowing of the crop. There is possibility that yields could have been higher with higher fertilizer rates and this should be investigated.

Effect of Irrigation on Principal Yield Components

Table 5a and 5b show the effect of irrigation on yield components-stalk height, population, girth and sucrose content (pol %). For both the PC and R1, irrigation significantly raised mean sugar yields (Pol % cane) compared to rain fed cane. Irrigated cane had on average 10% higher sucrose than rain fed cane. Varieties with highest pol % cane were EAK 70-97 (15.7), CO945 (15.3) and CB 38-22 (15.1)

Table 5: Effect of irrigation on principal yield components at harvest
a) Plant crop

Water regimes	Pol %	Purity %	Fibre %	Stalk Pop	Stalk Girth mm	Stalk ht cm
T1	15.1 a	86.9 a	14.5a	94,667 a	21.6 a	303 a
T2	14.9 a	87.1 ab	14.9a	99,667 a	21.6 a	309 a
T3	13.9 b	86 b	14.1a	90,333 b	20.7 b	252 b
Means	14.6	86.7	14.5	94,889	21.3	288
CV%	**4.4**	**3.5**	**9.6**	**13.1**	**6.4**	**10.7**

b) Ratoon 1

Water regimes	Pol %	Fibre %	Stalk Pop	Stalk Girth (mm)	Stalk ht (cm)
T1	15.3 a	14.1 ab	97,272 a	20.6 a	225.6 a
T2	14.8 b	14.3 a	95,148 a	20.3 a	216.0 b
T3	14.0 c	13.6 b	94,815 a	20.7 a	204.5 c
Means	14.7	14.0	95,745	20.5	215.4
CV%	**4.1**	**8.7**	**15.4**	**4.5**	**7.4**

Irrigation has major impact on stalk height, population and girth. Generally, the higher the amount of irrigation water applied, the higher the stalk height, girth and population. This trend was observed in the PC but not in R1 where irrigation only significantly influenced stalk height. Irrigation had no influence on fibre for both PC and R. This study has shown that stalk elongation decreased with increasing water stress as found by Hudson (1968). Figure 1 show that stalk elongation continues as long the cane receives water hence the need for drying off of cane 2-3 months before harvesting. Stalk elongation reduced significantly in the rain fed crop 2-4 months before harvesting due to severe moisture stress. Average stalk elongation rates were 29.3, 19.3 and 18.2 cm/month for EAK70-97, CO1148 and CB38-22, respectively for irrigated crop. These reduced to 13.3, 15.5, and 15.0 cm/month for rain fed crop (same variety).

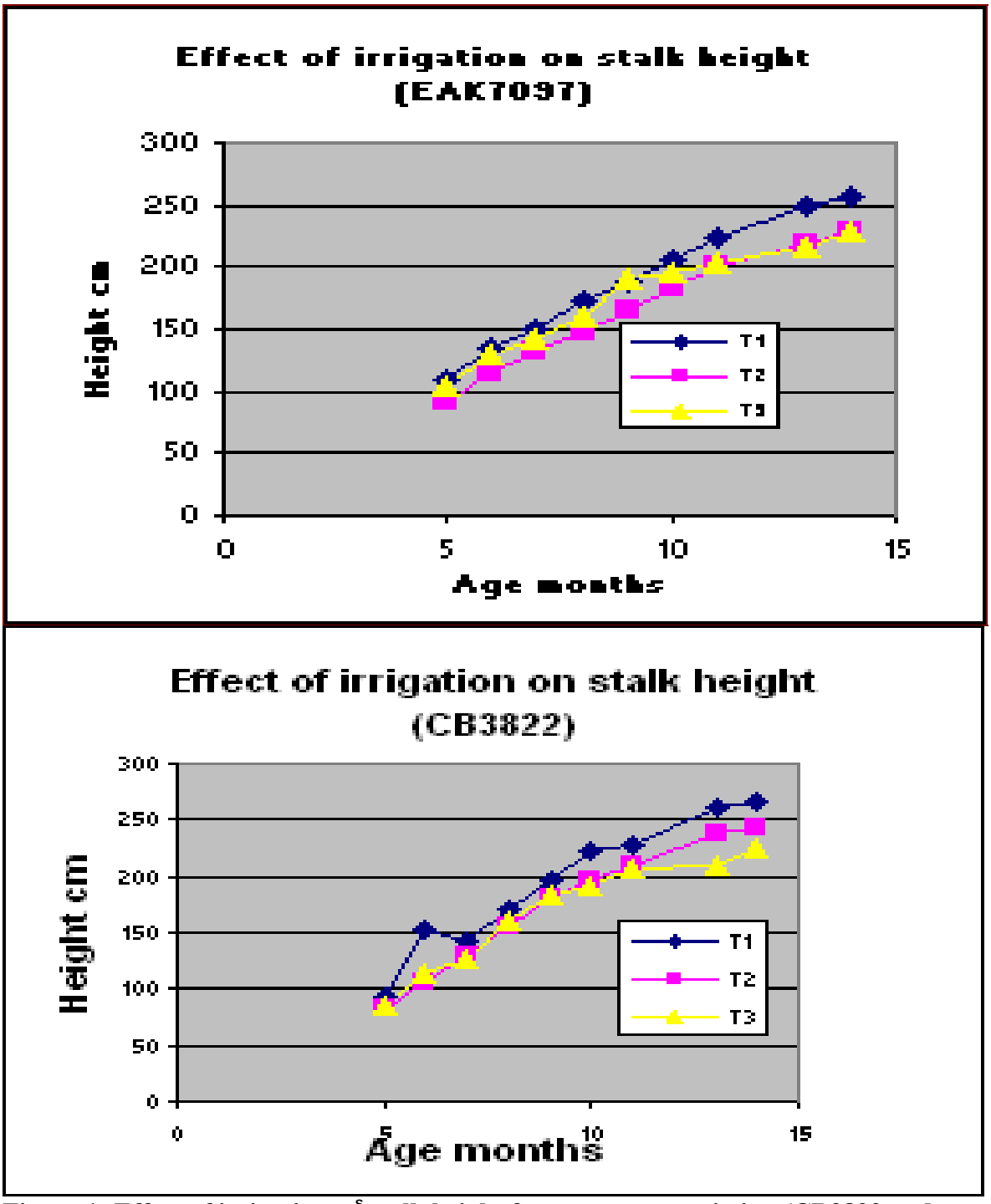

Figure 1: Effect of irrigation on stalk height for sugarcane varieties (CB3822 and EAK7097)

Sugarcane Yield-Water relationship in Kibos

Water use efficiency (WUE) is the ratio of cane yield to the season crop use or total irrigation amount used. It is calculated from yield-water graphs and its importance is that agronomist, engineers and economists use it to estimate cane yields for a mill area, water requirements for a given level of production and for calculating economic response to irrigation. According to Soopramanien (1999), WUE ranges from 3 to 20 t/ha/100mm and WUE value for Australia is 12.2 t/ha per 100mm. There is high variation in WUE which is

attributed to inaccurate measurements of effective rainfall, net amount of irrigation water, variations in soil properties and cultural practices, water use by different varieties etc.

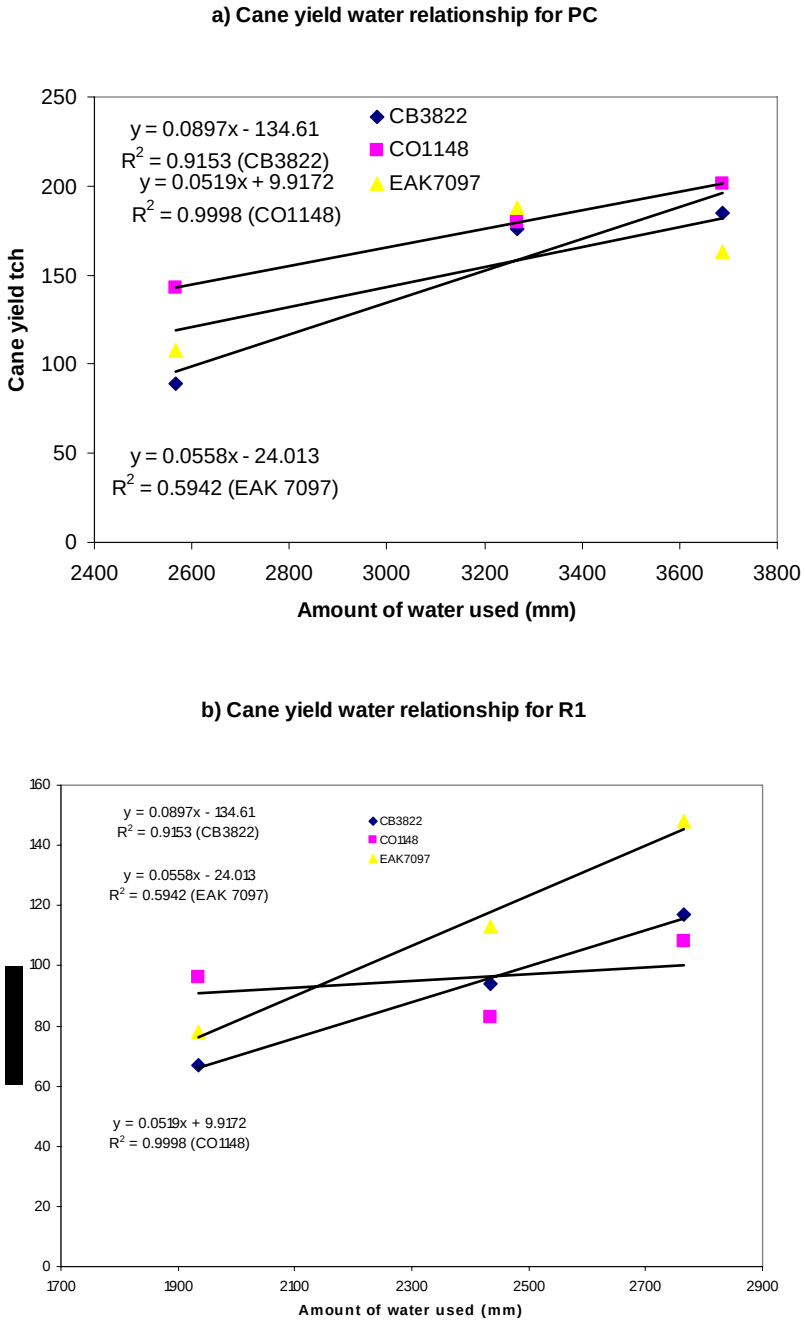

Figure 2: Yield water relations for sugarcane for PC and R1

A regression analysis was done between sugarcane yields and amounts of water used to develop yield-water relationships. Regression equations were obtained for CB3822, CO1148 and EAK 7097 (Figure 2). The regression coefficients (WUE) of CB38-22, CO1148 and EAK70-97 were 8.9, 5.2 and 5.98t/ha/100mm, respectively for PC. The coefficients were 5.9 and 8.3 for CB38-22 and EAK70-97 respectively for R1. It appears from above observations that plant crop uses water more efficiently than ratoon crop but this needs further research.

The WUE values obtained in this study were considered low compared with other studies done elsewhere. WUE can be increased in Nyando zone by increasing irrigation and rain water use efficiency. The latter can be improved by adopting practices that reduce runoff, evaporation and deep percolation. They include deep ploughing and sub-soiling, increasing organic matter in the soil through trash alignment and optimal time of planting (Fauconnier, 1993).

Conclusions

The main conclusions to be drawn from this study are as follows

- This study has confirmed other reported findinds that furrow irrigation can dramatically improve sugar and sugarcane yields for commercial varieties grown in Nyando zone.
- The most promising irrigated varieties in order of yield performance were: CO 1148 (190tch), CB 38-22 (180 tch), EAK 70-97 (175 tch), KEN 83-737 (167tch) and CO617 (167tch). The same set of varieties excelled even though R1 yields were 50% lower than PC yields.
- Irrigated cane had on average 10% more sucrose than rainfed cane.
- The sugarcane water requirement for Kibos was estimated as 2017 and 1780mm for PC and R1. CWR was highest in February at grand growth stage at 6.3mm/day.
- Irrigation water required for cane was 750mm for PC and 700mm for R1 delivered to crop at 28 days intervals for PC and at 14 days interval for R1.The irrigation water is required from November to March and from June to October.
- The current water use efficiency ranges from 5.2-8.9 t/ha/ML which is low due to the low rainfall use efficiency.
- The results of this study will be of value to the cane growers of the Nyando zone and other areas with similar soils and climate**.**

Way Forward

Based on the above positive findings on sugarcane irrigation, it is recommended that the area under irrigation should be expanded .Besides increasing cane production it will utilize the huge water resources currently lying idle. Furrow irrigation is particularly recommended on account of the fact that its installation and maintenance costs are comparatively lower compared with drip and sprinkler irrigation.

It is also recommended that this study be continued and expanded to facilitate collection of more accurate crop production, water use and soil data to develop and validate more reliable crop water models such as APSIM among others. Finally, it is recommended that these studies be carried out in other ecological zones where sugarcane irrigation may be necessary

Acknowledgements

The authors acknowledge the Director KESREF for funding this study and for his invaluable guidance in preparing the report.

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THE INFLUENCE OF PLANTING AND HARVESTING TIME ON SUGARCANE PRODUCTIVITY IN KENYA

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Abstract

A trial was established in four strategic sugarcane growing sites, representing both humid and sub-humid conditions, to assess the effect of planting and harvesting time on sugarcane development, yield and quality in three phases (2004, 2005 and 2006 long and short rainy period). The plant crop results for 2004 crop indicated that germination phase took up to 2 months; tillering phase 2 to 5 months, early elongation phase occurred between 5-7 months, grand growth stage took place from 7-15 months. Additional 2-3 months were observed to be for maturation. However, at SONYsugar site, representing humid conditions, harvesting ages significantly affected cane yields and quality for all cane varieties with the best harvesting age ranging from 17th to 20th months after planting (MAP). Months of planting, affected cane yield but not the quality. At this site, bulk of sugarcane planting may be undertaken during the long rains due to cane and sugar yield advantage of 9 and 8%, respectively. Sugarcane planting in the month of July in all the 4 sites should be avoided due to significant low cane yields and quality partly due to limited moisture availability for cane establishment, except where irrigation is available to supplement the rainfall. At Kibos site, representing sub-humid conditions, cane harvesting may commence on 16th to 20th MAP regardless of any variety.

Introduction

The current average sugarcane yields in the Kenya sugar industry stands at 71.5 t ha^{-1} (KSB, 2005), which is low compared to yields of 100 t ha^{-1} or more in the early 1970s. Sugarcane productivity is the ability of cane varieties to attain the potential yields. It is closely related to stalk biomass accumulation, which in turn positively affects stalk sucrose accumulation. Environmental factors (rainfall, radiation, temperatures) that enhance biomass accumulation finally improve the cane and sugar yields significantly. Biomass accumulation is the dominant component of sucrose accumulation and not sucrose partitioning (Lisson *et al*., 2005).

In Kenya, adequate moisture availability has for many years guided sugarcane establishment, with some regions extending their planting season almost throughout the year. This has resulted in shortage and/or glut in sugarcane supply due to lack of synchrony between cane development, harvesting and factory operations. A crop planted in advance of 4 to 5 months prior to onset of heavy rains may give the best results. Five to eight months of growth period may be considered as critical when moisture, nutrients and climatic factors like temperature and sunshine hours are optimal for the crop to express its full genetic potential. During the drought period leaf canopy should be as small as possible to minimize moisture loss through transpiration. On the other hand, coincidence of low rainfall and high diurnal variation on temperature during December to March present conducive natural conditions for stalk sugar accumulation. The peak solar radiation available coupled with low night temperatures and moisture stress during this period is ideal for sugar accumulation.

In Mumias zone, sugarcane yields for plant crops, to a large extent were found to be related to climatic factors especially rainfall (Mutanda, 1990). In a previous study on planting season versus age at harvest in Mumias zone, the optimal age for harvesting April planted cane was found to be 21 months after planting (MAP). In the same study, June planted cane was observed that it should be harvested after 21 months while October planted cane showed a steady increase in sugar accumulation from 17 to 25 MAP. However, no optimal harvest age was indicated by first ratoon results (Mutanda *et al*., 1980).

Ateshian and Wilkins, (1965) critically observed that sugarcane performance was related to the critical months when there was drought. In another study, simulated and measured results were compared in the Burdekin region of Queensland, Australia and there was good agreement between modeled and observed results where both time of planting and crop age at harvest significantly affected sugarcane and sugar yields (McDonald and Lisson, 2001).

Poor planning in cane development and harvesting in Kenya has significantly contributed to inefficient factory performance as a result of long season crushing period with no scheduled stoppages for sound factory maintenance. The trial was, therefore, established within the strategic sugarcane growing zones to assess the influence of planting and harvesting time on sugarcane and sugar productivities on varieties with different maturity patterns in Kenya.

Materials and Methods

Site Characterization

This study was conducted in 4 locations, namely KESRE Kibos centre, Chemelil, Mumias and SONY nucleus estates. These locations represented both sub humid and humid conditions, respectively, as shown in Table 1.

Table 1: Experimental site characteristics

Sites	Mean annual rainfall (mm)	Mean daily temp.(^{0}C)	Alt.(masl)	Lat. / Long.
Mumias sugar	1921 (humid)	21	1314	0° 21'N/ 34° 30'E
SONYsugar	1661 (humid)	21	1454	0° 54'S/ 34° 32'E
Chemelil sugar	1429 (sub humid)	22.5	1269	0° 03'S/ 53° 34'E
KESREF-Kibos	1464 (sub humid)	23	1184	0° 04'S/ 34° 48'E

Planting Procedure

The treatments included 8 planting months (April to November, 2004) and 3 to 4 sugarcane varieties CO 421 (late maturing), N 14, CO945, CB 38–22 (medium maturing) and EAK 70–97, CO617, D 8484 and KEN 83–737 (early maturing). The treatment factors were arranged in strip plot design with three replications. Planting was undertaken every month with seed cane of 12–15 months where the setts, placed end to end, were arranged within furrows spaced at 1.6m (at SONYsugar site), 1.2 m (at Kibos site), 1.5m (at Chemelili site) and 0.8 m (Mumias site) with Phosphate fertilizers applied at 45 kg P_2O_5 ha^{-1} for Kibos and Chemelil sites and 80kg P_2O_5 ha^{-1} for Mumias and SONYsugar sites in the form of diammonium phosphate except in Chemelil site where compound NPK (20:20:0 was used. Nitrogen fertilizer was used to top dress 4–5 months after planting at 100 Kg N ha^{-1} in the form of Urea at all the sites for each monthly planting. Weed control was manually executed 5 - 6 times for each planted month. At Kibos site, some supplemental irrigation was applied during the early crop development stage to save it from eminent failure occasioned by long drought. The trial was assessed for germination (30 and 60 days after planting (DAP); tiller count (3rd to 9th months after planting (MAP); height measurements (3rd to 20th MAP); quality (Brix %, POL % cane, fibre % cane and purities) monitoring and cane yield estimation (16th to 20th MAP) through destructive sampling of 8 to 10 stalks which were first weighed to get stalk weight for yield estimation at various ages. A product of stalk weight and millable stalks of each variety at various qualities monitoring ages (16th to 20th) gave the corresponding estimated cane yields; cane yields at harvest (20 MAP for all sites except Chemelil, and Mumias sites where data was lacking.

Results and Discussions

Effect of planting time on percent germination and tiller development

Sites comparison using a standard variety (CO421) indicated that percent germination at 30 DAP was moderate (30-60%) for all the months except September and November in Chemelil site. The June and October plant crop in Kibos and Sonygugar sites, respectively were poor. At 60 DAP, germination status for all the months and varieties tested improved except for October plant crop in Chemelil site remained poor. During this period tiller development commenced in some planted months. The missing gaps were due to uncollected data. The poor germination for October planted cane at Chemelil site, even after 60 DAP was partly attributed to drought and interference of contractors who erroneously removed the germinating setts as manual weeding was being executed. Peak tiller development during the long season planting (April to July) was between 4 and 7 months for all the planted months and varieties tested in all the 4 sites, that for the short season (August to November) planted cane went beyond 9 months at Mumias site; and September to November at the three other sites. The outstanding cane performance at Kibos site was partly attributed to the supplemental irrigation applied at early crop growth stages.

Effect of planting and harvest time on sugarcane yields

At Chemelil site, there was no significant difference in cane yields due to cane varieties at 21 months of harvesting though CO421 was leading with 106.1 t ha^{-1}, Table 2(i). However, April plant crop showed significant high cane yields of 148.9 t ha^{-1}, followed by May planted crop (100.3 t ha^{-1}) and June plant crop (93.8 t ha^{-1}) which were similar in cane yields although July plant crop had significantly low yields (58.5 t ha^{-1}) ,Table2(i).

Table 2(i): Sugarcane yields (TCH) as influenced by planted months -Chemelil site

Planted months	Varieties			Mean
	C0617	CB38-22	C0421	
	Yields (TCH)			
April	161.4	133.9	151.2	148.9*a*
May	84.8	82.7	113.8	93.8*b*
June	98.9	92.2	109.9	100.4*b*
July	57.8	68.4	49.4	58.5*c*
Mean	100.7*a*	94.3*a*	106.1*a*	
CV%	25			

Means with same letter are not significantly different at alpha=0.05

At Mumias site, varieties C0 421, C0 945 and KEN83-737 were superior in cane yields to D8484 at 20 months of harvest, Table 2 (ii). Sugarcane variety D8484 may have done poorly because it is an early maturing crop and it's harvesting at 20 month may have partly contributed to its poor yields at 20 month harvesting. All planted months were similar in cane yields except July planted cane which had significant low yields (109.9 t ha^{-1}), Table 2(ii). There is some yield advantage of 10% when cane is planted during the long rainy season (April to June) compared to the short rainy season (August to November). The high coefficient of variation (CV %) in the two sites (Chemelil and Mumias) may partly be attributed to poor crop establishment in some months occasioned by contractors who erroneously removed some cane setts during manual weeding period.

Table 2(ii): Cane yields (TCH) as affected by planted months - Mumias site

Planted months	Varieties				Mean
	KEN83-737	D8484	CO945	CO421	
	Yields (TCH)				
April	121.7	124.2	145.4	170.4	140.4*ab*
May	127.3	149.6	158.1	133.4	142.1*a*
June	146.3	133.4	154.2	116.5	137.6*ab*
July	104.4	101.9	92.3	141.1	109.9*c*
Aug	125.4	113.8	125.1	136.1	125.1*abc*
Sep	142.1	88.8	161.1	158.1	137.5*ab*
Oct	140.9	118.3	121.5	124.4	126.3*abc*
Nov	138.3	73.1	117.3	138.3	116.8*bc*
Mean	130.8*a*	112.9*b*	134.4*a*	139.8*a*	
CV%	20				

Means with same letter are not significantly different at alpha=0.05

At SONYsugar site, variety EAK70-97 was superior to N14 and C0421 in cane yields (9 and 20% yield advantage, respectively) while the latter maintained significant low yields, (Table 3). However June plant crop gave superior cane yields (152.6 tha^{-1}) followed by September plant crop. April, May July and August plant crop gave significant low cane yields. There is 9% yield advantage when cane was established in the long rains (April to June) than in the short rainy period (August to November period). Although cane quality was not affected by month of planting 8% more sugar could be made in the long rainy season. On harvesting ages, 16months harvested crop gave significant low cane yields (126.9 t ha^{-1}) and of low quality while 17^{th}-19^{th} harvested crop had similar cane yields and quality while 20^{th} month of harvesting was superior in cane yields and quality. At this site interaction of variety, planting seasons and harvesting ages was highly significant indicating that time of planting affected cane yield but not quality. Harvesting ages on the other hand affected both cane yields and quality. Although cane quality monitoring stopped at 20^{th} month, cane quality improved with age beyond 20^{th} month.

Table 3: Plant crop cane yields and quality as affected by varieties, planting seasons and harvesting ages- SONY sugar site

		TCH	POL % Cane	TSH	Fibre % Cane	Purity %
Varieties	EAK70-97 (v1)	146.4*a*	15.15*a*	22.2	15.54*a*	91.59*a*
	N14 (v2)	133.9*b*	15.10*a*	20.2	15.00*b*	91.72*a*
	C0421(v3)	122.2*c*	14.66*b*	17.9	15.31*a*	91.28*a*
Planting seasons	April (m1)	132.7*c*	15.14*ab*	20.1	14.88*b*	90.88*ab*
	May (m2)	136.9*c*	14.81*bc*	20.3	15.36*a*	92.37*ab*
	June (m3)	152.6*a*	14.88*bc*	22.7	15.72*a*	91.97*ab*
	July (m4)	135.4*c*	14.66*c*	19.9	15.26*ab*	91.28*ab*
	Aug (m5)	133.5*c*	15.26*ab*	20.4	14.81*b*	91.76*ab*
	Sep (m6)	145.2*b*	15.51*a*	22.5	14.79*b*	92.52*a*
	Oct (m7)	106.6*d*	14.87*bc*	15.9	15.57*a*	90.46*b*
	Nov (m8)	130.1*c*	14.69*c*	19.1	15.72*a*	90.97*ab*
Harvesting ages	16 mths (h1)	132.6*b*	14.72*b*	18.7	15.31*a*	91.30*ab*
	17 mths (h2)	126.9*b*	14.85*b*	20.0	15.41*a*	91.48*ab*
	18 mths (h3)	135.0*a*	14.86*b*	20.3	15.50*a*	91.47*ab*
	19 mths (h4)	136.3*a*	14.68*b*	20.1	15.51*a*	90.77*b*
	20 mths (h5)	136.8*a*	15.75*a*	21.4	14.66*b*	92.63*a*
CV %		13	6		7	4

Means with the same letter are not significantly different at alpha=0.05

Similarly, at Kibos site, planting seasons, varieties and harvesting ages affected cane yields. Superior cane yields were observed from June plant crop, followed by July up to October plant

crops. April and May plant crops gave significant low cane yields, (Table 4). Sugarcane variety KEN83-737 had superior cane yields followed by C0421 while C0945 had significantly low cane yields. Superior cane yields were observed from 16th- 19th harvested crop while the 20th month harvested crop gave significant low cane yields. Significant interactions were observed from planting seasons and varieties; planting seasons and harvesting ages. At Kibos site better cane yields were observed compared Chemelil site, though having similar climatic conditions, due to supplemental irrigation undertaken during the early growth stages.

Effect of planting and harvest time on sugarcane quality

At Sonysugar site, sugarcane quality (POL % cane) was affected by sugarcane varieties, planting seasons and harvesting ages although the interaction was not significant. Sugarcane varieties EAK 70-97 and N14 were superior to C0421 in POL % Cane, (Table 3). On planting seasons, superior cane quality was observed from September, August and April planted crops. In addition to that significant cane qualities were observed from 20th month harvested crop followed by 17th-19th month harvested crop. On the other hand the 16th month harvested crop gave significantly the lowest POL % cane compared to other harvesting ages. Fibre % cane was similarly affected by variety, planting seasons and harvesting ages. Variety N14 had significant low fibre compared to EAK70-97 and C0421. April, August and September planted cane had significant low fibre % cane. On harvesting ages, the 20th month harvested crop showed significant low fibre % cane. The interaction of variety, planting seasons and harvesting ages was significant indicating that there was also an influence on planting and harvesting on fibre % cane. These results concurred with observations made by McDonald and Lisson, (2001) which indicated that planting time and harvesting ages affected both cane and sugar yields. High cane yields favoured high cane quality, hence sugar yields. This concurred with Lisson *et al.,* (2005) finding that biomass (cane weight) accumulation was the dominant factor affecting sucrose content.

Table 4: Sugarcane plant crop yields as affected by planting seasons, varieties and harvesting ages - KESREF-Kibos site

		TCH	POL% cane
Planting seasons	April (m1)	132.5*c*	14.9*d*
	May (m2)	123.3*d*	15.4*c*
	Jun (m3)	154.6*a*	15.9*ab*
	July (m4)	141.7*b*	15.4*c*
	Aug (m5)	146.4*b*	16.3*a*
	Sep (m6)	143.0*b*	15.5*c*
	Oct (m7)	139.5*b*	15.3*c*
	Nov (m8)	81.3*e*	14.8*d*
Varieties	KEN83-737 (v1)	141.6*a*	15.3*a*
	C0945 (v2)	124.5*c*	15.5*a*
	C0421 (v3)	134.0*b*	15.4*a*
Harvesting ages	16 mths (h1)	138.7*a*	14.7*c*
	17 mths (h2)	136.7*a*	15.4*b*
	18 mths (h3)	136.1*a*	15.6*ab*
	19 mths (h4)	135.7*a*	15.4*b*
	20 mths (h5)	121.3*b*	15.9*a*
CV %		12	5

Means with the same letter are not significantly different at alpha=0.05

Conclusions

At SONYsugar site, representing humid conditions, harvesting for all cane varieties may commence from 17th to 20th MAP. Bulk of sugarcane planting may be undertaken during the long rains due to cane and sugar yield advantage of 9 and 8%, respectively. Sugarcane planting in the month of July should be avoided due to significant low cane yields and quality in all the 4 sites partly due to

limited moisture availability for cane establishment except where irrigation is available to supplement the rainfall. However at Kibos site, representing sub humid conditions, cane harvesting should commence on 16th to 20th MAP.

Way Forward

The trial is in progress since data collection on other phases (2005 and 2006 planted crops) is on-going.

Acknowledgements

The authors are grateful to the Director-KESREF for financial and logistical support, Biometricians for data analysis, Technicians for data collection, colleauges for useful comments. The authors also to aknowledge the companies agronomists for their input provision and trial management.

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EVALUATION OF TROPICAL SUGARBEET (*Beta Vulgaris – Saccharifera*) FOR ADAPTATION AND YIELD IN KENYA

J. Omollo and G.O. Abayo

Introduction

Advancement in sugar beet breeding has led to development of more heat tolerant varieties also known as Tropical sugar beet (TSB) suitable in the tropical regions where Kenya is located.

These varieties have gained momentum and created interest in tropical and subtropical countries as a promising source of sugar. Some of the major advantages put forward are their shorter period for harvest around 5-6months, sucrose content ranging from 12-15% and yields ranging 50-60tha^{-1}. Other values are its use as livestock feed and also promising alternative energy crop for production of ethanol.

KESREF therefore endeavored to undertake research on Tropical sugarbeet varieties, their performance and adaptation in the Kenyan sugarcane growing zones and also develop management practices ranging from crop establishment in the field, maintenance, harvesting and processing to sugar.

The sustainability of Tropical sugarbeet production in Kenya can only be possible if the biophysical (agronomic) factors affecting it are assessed and appropriate management practices adoptable to local environment are developed.

It was envisaged success of the trials will culminate in increased sugar production therefore a boost in the Kenyan sugar industry to satisfy the ever increasing local sugar demand. This will therefore form an alternative source of sugar to supplement sugar from sugarcane.

Materials and methods

Trials on evaluation of TSB varieties for adaptation and yield began in 2001 to 2006. A total of 10 varieties were evaluated.

Trials at KESREF – Kibos site were laid out in two soil types, *Eutric cambisol* (red soils) and *Eutric vertisols* (black soils), in two rainy seasons, short and long rains. Trials at SONY Sugar Co. and NZOIA Sugar Co. nucleus site were laid out during the long rains in 2006.

Randomized complete block design was used with 3 replicates. Plot size was 3 x 3metres, while the spacing was 60cm x 15cm.

Parameters observed were germination, diseases and pests. Harvesting was done manually 6months after planting. The tubers were weighed to determine the yield and samples taken for quality analysis of sucrose content (pol %). Sugar content was determined using a sacharimeter, after making a pulp and clarification using lead acetate.

Results and discussions

The results for variety Posada at different rates of Phosphorus and Nitrogen in 2001 are shown in Table 1. Yields recorded ranged from 20.7 - 62.5 tha^{-1} with the yield >50tha^{-1} comparable to results recorded in Australia and Tamil Nadu which indicated yields ranging from 50-60tha^{-1} as good (Morgan *et al*., 1995; Tamil Nadu Agricultural University, 2006 and Weeden, 2000)

In 2004, results of six varieties evaluated for adaptation and yield at *Eutric vertisol* siols at KESREF – Kibos during long and short rains as shown in Tables 2 and 3. Low germination was attributed to inadequate moisture, however yields recorded ranged from 24.3 – 57 tha^{-1} while the Pol % beet ranged from 10.5 – 13%.

Table 1: Effect of beet variety, Posada, at different rates of Phosphates and Nitrogen

	Yield tha^{-1}	Population '000/ha	Rotten/ha
N and P_2O_5 $Kgha^{-1}$		Tubers	
0	20.7^{d}	505^{a}	2778^{a}
20	38.5^{c}	431^{bc}	3333^{a}
40	54.1^{b}	468^{a}	4445^{a}
60	48.0^{b}	467^{a}	4167^{a}
80	62.5^{a}	358^{e}	2778^{a}
100	60.1^{a}	381^{cde}	3889^{a}
120	58.9^{a}	361^{de}	4722^{a}
CV%	6.1	8.6	8.4

Table 2: Beet variety evaluation at KESREF - Kibos during long rains, 2004

Variety	Germination	Healthy	Infected	Dead	Total infected
			Percent %		
Tomba	77.3	6.3	14	57	71
Posada	74.3	6	11	57.3	68.3
Inger	64	9.7	10	44.3	54.3
H10141	63	7	7.7	7.6	15.3
Monza	22.3	4.3	11.3	47.3	58.7
Penta	15	2.7	7	5.3	12.3

Table 3: Beet variety evaluation at KESREF - Kibos during short rains, 2004

Variety	Germination %	Yield t/ha	Pol % beet
Posada	34.8	57	12.3
Inger	32.9	52	11.7
Tomba	37.5	59	12.1
Monza	23.2	43.4	13
H10141	26.6	27	11.4
Penta	11.6	24.3	10.5
CV%	12.1	12.8	4.2

In 2005, results of six varieties evaluated for adaptation and yield at *Eutric vertisol* and *Eutric cambisol* in long rains is shown in Table 4 at KESREF. There was improved germination compared to planting during short rains. Yields were not attained due to crop failure four months after planting. This was attributed to disease infection. Report by plant pathologist revealed diseases as Rhizoctonia crown, Rhizoctonia foliage blight caused by *Rhizoctonia solani* and Sclerotium root rot caused by *Sclerotium rolfsii*.

In 2006, results of another four other varieties and 1 previous tested varieties were evaluated at KESREF – Kibos and SONY Sugar Co. is shown in table 5 and 6 respectively. Yield recorded from Kibos site ranged from 31.9 – 58.1tha^{-1} while the pol ranged from 12.3 – 13.5%. These are comparable to yield and pol recorded in Australia and Tamil Nadu.

Table 4: Beet variety evaluation at KESREF - Kibos during long rains, 2005

	Germination	Healthy	Infected	Dead	Total infected
Variety			Percent %		
Tomba	58.7	20	15.7	23	38.7
Posada	57.6	5.3	17.7	33.3	51
Inger	50.7	14	15	21.7	36.7
H10141	27	9.3	13.3	4.3	17.7
Monza	25.3	9	13	4	17
Penta	17	2.3	14.3	0	14.3

The results from SONY Sugar Co. nucleus site were not impressive as the range of yield was 7.0 - 24.5tha^{-1} while the pol % beet was 11.2 – 12.6. This was attributed to instances of inadequate moisture in the soil since the seeds were sowed mid May, 2006 when rainfall amount was low. Also disease attack by fungal pathogens was observed and no control measures were undertaken.

Table 5: Beet variety evaluation at KESREF - Kibos during long rains, 2006

			Healthy	Diseased	Average disease incidence
Variety	Yield tha^{-1}	Pol % beet	No. of tubers/plot		
TS50339	31.9^{b}	12.4^{b}	32^{b}	10^{a}	29.7
TS50335	55.1^{a}	13.5^{a}	56^{a}	3^{b}	4.7
TS50333	45.8^{ab}	12.3^{b}	42^{ab}	6^{ab}	19.6
H10141	58.1^{a}	13.1^{ab}	49^{a}	3^{b}	1.4
TS50337	49.3^{a}	13.4^{a}	54^{a}	1^{b}	1.9
Lsd	15.6	0.85	15	6	
CV%	17.2	3.5	17.4	69	

Table 6: Beet variety evaluation at SONY Sugar Co. nucleus site during long rains, 2006.

Variety	Yield t/ha	Pol%
TS50339	6.7b	11.6ab
TS50335	19.7ab	12.6a
TS50333	10.7ab	11.8ab
H10141	24.5a	1.6ab
TS50337	22ab	11.2b
Lsd	16.5	1.2
CV%	52.4	5.3

Yield and quality data was not available from the Nzoia Sugar Co. nucleus site due to crop failure attributed to inadequate moisture as a result of nature of the trial site which was sandy and sloppy. This Despite limited agronomic management practices some varieties yield recorded were within 50-60 tha^{-1} and pol % within 12-15 regarded as good. Varietal evaluation for adaptation revealed disease attack was varietals. Varieties such as H10141, TS50337 and TS50335 showed tolerance to disease attack which was manifested in their high yields. These results are similar to those in SONY Sugar Co. despite low yields where varieties H10141 recorded highest yield of 24.5tha^{-1} followed by TS50337.

Appropriate agronomic packages such as plant population, nutrient requirement (fertilizer rates), pests and diseases control, weed control, time for planting and harvesting vis a vis rainfall or irrigation water suitable for the given area if developed and applied will be able to counter the biophysical (agronomic) limitations leading to increased and sustained yields.

Studies on processing sugarbeet to sugar in Kenya also need to be explored. Studies in Australia showed a ratio of 15beet:85cane can be milled in a sugarcane processing channel (Morgan *et al*., 1995 and Weeden, 2000).

Seed availability locally is another limitation because seed production technology has not been explored under local condition in Kenya.

These recommendations can be possibly carried out by KESREF in collaboration with stakeholders in sugar industry and partners in sugarbeet research. Hence, the tropical sugarbeet production and processing could be a commercially viable and sustainable proposition if all the mentioned limitations are addressed.

Agronomic factors affecting performance and yield

During trial assessment, agronomic limitations identified which may lead to poor performance and yield decline were;

- Moisture availability; inadequate moisture leads to poor germination so is the crop establishment. This was the case in SONY and Nzoia Sugar Co. nucleus sites.
- Disease attack; Disease identified were Rhizoctonia crown, Rhizoctonia foliage blight caused by *Rhizoctonia solani* and Sclerotium root rot caused by *Sclerotium rolfsii*.
- Pests; signs of pest attack i.e. leaf cut and windows attributed to cutworms and beetles were identified.

Conclusions and recommendations

Despite limited agronomic management practices some varieties yield recorded were within 50-60 tha^{-1} and pol % within 12-15 regarded as good. Varietal evaluation for adaptation revealed disease attack was varietals. Varieties such as H10141, TS50337 and TS50335 showed tolerance to disease attack which was manifested in their high yields. These results are similar to those in SONY Sugar Co. despite low yields where varieties H10141 recorded highest yield of 24.5tha^{-1} followed by TS50337.

Appropriate agronomic packages such as plant population, nutrient requirement (fertilizer rates), pests and diseases control, weed control, time for planting and harvesting vis a vis rainfall or irrigation water suitable for the given area if developed and applied will be able to counter the biophysical (agronomic) limitations leading to increased and sustained yields.

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Acknowledgements

The authors are grateful to the Director-KESREF for financial and logistical support, Biometricians for data analysis, Technicians for data collection, colleuges for useful comments and the departmental Secretary for type setting the manuscript.

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COST REDUCTION STRATEGIES IN SUGARCANE PRODUCTION IN KENYA

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Abstract

Sugarcane production costs in the Kenyan sugar industry include such inputs as land preparation, acquisition of seed cane, fertilizers and herbicides, labour costs and cane transport to the factories. These costs have been increasing over time, in addition to processing costs. The result is high domestic sugar price in comparison to other sugar producing countries, thereby making Kenyan sugar non-competitive. This has led to reduced farmers' profits, a reason for some of them not paying much attention to cane management, and in turn resulting into low quality cane. Kenya is currently under a reprieve where the deficit sugar imported from COMESA countries has a zero-rated tax which is set to expire in February 2008. The production costs therefore, need to be reduced to make domestic sugar cheaper and hence competitive.

KESREF scientists undertook a study in West Kenya, Mumias, Chemelil and Sonysugar sugar zones with the aim of determining the high cost centers in sugarcane production and in collaboration with other stakeholders develop appropriate cost reduction strategies in the sugar industry. Interviews and participatory discussions were held with farmers, respective millers, contractors and farm inputs stockists. Six major high cost centers in sugarcane production were identified and ranked and they include cane transport, labour costs, levies, fertilizers, seed cane and land preparation. Sugarcane production cost reduction strategies were found to be zone specific. It is hoped that the recommendations contained in this report will help policy makers and other stakeholders in decision making that will lead to reduced cane production costs.

Introduction

A previous study undertaken by KESREF scientists (2005) on zonal sugarcane production constraints identified and ranked costs of farm inputs as one of the high ranking constraints in the sugar industry. In addition, a Cost Benefit Analysis (CBA) by KESREF socio-economists in August 2005 showed that the average return per shilling invested for plant crop was Kshs. 0.29, while that of ratoon crop stood at Kshs.0.88. Further, according to 'National Development Strategy: The Sugar Industry; Chapter 33' (2005), the most recent listing of the percentage share of proceeds attributable to the farmer indicates a range, with an average of 53% and a median of 61% over 19 countries, Kenya being one of them. This study shows that there is an approximate relationship between the cane grower's share of proceeds, on the one hand, and the ratio of labour costs to the value of the cane, on the other hand. Kenya's share of proceeds attributable to the farmer stands at 47% which is below the average, while the ratio of labour costs to the value of the cane is 0.13. Comparing the Kenyan situation with Mauritius, her share of proceeds attributable to the farmer stands at 64%, while the ratio of labour costs to the value of the cane is 0.26. The economic implication of this is that the farmer's income in Kenya is still low. Production costs must therefore be seriously addressed if farmers have to benefit from cane farming. This study therefore aimed at coming up with recommendations, which will go a long way in addressing the problem of high costs of cane production in Kenya.

The objective of this study was to identify and analyze factors that contribute to high costs of sugarcane production in Kenya.

The specific objectives of the study were:

1. Determining the cost composition of inputs in sugarcane production.
2. Evaluating the components against known targets.
3. Recommending strategies of reducing the costs.
4. Identification of researchable and policy interventions.

The expected output of the study was technical information of the recommendations on reduced sugarcane production costs strategies, given on zone specific, while others are general in that they cut across zones. The expected impact was suggested policies/recommendations that will be availed to the relevant stakeholders for implementation purposes with the aim of making the sugar industry more competitive.

Methodology

A team of scientists from KESREF visited four selected sugarcane growing zones (Mumias, West Kenya, Chemelil and Sony Sugar) in October 2005. In the first phase of the survey, the respective zonal Extension Officers in collaboration with out growers companies' representatives and sugar companies identified relevant farmers, contractors (land preparation and cane transporters) and farm inputs stockists. The team then visited these groups in their respective operational sites and carried out interviews using pre-designed questionnaires to solicit information on input levels, cost components and possible intervention measures. The farmers selected were the opinion leaders i.e. contact farmers, with up-to-date farm records. The information collected was then analyzed using statistical techniques. High cost centers in each study zone were identified from these interviews.

In the second phase of the survey, discussions on cost reduction strategies were held. The discussion team comprised of scientists from KESREF, together with the millers and out growers in each of the study zones. The team discussed and harmonized the costs reduction strategies recommended. The discussions were based on the high cost centers that were identified from the first phase.

Results and Discussions

The study identified six major cost components in cane production. These included land preparation, seed cane, fertilizers, labour, cane transportation and levies instituted on cane (Table 1 and Figure 1). A critical analysis of these costs indicates that the largest proportion of the costs is harboured in the cane transportation (28% for Pc and 42% in the Rc of the total costs). This is followed by labour costs which account for 22% in the Pc and 31% in the Rc of the total costs, levies accounting for 18% in the Pc and 14% in the Rc. These are followed by the fertilizers, seed cane and land preparation in that order. However, this order may change when one focuses on the individual sugar cane production zones.

The individual cost components are hereby discussed while recommendations are given on how costs could be lowered in order to make the Kenyan sugar more competitive, based on what farmers identified as high cost centers.

Table 1 shows the costs of the various operations which were arrived at by summing up all the components of each operation, while Tables 2, 3, and 4 show the rates charged for the various operations and inputs. The breakdown of the total costs have also have been presented graphically in Figure 1.

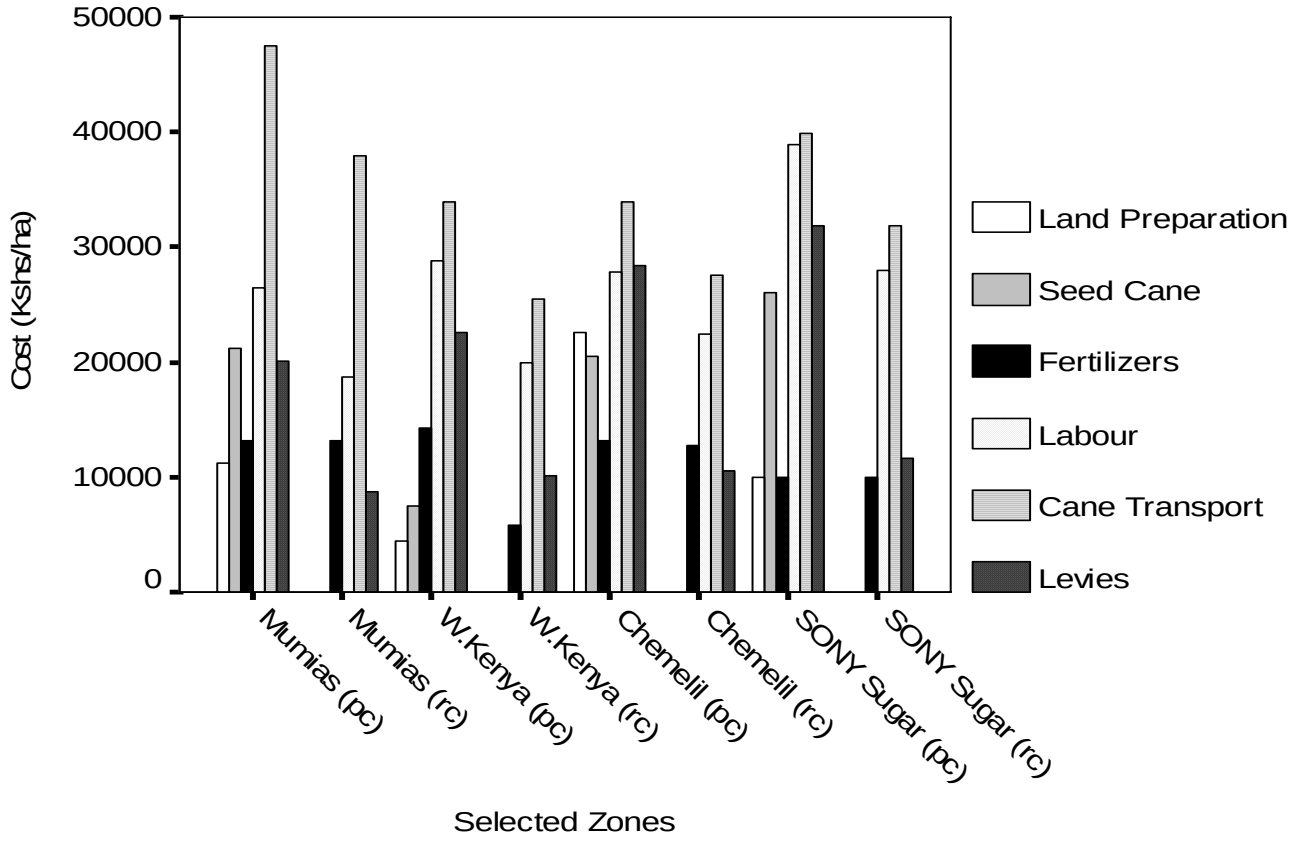


Figure 1: The cost components of cane production by selected sugar zones

Table 1: Individual cost and proportion of cane production by selected sugar zones per hectare

	Mumias				West Kenya				Chemelil				Sonysugar			
	Plant Crop		Ratoon Crop		Plant Crop		Ratoon Crop		Plant Crop		Ratoon Crop		Plant Crop		Ratoon Crop	
Activity/Operation	**Subtotal**	**%**	**Subtotal**	**%**	**Subtotal**	**%**	**Subtotal**	**%**	**Subtotal**	**%**	**Subtotal**	**%**	**Subtotal**	**%**	**Subtotal**	**%**
Land preparation(kshs)	11188	8.0	-	-	4500	4.0	-	-	22579	15.4	-	-	10000	6.4	-	-
Seedcane (kshs)	21176	15.2	-	-	7500	6.7	-	-	20540	14.0	-	-	25985	16.6	-	-
Fertilizers(kshs)	13200	9.5	13200	16.8	14210	12.8	5800	9.5	13125	9.0	12700	17.3	10038	6.4	10038	12.3
Labour(kshs)	26434	18.9	18686	23.8	28750	25.8	19900	32.5	27820	19.0	22490	30.7	38911	24.8	27911	34.2
Cane transportation(kshs)	47500	34.0	38000	48.4	33920	30.4	25440	41.6	34000	23.2	27625	37.7	39900	25.5	31920	39.1
Levies(kshs)	20039	14.4	8685	11.1	22554	20.2	10051	16.4	28348	19.4	10532	14.4	31854	20.3	11666	14.3
Total cost/ha (Kshs)	139,537	100	78,571	100	111,434	100	61,191	100	146,412	100	73,347	100	156,688	100	81,535	100

Note: Overall proportion of costs:

1. Land preparation; Pc – 8.5%
2. Seed cane; Pc – 13.1%
3. Fertilizers; Pc – 9.4%; Rc – 14.0%
4. Labour; Pc – 22.1%; Rc – 30.3%
5. Cane transport Pc – 28.3%; Rc – 41.7%
6. Levies Pc – 18.6%; Rc – 14.1%

Assumptions:

(1) Yield levels - 100 tch and 80 tch for Pc and Rc respectively for all zones except Chemelil (80 tch for Pc and 65 tch for Rc).

(2) Cane prices – Kshs/ton – Mumias (2,000); West Kenya (2,219); Chemelil (1,950); Sony Sugar (2,000).

(3) Transport zone – 16.1 to 20 km (i.e. zone C for West Kenya and Chemelil; and zone E for Mumias and Sony Sugar).

Cane Transport

Cane transport is the highest production cost across all zones, ranging from 23-42% of total production cost. High transport costs are as a result of poor roads which lead to a high rate of breakage of the transport units and hence a high frequency of replacement of spare parts. Tyres and tubes also wear out faster and they have to be replaced. Spare parts, tyres, tubes and other inputs are costly, hence increasing the transport costs.

Table 2 shows that Mumias has the highest transport rate. The same band (16.1-20 km) was compared across all zones, where Mumias charges the highest rate/ton of Kshs 475, which translates to 23.75 Kshs/km. For the same band, West Kenya charges 17.67 Kshs/km. Further comparison was made between factories that share the same zoning system (Figures 2 and 3). Mumias charges higher than SONYsugar for the same bands apart from the last two. West Kenya charge lower for the first band and higher for the last two bands than Chemelil. The companies should therefore harmonize the rates so that they charge the same rate for similar bands. On average i.e. A-J zonal charges for Mumias and SONYsugar, and A-E zone charges for W. Kenya and Chemelil, the 10 km band appears cheaper in terms of Kshs/km as seen in W.Kenya and Chemelil (19.60 and 19.81 Kshs/km), in comparison to the 4km band for Mumias and Sony Sugar (27.22 and 23.96Kshs/km). In terms of Kshs/ton, Sony Sugar is the cheapest (409Kshs/ton), followed by Chemelil, W. Kenya and lastly Mumias charging the highest (449 Kshs/ton). From Fig. 4 it is seen that the cost of cane transport /km/ton is higher for short distances (Kshs 67) of haul than for long distances (Kshs 13.68). However, as the distances increase, costs/km/ton tend to merge for all zones. Thus the present system tends to disadvantage those close to the factory and favour those far away. The reason for this is unclear, unless it is for the purposes of giving incentives to farmers located far away from the factories. There are distinct advantages in charging transport cost on a flat rate basis because of the relative ease in cost computations, but more so because every farmer will be charged fairly in terms of the distance from the factory. The recommended cost is Kshs 20 /km/ton i.e. Kshs (16+ (16*36%)); based on the KSB Cane transport Study findings (2003). Inflation rate was assumed as 16%.

Table 2: Cane transportation rates across selected sugar zones

Zone		Mumias Zone				West Kenya Zone				Chemelil Zone				Sonysugar Zone			
		Band (km)	Mid (Km)	Ksh/ ton	ksh/ km/ton	Band (km)	Mid (Km)	Ksh/ Ton	Ksh/ km/ton	Band (km)	Mid (Km)	Ksh/ ton	Ksh/ km/ton	Band (km)	Mid (Km)	Ksh /ton	Ksh/ km/ton
A	1	0-4	2	268	67	0-10	5	270	27	0-10	5	290	29	0-4	2	251	62.75
B	2	4.1-8	6	314	39.25	10.1-16	13	342	21.38	10.1-16	13	347	21.69	4.1-8	6	251	31.38
C	3	8.1-12	10	365	30.42	16.1-24	20	424	17.67	16.1-24	20	425	17.71	8.1-12	10	288	24.00
D	4	12.1-16	14	426	26.63	24.1-32	28	522	16.31	24.1-32	28	502	15.69	12.1-16	14	326	20.38
E	5	16.1-20	18	475	23.75	32.1-40	36	625	15.63	32.1-40	36	598	14.95	16.1-20	18	399	19.95
F	6	20.1-24	22	521	21.71					>40	-	-	-	20.1-24	22	399	16.63
G	7	24.1-28	26	523	18.68									24.1-28	26	498	17.79
H	8	28.1-32	30	525	16.41									28.1.32	30	498	15.56
I	9	32.1-36	34	527	14.64									32.1-36	34	590	16.39
J	10	36.1-40	38	547	13.68									36.1-40	38	590	14.75
K	11	>40	-	-	-									40.1-44	42	680	15.45
L	12													44.1-48	46	701	14.60
Av				**449**	**27.22**			**437**	**19.60**			**432**	**19.81**			**409**	**23.96**

Source: Sugar companies.

Notes:
1. Mid refers to the mid-point of the band.
2. The rates used obtained at the time of the survey.

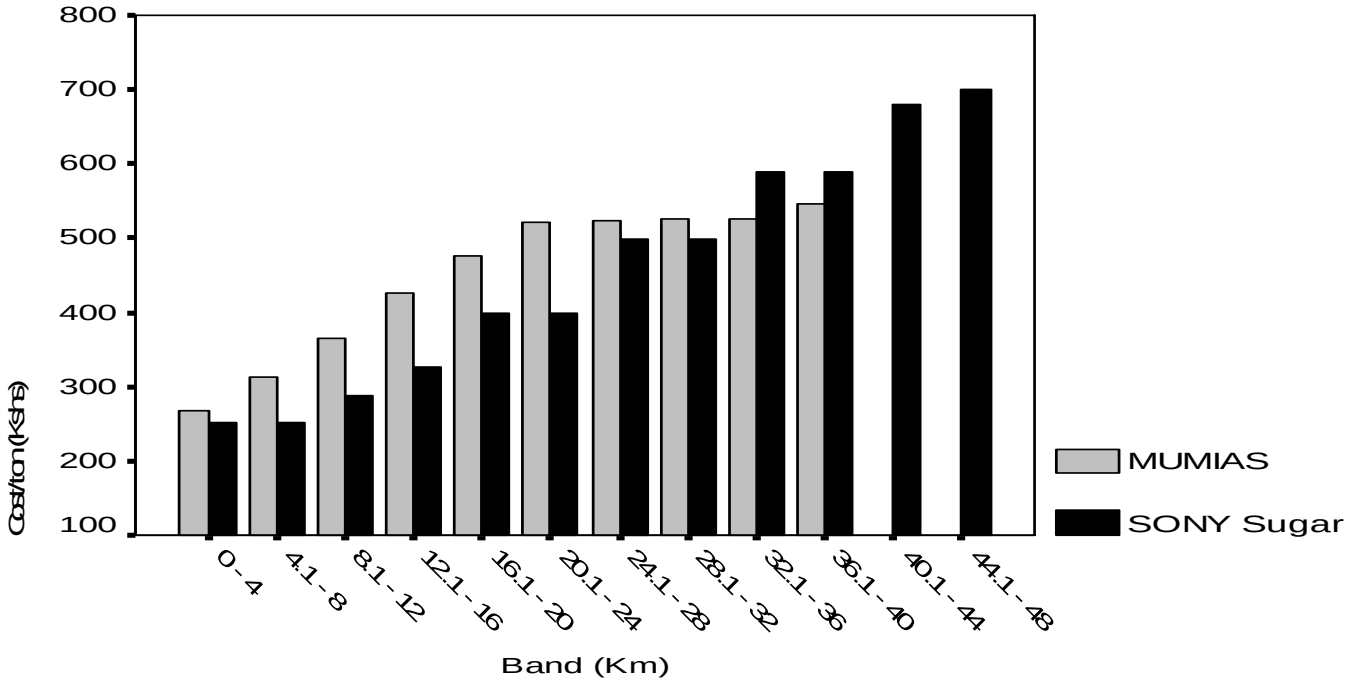


Figure 2: Comparison of cane transport rates for Mumias and SONY Sugar zones

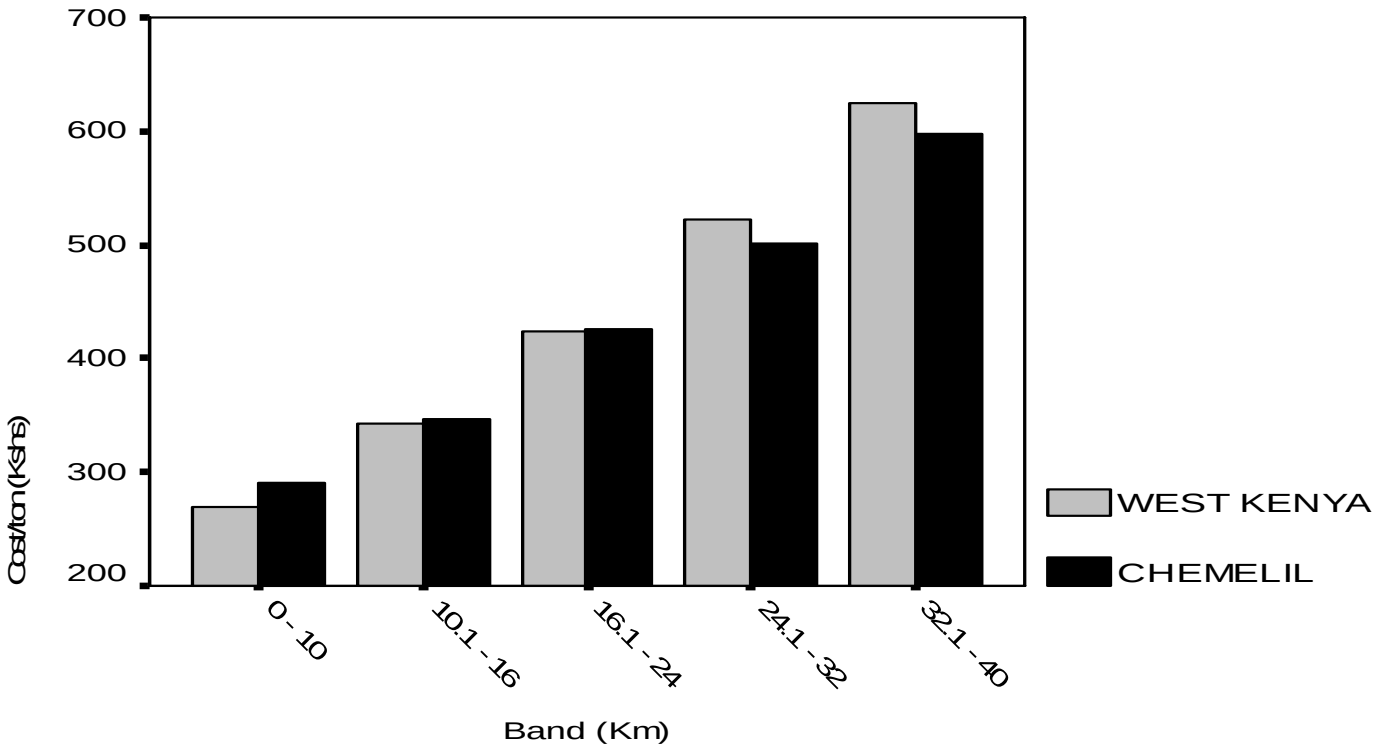


Figure 3: Comparison of cane Transport Rates for W. Kenya and Chemelil sugar zones

Table 3: Land Preparation Rates across sugar Zones (Ksh/ha)

Operation	Mumias		West Kenya		Chemelil		Sonysugar	
	Company	**Private**	**Company**	**Private**	**Company**	**Private**	**Company**	**Private**
1st plough	4248	-	-	3960	8776	10540	4200	3668
2nd plough	-	-	-	3333	-	7548	4200	2333
1st harrow	3000	-	-	2250	3433	6163	2400	-
2nd harrow	2340	-	-	-	3034	-	2000	-
3rd harrow	-	-	-	-	2055	-	-	-
Furrow	1600	-	-	500	2100	3143	1400	1028
Total	**11,188**	**-**	**-**	**10,043**	**19,398**	**27,394**	**14,200**	**7,029**

Source: Relevant Sugar companies
Sample Contractors mean rate.

Table 4: Input Prices (Kshs/unit) as reported by Stockists in the sugar zones

Input	Mumias	West Kenya	Chemelil	Sony Sugar
Fertilizers				
DAP(50kg)	1700	1690	-	1693
CAN(50kg)	1550	1400	1500	1500
Urea(50kg)	1520	1525	1600	1553
NPK (50kg)	-	1540	-	-
Herbicides				
Roundup (ltr)	1310	-	1000	938
Sencor (ltr)	1475	-	-	1567
Fungicides				
Confidor (ltr)		6800	-	6500

Source: Sample stockists mean rate

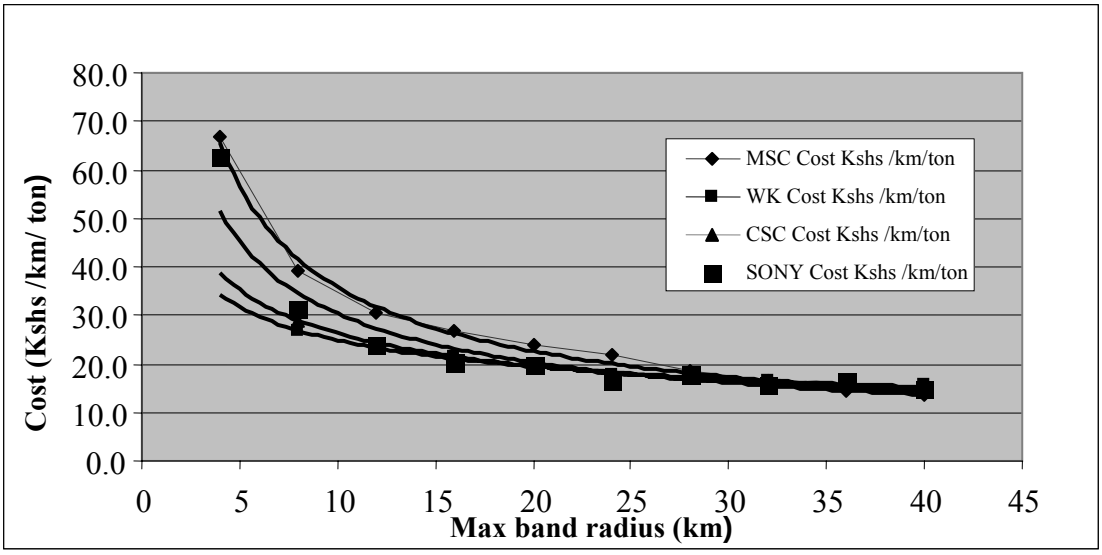


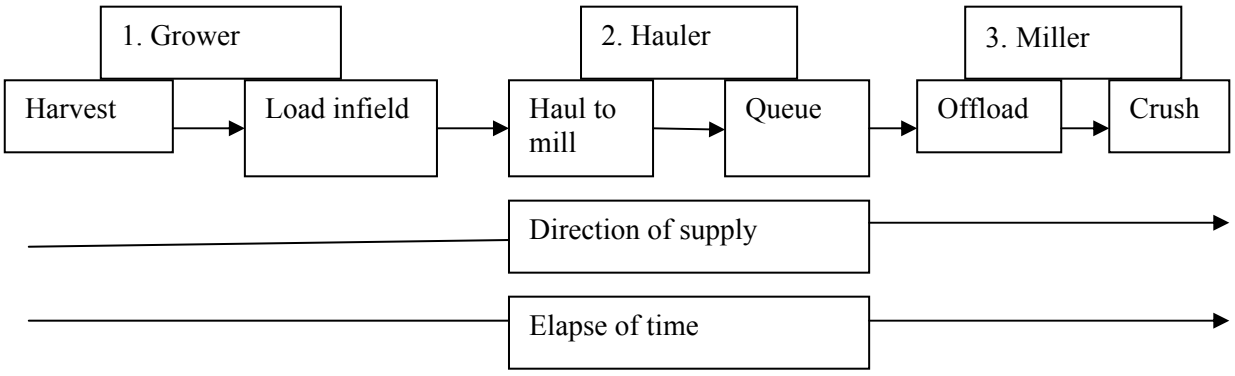
Figure 4: Cost of cane transport in all zones

High fuel costs are not only as a result of the world fuel price increases, but also due to high consumption by the transport units. The poor roads call for use of high hp units which consume more fuel. W. Kenya and Chemelil which charge less (Fig.1) have their transport units having the same hp i.e. 90, with those of Mumias and Sony, so probably the latter should reduce their rates.

Another factor that leads to high fuel consumption is the fuel siphoning from the tractors by the drivers. This was reported to be a rampant practice in the sugar industry. This needs to be checked and appropriate corrective measures taken.

Generally, the costs are high more significantly due to low efficiency in cane supply chain which results in: Poor trailer utilization and over fleeting (tons of cane delivered/trailer), Long mill queue delays, Low trailer efficiencies, Long delays between cane burning and crushing The costs of these inefficiencies are transferred to the farmers.

There is need to spearhead an initiative to improve cane supply efficiencies by capturing logistical supply chain information in various zones, identify problems and best practice. The typical cane supply chain in Kenya is shown below:



Labour

Labour is the second highest production cost across the zones. The labour costs include all labour charges i.e. planting, topdressing, crop maintenance (weed control and rouging activities), harvesting and loading in some sugar zones. The labour costs range between 19-34 % of the total costs in both pc and ratoons. Sony Sugar shows a markedly high cost compared to the other zones whose rates are more or less similar and followed by West Kenya. One of the causes is labour

scarcity. Another cause is high frequency of operations, for example weeding (6 weeding for plant crop and 4 for ratoon crop). Mumias which has the same frequency of 6 and 4 weeding charges lower, hence it is possible for Sony to reduce their charges. It appears that the herbicides on the stockists' shelves are mostly used for maize and not cane.

Levies

Three items are captured here which include interest costs, cess and outgrower levies. The cause of high levies is high interest rates. W. Kenya, Chemelil and Sony charge 17%, 16% and 19% respectively, while Mumias charges 12%. Companies could reduce these rates in order to lower the cess component. The SDF loan is given at an interest rate of 5% p.a. for cane development. Cess is charged at 1% while outgrower levy range from 1-2% in each zone.

Fertilizers

The fertilizer costs across all zones range between 6-17% of the total costs. The farmers reported that the prices for fertilizers had significantly increased varying between 1400-1700 Kshs/50kg per bag of fertilizer. This makes the cost of fertilizers to be enormous, an area where farmers could make a saving if prices were lowered through tax concessions.

Seed Cane

Except for W. Kenya, seed cane costs are high in the other zones. The seed cane costs range between 7-16% of the total costs for the different zones. W. Kenya uses cane tops while the rest use setts. Setts are generally more expensive than tops, but more so their (setts) transport increases the cost. The transport is double i.e. from the donor's farm to the weighbridge at the factory, then to the recipient's farm. In most of the sugar zones, transport is charged at one and a half times the rate for mill cane transportation. Farmers do not grow their own seed cane; they are supplied by the sugar company.

Land Preparation

Land preparation cost is quite highest in Chemelil, at 15% of the total costs. This is because of heavy clay soils that require heavy machinery of high hp. High hp calls for more fuel consumption and maintenance costs. However, not all soils are heavy, others are light and do not have to be worked on with heavy machinery. The rate is also increased by frequent replacements of spare parts, tyres and tubes which break and wear out fast due the heavy soils, more so during the wet season. Chemelil also does many operations, i.e. two ploughs and at least two harrows.

Land preparation is cheapest in W. Kenya. This is due to the fact that farmers mostly use ox-ploughs which are cheaper not only in terms of rate/ha but also in maintenance. Mumias and Sonysugar have almost similar costs. In both zones, there is a delay of harrowing after ploughing which calls for additional ploughing to be done before harrowing thereby increasing the costs. There is need for proper timing in land preparation to get rid of unnecessary costs.

Suggested Cost Reduction Strategies

The cost reduction strategies recommended are as a result of the discussions held in the second phase of the survey between KESREF scientists, out grower representatives and the millers.

West Kenya Zone

High cost of cane transportation and monopoly. Cane transportation costs account for 30-42% of the total costs of cane development. Although private transporters are allowed, the off-loading system favors only the miller.

Proposals for reducing costs are:

- Roads should be repaired and maintained to reduce frequent replacement of tractors' tyres and tubes and other parts; government should also exempt VAT from tyres and tubes, tractors and fuel. This is likely to increase both cane production and profit to the farmer.
- Cess money for roads repair should be left to the factory since they know well which roads need repair; since this money is recovered from the farmer, all of it should be retained by the miller for this purpose.
- There is need to exempt VAT from parts that are used to build agricultural transport units; currently, these parts are charged VAT when they are used to build trailers, yet ready assembled trailers are exempted from the tax.
- Short cuts including bridges can be made so as to reduce transport distance.
- Private transporters are technically allowed to transport farmers' cane. However, the private contractors should conform to the off-loading system of the company; this involves change of the trailer by making it more flat; in addition, they should have a winch on the trailer, which requires some small extra cost to install. This will allow the farmers to negotiate for the transportation rates.

Cane loading costs are high. The factory advances Kshs800 per trailer to the farmers in order to facilitate this process. However, farmers end up paying more, as the driver demands an extra Kshs200-300, while the loaders ask for extra payment when the farm is inaccessible; a farmer therefore ends up paying between Kshs1000-1500 instead of the Kshs 800 per trailer.

Proposals for reducing costs are:

- The factory should bear the cost of loading while farmers take care of harvesting costs; or factory takes care of both harvesting and loading so that they utilize the Kshs800 only instead of advancing it to farmers. This will save farmers' costs since they will not incur extra charges for drivers and loaders where the farms are not easily accessible. Drivers are paid per ton of cane delivered to the factory, hence there is need to educate farmers on the payment mode so that they stop paying unnecessary costs to the drivers.
- The out grower company (WEKO) should help farmers by contracting and registering cane cutters and loaders who should be paid on piecemeal basis. This will prevent them from exploiting farmers by demanding high pay.

Use of cane tops as seed cane leads to poor yields and low ratoonability. The uprooting of cane after 2nd ratoon increases costs of land preparation in the long term.

Proposals for reducing costs are:

- Quality seed cane should be used to increase ratoonability. This will reduce frequency of uprooting and land preparation hence reducing costs associated with this frequency. For those farmers leasing land, they could request the land owner for extension upto the 3rd ratoon. WEKO could also facilitate availability of seed cane by having some farmers grow it for supply.
- Management of seed cane should be improved and farmers should be educated on this.
- Research should be undertaken to compare the performance of cane tops versus setts in terms of germination, yields, ratoonability and economics. Farmers claim that cane tops germinate better under drought conditions than setts because they are more succulent than setts, and the water helps in facilitating a quick germination process. ***KESREF will undertake a study in the short-term to verify this claim.***
- Fertilizers should be made affordable to increase ratoonability. This will increase yields thereby reducing costs. Bulk purchasing of fertilizers by KSB through direct importing for the sugar industry would reduce their cost. It could then be supplied to regional stores where farmers could easily collect it. This could reduce the cost which would otherwise be higher to the farmers if the factory stored and later transports to them.

Delayed harvesting. Harvesting period of 36 months (3 yrs) leads to low yields**,** poor ratoonability and low return per shilling. When a farmer takes a loan or leases land to grow cane, it implies that he/she pays back with high interest and therefore stands losing his money.

Proposals for reducing costs are:

- The factory should improve on cane harvesting by doing it at the right time. This could be achieved through factory expansion in order to handle all farmers' cane. W. Kenya has set the pace in this direction by expanding the tcd from 1250 to 2500.
- There should be synchronization of planting and available crushing capacity programs.

Mumias Zone

High cane transport costs. Cane transport cost is high, it takes a high percentage of total revenue**.** Farmers are not comfortable with the 4 km band zoning system.

Proposals for reducing costs are:

- Short cuts by constructing bridges could lead to reduced transport distance and hence save on transport costs. This could help some farmers to move from far zones to nearer ones.
- Farmers should form co-operative societies or self-help groups to aid them in buying tractors and carry out their own transport. They could get loans from Kenya Sugar Board (KSB) or elsewhere. Farmers could also agree on lower rates with the out grower company.
- There should be a review of transport costs every two years. The farmers and transporters should discuss and arrive at a consensus on the rates that should be charged based on realistic costings.
- Farmers should be educated to understand the zoning system. The system should be developed considering the three parties i.e. the farmer, contractor and the miller. The current cost/ton should be reduced.

Poor land preparation standards and high interest rates. The poor land preparation standards make this operation expensive due to the need for extra operations in the passes and frequency of weedings.

Proposals for reducing costs are:

- More farmers should be educated on land ownership so as to increase collective responsibility. Most farmers lack ownership in that they are not available during land preparation and other crucial operations.
- Farmers should sign Job Completion Certificate (JCC) by following standards that are already set by the miller. The contractor should not be paid before the farmer signs the JCC.
- The miller should also help farmers by supervising the contractors when preparing land to ensure they do quality work. This would reduce the number of weedings and hence the costs.
- Quality of machinery should be improved. Speed should be reduced during harrowing to ensure quality work.

Cost of seed cane is high due to high transport cost. Farmers do not seem to know how much tonnage they get, hence paying more or less than they get. They are also not aware how the costs are compared and they end up paying more than what they expect i.e. they pay more than the usual rate of Kshs 2,000/ton.

Proposals for reducing costs are:

- Seed cane should be sourced locally and supplied to many farmers at the same time so that they share costs.
- Seed cane development committee (SDC) should be formed in the zone. The SDC should identify suitable places where seed cane could be developed. It should also check on planting

to ensure farmers do not plant using overlapping method (unless when necessary) since this increases rate per hectare and hence increases farmers' costs. The committee should ensure seed cane is grown as seed cane and not mill cane.

Fertilizer prices are high since the interest charged after importation is high. The uses of both DAP and Urea in ratoons is questionable.

Proposals for reducing costs are:

- Farmers who are able should be allowed to import their own fertilizers or simply purchase on their own, from stockists since this would be cheaper.
- If the factory continues to supply, then prices should be negotiated. The factory should import directly to enjoy economies of scale, making it also cheaper for the farmer.
- Farmers who have access to Farm Yard Manure (FYM) should combine it with chemical fertilizers. They should be encouraged to practice mixed farming. Blending of fertilizers should also be considered since this might be cheaper. Bagasse should also be broken down into manure within 2-3 weeks and the farmers can then use it.
- Farmers should be educated on the benefits of fertilizer to arrest fertilizer diversion. There should be an enacted law to protect cane like it is with other crops (tea and coffee), so that farmers are responsible in managing the crop. Mumias Outgrower Company (MOCO) should distribute fertilizers on regional basis, and supervise the application to ensure there is no diversion.
- If cane is performing well, then the 2nd supply of DAP for ratoon should not be necessary since it is an added cost. However, research should be done to investigate whether the difference in yields is statistically significant when DAP is used and not used on ratoons. This should be accompanied by a Cost Benefit Analysis (CBA). KESREF should take up this.

Yield loss at weighbridge. Farmers complained that there is a lot of loss due to inaccurate weighing and this reduces their tonnage, thereby decreasing their return per shilling.

Proposals for reducing costs are:

- Accuracy at weighbridge should be looked into; some coordination by KSB should be done to ensure the weighbridge is in proper working condition; Agricultural Mechanization Services (AMS) is already being implemented to weigh the tractors without human intervention to ensure there is no manipulation.

Chemelil Zone

Land preparation. Although the official rate from the company is Kshs 8,776 for ploughing, farmers are charged highly by the contractors. The same rate is used for lighter soils yet they can be done at a cheaper rate. The rate is high due to two ploughings and delayed harrowing after first plough. Generally, the standard of land preparation by contractors is poor.

Proposals for reducing costs are:

- In heavy soils, there should be one plough and two harrows, while in light soils it should be one plough and one harrow, so long as operations are done timely.
- Land preparation charges should be based on the implements used. Heavy soils require mould board plough since it ploughs deeper, thereby facilitating water percolation and proper root penetration.
- Operational rates should be reviewed on a two year basis so that there is harmonization between Chemelil Sugar Company (CSC), Chemelil Outgrowers Company (COC) and Nandi Escarpment Outgrowers Company (NEOC) rates. Realistic rates should be set with the consideration that factory overheads are more. The contractors should also have in mind that they are there to facilitate cane growing and not just to make profits from the farmers.

- Research should be done on choice of implements i.e. between mould board and disc ploughs. Mould board is said to increase ratoonability and give better yields, while continuous use of disc plough is said to create hard pans. A CBA should be done to compare the two methods.

Weeding. Poor land preparation increases the number of weedings. For example, the rate is Kshs 2,000-2,500 per ha, and most farmers do 5-6 weedings for plant crop. This translates to Kshs 15,000 for only weeding. Timeliness of weeding is also a problem. The quality of seed cane also features as a problem leading to poor germination. Scantiness encourages weeds to grow.

Proposals for reducing costs are:

- Supervision of land preparation to ensure it is done properly and timely. JCCs are already there for all company operations. This would reduce the number of weedings.
- Loans to farmers to facilitate them do the land operations should be given on time, and their interest rates should be reduced. Farmers should also be sensitized on forward planning. They should be left to do some operations on their own and do them properly and timely.
- Tractor operators and contractors should be in- serviced on how to carry out operations effectively.
- Use of effective herbicides like Roundup combined with manual weeding would reduce the frquency of weeding and hence reduce costs. Farmers are very much aware of herbicides and they buy them, but they should be trained on proper application and timing of the same. Extension services should handle this.
- Inter-cultivation should also be done.

Fertilizers. It was indicated that company prices of fertilizers are too high as compared to market prices due to high interest rates and service charges charged. This makes the fertiliser cost to be one of the high cost centres.

Proposals for reducing costs are:

- There should be bulk sourcing of fertilizers by KSB.
- Farmers should be educated on the use of FYM as it may be a cheaper alternative. It is already being used in the nucleus estate and cane is responding well. It has been found to suppress weeds. The recommendation is 50-70 tons/ha. KESREF should research on how to compact it to make it easier to transport. COC and NEOC should explore the possibility of using their trailers to transport it to farmers.

Mill-cane transport. The cost cane transport is too high due to poor roads, high fuel cost and high cost of spare parts.

Proposals for reducing costs are:

- Self-transportation is cheaper. In the long run, farmers should be empowered to have their own transport units. Empowerment could be done by SDF through soft loans or any other source.
- Use of lorries to transport the cane for long distances would be cheaper. CSC already accommodates pick-ups and could accommodate lorries so long as the farmer does the offloading.
- Roads should be improved. Already there is an agreement between CSC and county council for CSC to take up a contract and repair the roads. The company should retain cess money since the county council does not know the sugar roads that require repair. In addition, some of the cess money is used on other things leaving a very small percentage for roads repair. Road maintenance levy held by KSB should also be channeled back to the company.
- Timely harvesting should be done to avoid wet weather conditions. Wet weather makes transport difficult and may lead to higher fuel consumption.

- Use of Double-Basket (DB) trailers should be encouraged since they carry more tonnage with less fuel consumption. Study done on the same zone has shown that DB trailers of 80-100 HP can carry 18 tons with a consumption of 18 litres, while Single-Basket (SB) trailers of 100 HP carry 7 tons with consumption of 15 litres.
- Possibility of having about 2-3 trailers towed by one tractor should be explored, so long as the roads are in good condition.
- Explore the possibility of having transloading zones, and the use of train boogies to transport the cane.

Seed-cane cost. The cost is too high since it has to be taken to the weighbridge and then transported to the farms. The cost is normally one and a half times the zonal transport rate for mill cane. The farmers do not know how the estimation of seed cane that each gets is done, making some to pay for a higher quantity than what they get. There is need to establish the optimum seed rate.

Proposals for reducing costs are:

- There should be use of mobile weighbridge to minimize the transport cost. Weighing at the farms would also ensure the donors and recipients of seed cane pay exactly for the quantity they donate and receive. The overall cost would then be reduced. Alternatively, estimation of seed cane according to hectares could be done without taking it to the weighbridge. More cost effective methods of estimating seed cane weight should be established e.g. calibrating grab loader or calibrating various stacks of cane. It should also be grown in strategic regions so that it is not only easy for farmers to get it, but also cheaper.
- Farmers should be allowed to grow their own seed cane using the right variety since it is cheaper. It should be certified by CSC, and in future KESREF should also join in the certification. Trash should be left on the seed cane to protect the buds, but its estimation should be well done. Topping should also be well done.
- More bridges should be constructed to create short cuts so as to reduce transport distance and hence cost.

Poor harvesting method. The cane is cut too high instead of at the base. This leads to cane loss by the farmer, more so by incurring the cost of stubble shaving. It also disadvantages the miller since most sucrose is at the base.

Proposals for reducing costs are:

- Proper supervision should be done to ensure that appropriate harvesting is done. JCCs have already been introduced. This will eliminate cost for stubble shaving and at the same time benefit the miller.
- Harvesting should be done at the right age. This should be based on the variety characteristics.
- Transporters who do unsatisfactory job should be taken to the sugar tribunal for the necessary action.
- There should be synchronization of planting and crushing capacity to ensure there is no delayed harvesting.

Sonysugar zone

Land preparation. The current company rates for land prepartion are very high. There is delay in land preparation especially after 1st plough, also delay before harrowing allows weeds to grow making it necessary to replough, hence increasing costs. Quality of work by contractors is also poor.

Proposals for reducing costs are:

- The land preparation rates should be based on soil type and not the tractor HP.
- An independent body should come up with realistic estimates to assist in the review of the land preparation rates. KESREF could do this.

- Better planning for land preparation should be in place to avoid delays. The number of implements should match number of operations to reduce delay.
- The second harrow should be made optional. It may not be necessary where the land has weathered well. The farmer should request for it if he finds it necessary. A CBA should be done to compare use of 1 plough and 2 harrows, 2 ploughs and 1 harrow.
- Farmers should combine tractor and oxen use since it is cheaper. Farmers who are able to prepare land with their own tractors should be encouraged. Small-scale farmers should use oxen for land operations since this is more economical. They are already being encouraged to do most operations on their own.
- Proper ploughing should be done and soil given time to weather. JCCs are already in use to take care of work quality in all operations.
- Disc ploughs are in use and should continue being used, with occasional ripping to avoid formation of hard pans. Mould board plough inverts the furrow slices fully exposing the subsoil which is less fertile. The consequence is that it takes long for soil benefits to be realized in terms of yields.
- Possibility of conservation tillage in cane production should be considered.

Seed cane cost. The cost is too high since it has to be taken to the weighbridge and then transported to the farms. The cost is normally one and a half times the zonal transport rate for mill cane due to the double movement. The farmers do not know how the estimation of seed cane that each gets is done, making some to pay for a higher quantity than what they get. The interest rate charged is quite high. It is 19% up to 24 months on services offered.

Proposals for reducing costs are:

- There is need to establish the optimum seed rate and farmers need to be educated on the estimation of seed cane. A small sample is weighed at the weighbridge and used to estimate the tonnage farmers require. Seed-cane should be sourced locally to reduce transport cost.
- Farmers need to be educated so as to stop extending the surveyed area. After survey, some go ahead to plant unsurveyed areas, leading to use of more seed cane. Measures should be taken on those who misuse seed cane. Their cooperation is required for them to be charged accordingly.
- Quality seed cane that is certified should be supplied to farmers. The rate is normally 10 tons/ha since they use a spacing of 1.2m.
- Farmers should be allowed to grow their own seed cane using the right variety since it is cheaper. Seed cane farmers should be contact farmers who can be entrusted to produce quality seed cane. They can have their nurseries established by Sonysugar and supervised to ensure the seed cane is of high quality. KESREF should also give technical back-up.
- Farmers should be encouraged to be self-reliant. They are too dependent on the factory.

Delayed harvesting, transportation and payment. Other delays could be in delivery of inputs like fertilizers. The opportunity cost is too high.

Proposals for reducing costs are:

- Self-transportation is cheaper. Sonysugar has already allowed own transport using lorries, pick-ups, e.t.c. so long as the farmer offloads by himself.
- Farmers should be encouraged to form cooperatives and buy their own tractors for transport. Sonysugar will only give the program of taking cane to the factory, and hence opportunity cost incurred during delays will be reduced. Two cooperatives are already coming up, and they will also be allowed to transport cane for other farmers.
- Farmers should be encouraged to adopt changes. Less costly changes should be brought in gradually so that they learn to change. They have a culture of not willing to adopt change,

hence they need to be exposed. Change is important in helping them to be independent in carrying out most cane operations.
- Expansion of factories so as to accommodate all the farmers' cane.
- Inputs should be supplied on time by Sonysugar.
- Generally, there should be synchronization of events within the production- supply-demand chain.

Mill-cane transport. The cost is too high due to poor roads, high cost of fuel and spare parts.

Proposals for reducing costs are:
- Roads should be improved. The company should retain cess money since the county council does not know the sugar roads that require repair. In addition, some of the cess money is used on other things leaving a very small percentage for roads repair. 80% of it should be retained and this should be included in the sugar act. The composition of cess committee should be 50% farmers and the miller, and the council should be made aware of this. Road maintenance levy held by KSB should also be channeled back to the company.
- Bridges should be used to make short cuts so as to reduce the transport distance and cost.
- Farmers should be educated to understand the new zoning system.

Fertilizers. It was indicated that company prices of fertilizers are too high as compared to market prices due to high interest rates and service charges charged. This makes the fertiliser cost to be one of the high cost centres.

Proposals for reducing costs are:
- There should be bulk sourcing of fertilizers by KSB.
- Research should be done on the use of filter press mud as an alternative source of fertilizers.
- Possibility of blending fertilizers to come up with a cheap but right dose should be explored.
- Soils should be analyzed before planting in order to determine the nutrient status and hence apply the fertilizers accordingly. KESREF should take up this.

High cost centred and recommended strategies by contractors

Land preparation contractors: The high cost centres and recommendations in land preparation and cane transportation are highlighted below.

High cost centres

1. Price of fuel and other lubricants is quite high.
2. High prices of spare parts (especially discs and bearings) and yet some cannot be found easily; others are not genuine hence increasing costs due to frequent replacement.
3. Frequent service has to be done to maintain the tractors; involves change of oils and filters, labour charges for mechanics, greasing (daily service) and replacing broken parts, which are costly.
4. Distance to the farms wastes time and fuel since the farms are far apart.
5. High cost of tractor tyres and tubes

Suggested strategies

1. Companies should buy fuel in bulk and the contractors buy from them since this would be cheaper. It would also reduce delays of preparing land, which normally happens when contractors miss money for fuel.
2. Spare parts should be appropriate i.e. the manufacturer should match spares with the type of tractor. They should be duty-free. Nongenuine spare parts should be discouraged from the market. KBS

should also try to ensure such parts do not find their way into the country. Contractors should also source only the very essential spare parts and the rest could be fabricated locally by a suitable agent.

3. Farmers should clear obstructions before ploughing to make the operation easier.
4. Factories should do proper mapping of land to give the contractors in such a way that the pieces are consolidated in one area i.e. operations should be done in blocks. This would reduce distance and hence costs.
5. Taxes on farm machinery need to be lowered or waived.
6. HP should be recommended as per the operations so as to use the appropriate tractors. This will take care of fuel consumption. Cost of operation should also be related to performance.
7. Equipment performance review should be done periodically. Most contractors are ignorant and the agricultural engineers should train them on this.
8. Farm surveyors, contractors and engineers should harmonize their operations to breach the gap on the ground so that there is no repeat of operations.

Transport contractors

High cost centers

The high cost centres include:

- High rate of tear and wear of tyres and tubes due to poor roads.
- High fuel costs; fuel siphoning is quite high leading to high fuel consumption. For some contractors, fuel takes about 38-40% of the total income, others 43% or even 50%.
- Breakage rate of parts is high especially in wet weather. Prices of spare parts are high and yet some cannot be found easily. Some companies sell weak, non-genuine spare parts.

Suggested strategies

- Roads should be repaired to minimize wear and tear of tyres and tubes and other parts. Cess money should be left to the miller who knows which roads to maintain. It should be a policy to empower the miller to manage this money. The Ministry of Works should also take it up to repair roads instead of leaving them in poor conditions. If they are well maintained, HP can be reduced and at the same time maintain the same cane tonnage (on average 12 tons) while lowering fuel consumption.
- Transport units should be road worthy to make them cheaper to maintain. Most do not meet traffic rules. There should be regular meetings between the miller, contractors and the drivers for proper management of units. This will help to reduce maintenance costs, hence reducing transport charges.
- Exempt VAT from tyres, tubes and fuel. Fuel levy should be removed from all fuel being used in agricultural practices. ***This is a policy issue that needs to be followed up seriously.***
- Dialogue with suppliers to supply genuine parts. Kenya Bureau of Standards (KEBS) should also try to ensure only genuine parts are being sold. There should also be subsidy on spare parts.
- A contractor should manage one or two models of tractors, which is not only easy to manage but also cheaper since he can buy spare parts in bulk and enjoy economies of scale. Tractors should also not be used beyond their useful economic life.
- Fuel siphoning should be controlled by monitoring the fuel consumption in relation to the distance covered. This should be achieved by filling fuel tanks before the tractor leaves for wherever it is destined, checking how much fuel has been consumed once it is back, and comparing with distance covered and quantity of work done. Improved remuneration of tractor drivers could also discourage this practice.
- Sugar companies should purchase fuel in bulk and supply it to the contractors at discounted prices.
- There should be ***total revolution*** in the agriculture industry; e.g. Kenya Farmers Association (KFA) should be revived so that farmers are in a position to buy not only cheap inputs but also of high quality.

Conclusions

The survey aimed at identifying high cost centers and reduction strategies in sugar cane production process, through interviews, and discussions with the relevant stakeholders. The land preparation and transport

contractors were included in this survey for the simple reason that they work for the farmers. The costs they charge the farmers are part of the cane production costs. In arriving at these charges, they consider several factors, among them fuel, oils, cost of spare parts, frequency of tyres and tubes replacement, e.t.c. All these narrow down to the cane production costs, and they were useful in determining the causes of the high cost centers, and hence in suggesting the cost reduction strategies.

The highest cost center across all zones was mill cane transport. It accounts for about 28% for plant crop and about 42% for ratoon crop. Farmers in Mumias and SONY Sugar are not comfortable with the 4km band zoning system. The poor state of the roads in all zones seems to be the key factor in increasing the transport costs. This is because they lead to high cost of breakages and high frequency of tyres and tubes replacement. The high cost of fuel is another contributing factor.

Labour featured as the second highest cost center. In some zones, labour tends to be scarce for some periods and farmers do not have much choice, but to pay what the labourers demand. However, some labour components like weeding, harvesting and loading seem to increase the cost. Most farmers across all zones carry out manual weeding and its frequency in both pc and rc is quite high, i.e. on average, 6 and 4 times respectively across the zones. Most farmers do not use herbicides, and this was confirmed from the information gathered from the stokists. The cane harvesters and loaders demand some extra money from the farmers, even in the zones where the miller is in charge of paying them. This further increases the farmers' costs from these operations beyond what it should be.

Seed cane was also another highest cost center. The cost per ton and the double transport system seem to make the overall cost quite high. Except for West Kenya, where farmers obtain seed i.e. cane tops, on their own, the rest obtain their supplies of setts from the miller. The farmers, who have ever tried to grow their own seed cane and have compared the total costs of doing so with the miller's cost, claim that it is much cheaper to grow their own, than to be supplied by the miller.

As far as the levies are concerned, the major complaint was on the 1% cess levy remitted to the county council for roads repair. The money is not used for this purpose and this is confirmed by the poor state of the roads as mentioned earlier. It appears that this levy is diverted to other uses. Interest rates are also quite high. In the zones included in the survey, only Mumias that charges low cost interest rate of 12% p.a., while the rest charge between 16% to 19% annually.

In West Kenya, most farmers do not use fertilizers due to the high costs and their attitude, and this has led to low yields. In the other zones where the miller supplies the farmers with the fertilizers, the complaint is still high cost. This is due to the high interest rates. The fertilizers also pass through the hands of many middlemen before they eventually reach the miller, hence the miller has to price them accordingly. Some farmers use FYM and others use filter press mud to improve their yields.

Land preparation costs are increased by unnecessary operations like 2nd plough and 2nd or 3rd harrow. Untimeliness of land preparation leads to delays in carrying out some of the operations due to lack of enough machinery at the time, hence resulting in these unnecessary operations. Farmers who prepare land with their own machinery have found it cheaper in comparison to use of contractors. The farmers also do high quality work in their farms than what the contractors do.

The strategies suggested were recommended having taken into consideration all the above aspects of cost components. The farmers should adhere to good management practices and the stakeholders should adhere to the strategies given so as to reduce the cost of cane production. All the relevant stakeholders (The government, KSB, Farmers, Millers, etc) should consider and implement the policies suggested. Once this is done, it will eventually reduce the costs of sugarcane production, hence making Kenyan sugar competitive locally, regionally and globally.

General Recommendations and strategies

Low yields are experienced in all zones. Potential yields are not obtained. The cause of these low yields is poor cane management. There are some generally accepted management practices in cane production which farmers should adhere to, in order to increase yields.

Strategies

- The number of ratoons maintained should be increased to a minimum three, but farmers should aim higher than this. Break-even point should be checked so as to determine whether to retain or uproot the crop (farmers operating on leased land can request for extension). Improvement of yields leads to spread of costs hence reducing cost per ton.
- Soil analysis should be done in order to recommend appropriate fertilizers for the different regions.
- Cane should be loaded during daytime to avoid most of it being left in the field. Farmers should supervise loading to minimize cane loss.
- The bell loader should be done away with due to high destruction of stools. Restriction should be on grab loaders. Movement in the fields should be minimized and this should be ensured through supervision. Loading and capacity should be synchronized to reduce destruction of stools.
- Arrangement of cane in the trailer should be improved to avoid spillage during transport. It should be harnessed to secure it. The trailers could also be caged so that there is no cane protrusion. Cane should be arranged facing backwards for it to fit properly. Standard trailers and standard stacks should be used so that there is no overloading, and supervision on this should be emphasized.

Wayforward.

The study identified some areas for research that require investigation and recommendations in order to improve the efficiency and profitability of cane production. For better production efficiency and higher profitability to be realized, some policy and research issues that need to be addressed include:

Policy areas

The policy areas include:

- The management and operation of cess funds meant for roads repair should be shifted from county councils to the sugar factories in order to improve the efficiency. The Ministry of Works should complement this effort.
- The government should exempt or lower VAT on agricultural inputs (e.g. fuel, tractors together with the tyres, tubes and spare parts) and other parts used in the sugar industry.
- Kenya Sugar Board should competitively source fertilizers in bulk for the sugar industry.
- The government should assist in the rehabilitation and expansion of sugar factories in order to enhance their crushing capacities to address the problem of delayed cane harvesting.
- Kenya Bureau of Standards should ensure that only genuine spare parts for tractors and farm inputs are imported into the country.
- A total ***revolution*** is required in the agriculture industry. For example, Kenya Farmers Association could be revived so that farmers could buy high quality inputs and buy them cheaply.

Research issues

Some researchable areas emerged from the study and those that could be investigated are:

- An evaluation/demonstration of seed cane, to assess the performance of cane tops versus setts in terms of germination, yield, ratoonability and the economics.
- Investigate whether the difference in yields is statistically significant when DAP fertilizer is used and when it is not used on ratoons, and this should be accompanied by a Cost Benefit Analysis.
- Investigate on the use of filter press mud as an alternative to chemical fertilizers in terms of productivity, weed suppression, and any other beneficial effect it may have on cane development.
- Assess the choice of land preparation implements, i.e. choice between mould board and disc ploughs, in terms of effects on ratoonability and yields, and on formation of hard pans. A Cost Benefit Analysis should be done to compare the use of the two implements.

Acknowledgements

We would like to appreciate the staff of the sugar companies (West Kenya, Mumias, Chemelil and Sony Sugar) for their contribution in developing strategies for cost reduction in the sugar industry. In addition, the staffs of the Outgrower companies are appreciated for both their contribution in developing strategies for cost reduction and for recruiting farmers, contractors and stockists who were interviewed during the survey, and ensuring the interviews went on smoothly. The authors would also like to appreciate the Director, KESREF, for providing financial and logistical support, and for permission to publish this report.

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TECHNOLOGY ADOPTION STUDY IN THE KENYA SUGAR INDUSTRY

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Abstract

Technology adoption studies in agriculture are very pertinent as they give an indication on the rate or extent of uptake of new technologies and also identify associated constraints. Since inception of sugar research in Kenya, there is no documented work on the adoption of sugarcane production technologies in the sugar industry. The basic technologies tested and released for cane production include new varieties (introduced and locally bred), accompanying production packages, pest and disease management strategies. The technology transfer process is undertaken by KESREF extension officers through joint extension programmes with the millers, and Outgrower companies. The main outlet of technologies is through farm visits, field and open days, field demonstrations, ASK shows, seminars and workshops. KESREF scientists administered a questionnaire to each respondent with a view of collecting information on demographic, socio-economic and sugarcane production technology adoption characteristics. Technologies tested were sugarcane varieties grown, land preparation methods, planting methods, fertilizer use, weed management, trash management and ratoon maintenance. Binomial logistic regression was done to find out the factors that significantly influenced adoption of technologies especially adoption of new sugarcane varieties and fertilizer use. The sugar zone, possession of title deeds and membership in farmers' organization were the factors that significantly influenced the adoption of improved cane varieties whereas area under cane was found to significantly and positively influence adoption of fertilizers. The findings in this study are important as they highlight the current technologies in use in sugarcane production in Kenya and the adoption status.

Introduction

Sugarcane growing in Kenya started in the early 1900's when it was introduced around Lake Victoria by the Indian labourers engaged in the construction of the Uganda Railway. The first factory was established at Miwani in the year 1923, followed by Ramisi (1927), Muhoroni (1966), Chemelil (1968), Mumias (1973), Nzoia (1978), Sony (1979) and West Kenya (1986).

The sugar industry supports directly or indirectly over 6 million Kenyans and is a source of income to over 170,000 farmers. It is the third largest contributor to Agricultural Gross Domestic Product (GDP) after Tea and Coffee.
Sugarcane production in Kenya is mainly undertaken by small scale farmers who contribute up to 90% while the remaining 10% is done by large scale farmers and the factory nucleus estates.

Kenya produces approximately 500,000 tonnes of sugar annually while the consumption averages 700,000 tonnes creating a deficit of 200,000 tones.

The sugarcane technology that was first used in sugarcane growing may have been the knowledge from the Indian labourers based on experience from India. This was followed by individual efforts in the importation and testing of cane varieties for adaptation to local conditions, which resulted in the commercialization of the legendary varieties including CO 421 and CO 331 in the 1950's.

After independence research on sugarcane was directly undertaken by Scientific Research Division in the Ministry of Agriculture. Field experiments were done on farmer's fields at Kibos and Miwani in Kisumu district while all laboratory investigations were undertaken at Nairobi Agricultural Laboratories (NAL) Kabete.

In 1989, Kenya Agricultural Research Institute (KARI) took over research management with sugar research being coordinated at the National Sugar Research Centre – Kibos.

During 2001, Kenya Sugar Research Foundation was established as a premier provider of research, development and extension services in the sugar industry, in collaboration with the sugar companies and other relevant stakeholders.

KESREF's aims at making available appropriate technology, products and services on sugarcane, its derivatives and related factors. Previous and current work in sugar research has led to the generation and dissemination of the following technologies:

1. Introduced and adopted varieties: CO 421, NCO 376, B41227 CO 331, CO 617, CO 945, N 14, CO 1148 and CB 38-22,
2. New and locally bred, high yielding, pest and disease resistant varieties i.e. EAK 69-47, EAK 71-402, EAK 70-97; KEN series – KEN 82-216, KEN 82-219, KEN 82-247, KEN 82-401, KEN 82-808 and KEN 83-737.
3. Economic inter-row spacing of 1.2m for high potential and 1.5m for low potential areas.
4. Fertilizer rates of 60kg P_2 O_5/ha and 100kg N/ha for plant crop and 120kg N/ha for ratoon crops.
5. Integrated weed control (a combination of hand-weeding, mechanical and herbicides).
6. Inter-cropping of sugarcane with short- term food crops (e.g. beans).

KESREF has the mandate of developing and disseminating appropriate technologies to sugarcane farmers. Efforts have been made culminating into the release of new varieties and production practices. The farmers have been reached through the networked system of the Technical Service Department's extensionists in collaboration with both the millers and the out grower companies. The extensionists use farm visits, field and open days, field demonstrations, public barazas, ASK shows and sometimes seminars, workshops pamphlets and bulletins to reach these clients.

The overall objective of this study is to establish the extents to which farmers have adopted the different technologies including the new cane varieties; whereas the specific objectives are:

- To determine the extent of adoption of the varieties released in the last 10 years (since 1996) and recommended production practices in each sugar zone.
- To establish determinants of technology adoption.
- To establish constraints related to the adoption of the recommended technologies.
- To make recommendations on policy, research and extension approaches in the sugar industry.

The study area are major sugarcane growing districts which include Migori, Kisumu, Gucha and Nyando districts of Nyanza Province, Bungoma, Kakamega, Lugari Butere/Mumias and Busia districts in Western province, Kericho, Transmara and Nandi districts in Rift valley Province of Kenya.

The Sugar Industry may be divided into seven major sugar production zones which include Mumias, Nzoia, West Kenya, Chemelil, Miwani, Muhoroni and Sonysugar. For this study, four sugar zones, Mumias, West Kenya, Chemelil and Sonysugar were picked based on the size and agro ecological characteristics.

There are about 170,000-200,000 farmers in the industry who currently have a total acreage of 145,000 ha with an average holding of 0.8 ha per farmer. The crop is mainly rain fed grown in warm and wet climates with an annual average rainfall of 1500mm. Table 1 gives the characteristics of the four study zones.

Table 1: Description of sugarcane zones studied

Zone	Sugar Belt	Longitude/ Latitude	Altitude (m asl)	Mean Rainfall(m)	Mean Temperature (^{o}C)Max/Min	Total area under cane (ha)
Mumias	Western	34^{o}30'E/ 0^{o}26' N	1314	2194	30.9/16.4	51,296
West-Kenya	Western	34^{o}50'E/ 0^{o}33' N	1620	2028	Not Available	12,558
Chemelil	Nyando	35^{o}13'E/ 0^{o}06' S	1268	1490	29.8/14.3	13,607
Sonysugar	Awendo	34^{o}32'E/ 0^{o}54' S	1454	1750	28.6/15.3	22,970

Source:

- The information is based on agronomy annual reports.
- Area under cane is as at Dec 2005 (KSB year Book of statistics 2005).

Methodology

Sampling Method

All sugarcane farmers who deliver their cane to sugar millers in Kenya constituted the study population. Of the seven sugar zones four sugar zones viz Mumias, West Kenya, Chemelil and Sonysugar were purposively selected as representative of Kenya sugar industry. For every selected zone, the outgrower's area zoning system was used to select a sample of approximately 40 farmers.

The total sample size for the whole study population was 163 farmers. The selection of the farmers was done with the assistance of the extension officers and out-grower managers in the respective regions. Random sampling was used to obtain the samples of farmer respondents in each area zone. The outgrower supervisors in each area zone used the list of farmers in that zone to select the sample. The choice of the sample in each study zone was done carefully to ensure representativeness by sectors/subzones and size. Table 2 below shows the distribution of sampled farmers in the four sugar zones and their respective area zones

Table 2: Distribution of respondents by sugar zones

Sugar Zone	Area Zone	No. of farmers (respondents)	
		Questionnaire	Agronomist/Breeder
West Kenya	South	10	3
	Central	10	3
	East	10	4
	North	10	4
Total		**40**	**14**
Mumias	Northern	10	3
	Southern	10	5
	Western	10	4
	Eastern	12	3
Total		**42**	**15**
Chemelil	Area 1	22	8
	Area 2	11	1
	Area 3	9	1
Total		**42**	**10**
Sonysugar	Sector 1	6	2
	Sector 2	10	3
	Sector 3	8	2
	sector 4	5	2
	Sector 5	4	1
	Sector 6	3	1
	Sector 7	3	1
Total		**39**	**12**
Grand Total		**163**	**51**

Note: *Respondents interview using a questionnaire are inclusive of those interviewed by agronomist/breeder*

Data was collected in two phases, the first phase involved direct interviews using structured pre-designed questionnaires administered either by a socio-economist or a biometrician. In this phase functions (estimators) that were constructed according to the survey's model defined by the design and the sample selection procedure were administered. Given that the study team considers not only the quality of the estimates (outputs of the survey) but also, and primarily, the quality of these estimates as input (information) to their decision frameworks, every effort was made to have more comprehensive data of unquestionable quality, hence the use of qualified interviewees. The second phase of the survey involved the use of an agronomist or a breeder who collected qualitative data through observation and discussion with farmers using the pre-designed datasheets. The main aim of this phase was to identify the actual practices on the farmer's fields. The questionnaire was administered to all farmers in the sample while a breeder/agronomist surveyed about 12 farmers per sugar zone. The information generated by the agronomist/breeder supplemented the findings through the questionnaires.

The questionnaire was designed to capture all measurable functions of technology adoption. The questionnaire development was an all inclusive activity which brought on board all scientists involved in technology development and dissemination. This ensured that all aspects of the study were captured in a way fit for the analytical model. The breeder/agronomist datasheet was designed with the same rigor as the questionnaire.

Results and discusions

Socio-economic Characteristics

For the farmers interviewed, the mean age ranged from a low of 43yrs in Sonysugar to a high of 51yrs in West Kenya with Chemelil and Mumias having a mean age of 48 and 47 years, respectively. Chemelil and Sony farmers had on average 1.4 spouses whereas West Kenya and Mumias farmers had 1.1 and 1.2 spouses respectively, though the number of spouses was not significantly different for the four zones. Mumias and Sonysugar had the lowest number of sons: 2.7 and 3 sons respectively, while West Kenya and Chemelil had the highest number of sons: 4.1 and 4.0 sons, respectively, with the number of sons being significantly different with respect to the zone as indicated by the F-statistic. The number of daughters was not significantly different in the four zones. Chemelil farmers had the highest cane farming experience while Sony farmers had the least cane farming experience (Table 3).

Table 3: Family respondent's demographic characteristics

Sugar Zone	Farmer's Age	No. of Spouses	No. of Sons	No. of Daughters	Total of Family Size	Cane Farming Experience(Yrs)
Mumias	47.07	1.20	2.68	3.75	8.73	16.90
Chemelil	48.38	1.38	4.03	3.94	10.60	20.78
Sonysugar	43.26	1.44	3.05	3.76	9.33	14.67
West Kenya	50.65	1.13	4.18	4.21	10.51	17.52
Total	47.36	1.28	3.46	3.91	9.76	17.48
F Statistic	2.115 ns	2.568 ns	5.103*	0.275 ns	1.638 ns	2.404 ns

Note: *ns = not significant; * = significant at p < 0.01*

On education front only 2.6% of Sony farmers interviewed had no education while West Kenya had 5.0% of the farmers' interviewed having no education (Table 4). This was closely related to 4.9% of Chemelil and 4.8% of Mumias. 20.5% of the farmers interviewed in Sony had achieved tertiary education but only 5.0% had achieved the same in West Kenya. The education level has a bearing on the ability to read and write, hence may affect the decision taken on technology uptake.

Table 4: Level of education for the respondents

	Sugar Zone			
Education level	Mumias(%)	Chemelil (%)	Sonysugar (%)	West Kenya (%)
None	4.8	5.1	2.6	5.0
Primary	47.6	41.0	46.2	47.5
Secondary	35.7	38.5	30.8	42.5
Tertiary	11.9	15.4	20.5	5.0
Total	**100.0**	**100.0**	**100.0**	**100.0**

Most of the farmers (over 60%) in each of the four zones practiced farming as the major occupation (Table 5). Sony had the highest number of farmers who had other occupations/professions (35%),

followed by Mumias. The higher the % of respondents on other activities other than farming indicate the higher the number of absentee who may not be concentrating on farming.

Table 5: Farmers' occupation/profession by zones

Occupation/Profession	Sugar zone			
	Mumias (%)	Chemelil (%)	Sony (%)	West Kenya(%)
Farmer	66.7	70.7	64.1	75.0
Teacher	9.5	2.4	7.7	5.0
Administrator	4.8	7.3	10.3	-
Casual Labour	2.4	-	2.6	-
Business	11.9	4.9	12.8	15.0
Mechanic	2.4	7.3	2.6	-
Doctor	-	2.4	-	-
None	2.4	4.9	-	5.0

From Table 6, approximately 10% of the sample farmers in Chemelil have leased their land for cane farming, and similarly to 7.1% and 2.5% of farmers in Mumias and West Kenya respectively. Most farmers operate on self free hold farms (Table 6). Most of the farms in Mumias (89.7%) and Sony (89.7%) were inherited from the family, while more than half of the land on cane farming in Chemelil (63.9%) is purchased. Chemelil has the highest number of title deed holders (71.1%) (probably because most of their land being purchased), followed by West Kenya (Table 6). The availability of title deeds has a bearing on the acquisition of loan facility from financial institutions.

Table 6: Land ownership by zones

Ownership	Sugar Zone			
	Mumias (%)	Chemelil (%)	Sonysugar (%)	West Kenya (%)
Self free hold	90.5	85.0	87.2	82.5
Leased	7.1	10.0	-	2.5
Self free hold/ Leasehold	2.4	-	12.8	15.0
Other	-	5.0	-	-
Total	100	100	100	100
Farm source				
Family	89.7	27.8	89.7	64.1
Purchased	-	63.9	-	23.1
Other	-	5.6	-	-
Family/Purchased	10.3	2.8	10.3	12.8
Total	100	100	100	100
Title deed				
Have	42.1	71.1	33.3	59.0
Don't have	57.9	28.9	66.7	41.0
Total	100	100	100	100

The area occupied by cane within the farmers' farms is significantly different in the four zones (Table 7). Chemelil farmers have the largest sugarcane area in their farms, which is far much higher than in the other zones, a reflection of the large scale farms in this zone. The homestead area is also significantly different in all the four zones.

Table 7: Farmers allocation of land to different enterprises

Sugar Zone	Area under different enterprises (Ha)			
	Sugarcane	Other crops	Grazing land	Homestead
Mumias	1.86	1.63	0.75	0.21
Chemelil	59.23	96.97	1.40	0.74
Sonysugar	2.90	2.06	1.85	0.32
West Kenya	2.47	2.53	1.25	0.27
Total	16.78	18.97	1.37	0.37
F statistic	4.031**	2.014^{ns}	0.541^{ns}	9.664***

Note: *ns = Not significant; **significant at p<0.01 *** = significant at p<0.001*

Farmers keep various assets on the farm which are a major resource through their use or disposal. These include bicycles, vehicles, livestock and tractors (Table 8).

Table 8: Distribution of various assets in the sugar zone for sample respondents

Assets	Sugar zone			
	Mumias	Chemelil	Sonysugar	West Kenya
Tractor	1	108	0	0
Pick-up	0	26	8	4
Bicycle	47	46	44	54
Oxen	14	48	90	36
Local poultry	554	1191	590	616
Exotic poultry	0	28	0	19
Local cattle (apart from oxen)	78	156	248	99
Grade cattle	0	30	13	46.5
Cross cattle	27	0	0	9
Small ruminants (goats and sheep)	55	241	174	76.5
Motor bike	0	5	0	0
Posho mill	0	0	1	2

Sugarcane Production Technologies

Varieties

Sugarcane varieties generation form the core of sugarcane production technologies. With the sugar belt stretching across different agro-ecological zones and changing socio-economics realities, development and dissemination of widely adaptable varieties capable of improving farmers' livelihood and concurrently addressing other issues e.g. sugar content and resistance to diseases is a requirement. The CO series are still widely used by farmers even with their numerous short comings as evidenced in Table 9.

The sugarcane variety CO 945 is the most prevalent variety in the Mumias sugar zone at 54%, N14 follows a distant second with a prevalence rate of 15%. Mumias sugar zone has the highest number of new varieties grown by farmers. (Table 9). In Chemelil CO 617 is planted by 66% of the farmers, CO 421 constitutes 15% of sugarcane cover. For Sonysugar zone CO 945 and N14 are equally prevalent at 35% each. In West Kenya, CO 421 is the single most dominant variety constituting 86% of sugarcane in the zone, CO 945 is grown by 12% of the West Kenya farmers. Only three varieties namely CO421, CO 945 and CO 1148 are grown in West Kenya sugar zone (Table 9)

Table 9: Distribution of different sugarcane varieties in the sugar zones

	Percent of farmers reporting			
Variety	**Mumias**	**Chemelil**	**Sonysugar**	**West Kenya**
CO 421	7.7	14.5	12.7	85.7
CO 945	53.8	6.5	35.2	11.9
N14	15.4	-	35.2	-
KEN Series	1.9	-	-	-
CB 3822	1.9	4.8	4.2	-
EAK series	5.8	-	-	-
CO 1148	7.7	1.6	11.3	2.4
D8484	1.9	-	-	-
NCO376	1.9	-	-	-
CO617	1.9	66.1	-	-
CO331	-	6.5	1.4	-
Total	100	100	100	100

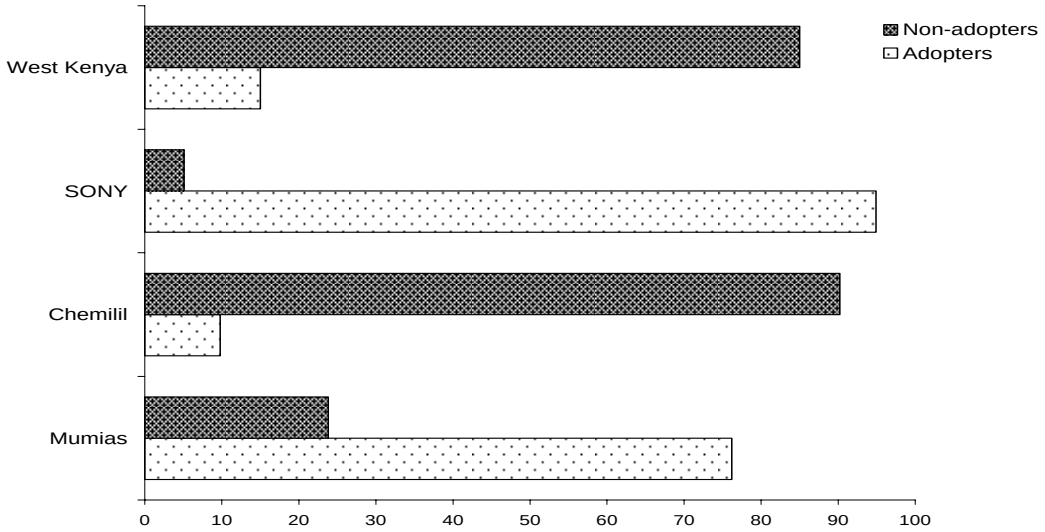

Figure 1: Sugar cane varieties adoption in different sugar zones

Assuming that any farmer planting variety released in the last 10 years is an adopter of sugarcane variety technology, then Sony sugar zone had the highest number of adopters at 95% followed by Mumias at 76%. Chemelil sugar zone had the lowest number of adopters at 10% followed by West Kenya at 15% (Fig 1).

Land Preparation

Use of tractor for plough purpose is prevalent in all sugar zones except West Kenya. Over 80% of all the farmers interviewed plough using tractor in Mumias, Chemelil and Sony (Fig. 2). Oxen are the most important power source in West Kenya, accounting for over 60% of plough power. Manual labour is also highly used in West Kenya where it constitutes 30% of power source. Sony farmers hardly use any manual labour to plough. In Mumias and Chemelil, manual labour for plough constitutes less than 10%. Most of the farmers in West Kenya do not harrow their farms before planting sugar cane though 87.5% plough their land more than once. For the few farmers who harrow their farms in West Kenya, majority use oxen power, manual labour is also used for harrowing in West Kenya. For all the other zones, harrowing with tractor is common. Tractor is the preferred power source for furrowing in Mumias, Chemelil and SONY. Most West Kenya farmers

prefer to use oxen to furrow their farms, while manual furrowing is also used by 25% of the sample farmers (Table 10).

Table 10: Number of times the land was ploughed

	Percent number of farmers reporting			
	Mumias	**Chemelil**	**Sony**	**West Kenya**
Once	90.2	65.0	65.8	12.5
Twice	7.3	30.0	21.1	45.0
Thrice	2.4	5.0	13.2	42.5

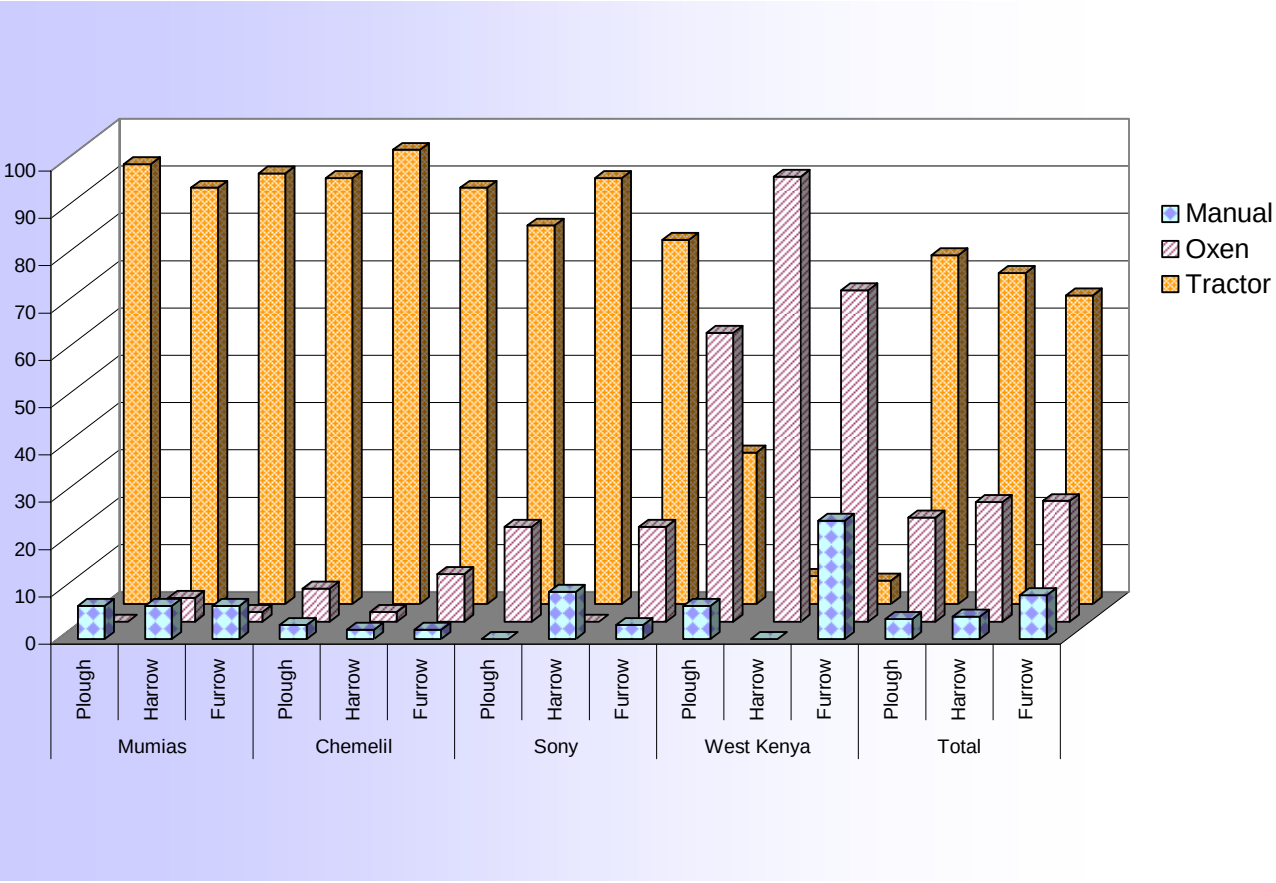

Figure 2: Power source for major land preparation activities

Approximately 56% of farmers in Mumias plant their cane using end-to-end methods, 12% use overlapping method and 32% use whole stalk method. For Chemelil, the preferred method is the overlapping method with 79% usage, end-to-end follows with 19% usage. Overlapping is the predominant method in Chemelil, Sony and West Kenya (Fig 3).

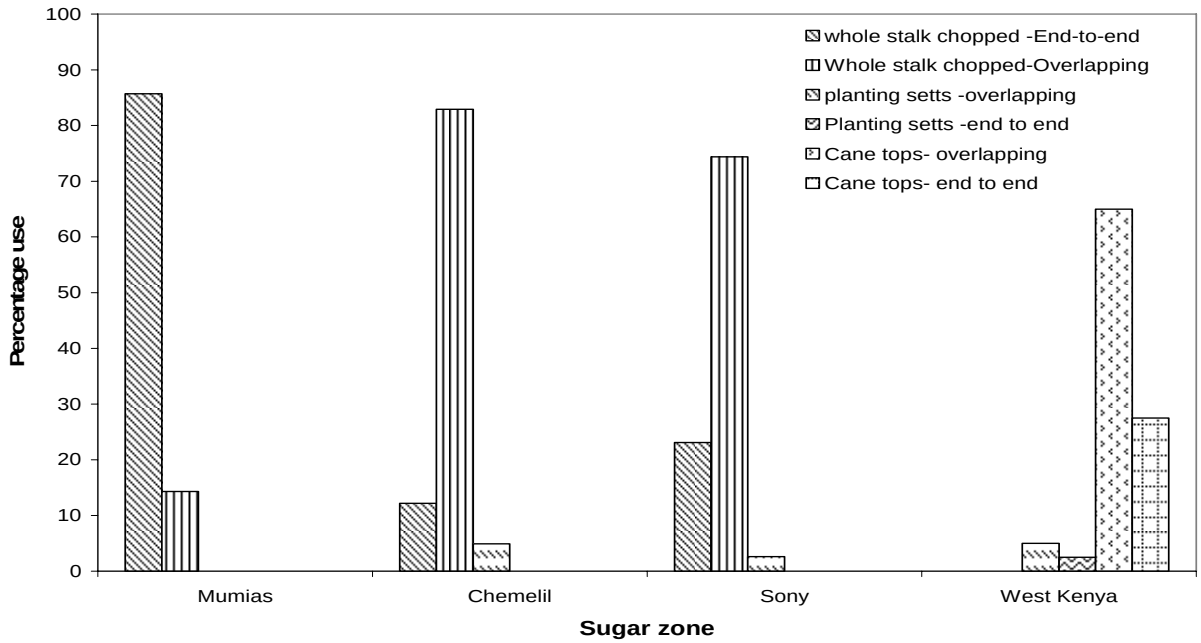

Figure 3: Percentage of farmers using different cane planting methods

Table 11: Responds of farmers on Seedcane source

	Sugar zone			
Seedcane source	**Mumias (%)**	**Chemelil (%)**	**Sony (%)**	**West Kenya (%)**
Sugar Company	95	25	93	-
Neighbours	2	15	7	38
Neighbours/self	3	5	-	10
Self	-	55	-	52

Over 90% of farmers in Mumias and Sony zones get their seedcane from the respective sugar companies. For Chemelil and West Kenya farmers, they obtain most of their seed cane from their own farms (over 50%). About 25% of the farmers in Chemelil sugar zone reported obtaining seed cane from the sugar company, while none is supplied by West Kenya Sugar Company (Table 11).

Fertilizer Application

Most farmers in Mumias sugar zone, have had their soil sampled and analyzed for plant nutrients (84%). This is because it is a company policy to sample and analyse soils before giving out inputs to farmers, for every new crop cycle. Only 5% of farmers in West Kenya sugar zone have had their soil sampled and analyzed, while 32% and 29% of farmers in Sony and Chemelil sugar zones respectively have had their soil sampled and analyzed. (Table 12)73% of farmers in Sony have been advised on fertilizer regimes but only 28% in West Kenya have had the same. Use of inorganic fertilizers is practiced in all sugar zones although only 53% of farmers in West Kenya use them.

Table 12: Percentage of sample farmers whose soils were analyzed, advised on fertilizer regimes and use of inorganic fertilizers

Sugar zone	Soil sampling and analysis		Advised on fertilizer regimes		Use inorganic fertilizer	
	%Yes	%No	%Yes	%No	%Yes	%No
Mumias	84	16	56	44	95	5
Chemelil	29	71	41	59	88	12
Sony	32	68	73	27	95	5
West Kenya	5	95	28	72	53	47

Weed Management

The study sample in Mumias and West Kenya indicate that all farmers use hand weeding (100%) to manage weeds on their sugar cane farm. Approximately 2% of farmers in Chemelil use herbicides, as alternative weedmanagement option. In Sony 13% of farmers use oxen as alternative weedmanagement option to weed their cane farms. The numbers of weedings were not statistically different across the sugar zones for both the plant crop and the ratoon crop. However, the number of weedings for plant crop was significantly higher in plant crop than in ratoon crop in all sugar zones, as indicated by the F statistic (Table 13).

Table 13: Average number of weedings done in PC and RC across the sugar zone

	No. of times plant crop is Weeded		No. of times ratoon crop is Weeded		
Sugar zone	Mean	Std. Deviation	Mean	Std. Deviation	F Statistic
Mumias	6	1.3	4	0.8	61.21*
Chemelil	5	1.6	3	1.1	26.18*
Sony	5	2.0	4	1.3	21.45*
West Kenya	5	1.7	4	1.8	20.80*
Total	5	1.6	4	1.3	

Note: * = *significant at p<0.001*

In the four sugar zones, an average of five and four weedings was practiced for plant crop and ratoon crop, respectively.

Trash Management

Trash aligning is done in most sugar zones. Farmers in Mumias sugar zone trash align all the fields (100%), while trash burning is done in Chemelil sugar zone (Figure 4), probably due to the high number of acreage involved, and the fact that it is faster and cheaper to harvest.

Most of the farmers in Mumias (88%) apply the trash in all inter-rows while only 48% and 37% in West Kenya and Chemelil respectively (Table 14) apply the same. In SONY 37% of the farmers arrange the trash in alternate inter-rows while a majority of farmers arrange trash alternately in at least two rows i.e. in Chemelil (50%) and SONY (60%). Farmers in West Kenya apply (48%) each in all inter-rows and blanket.

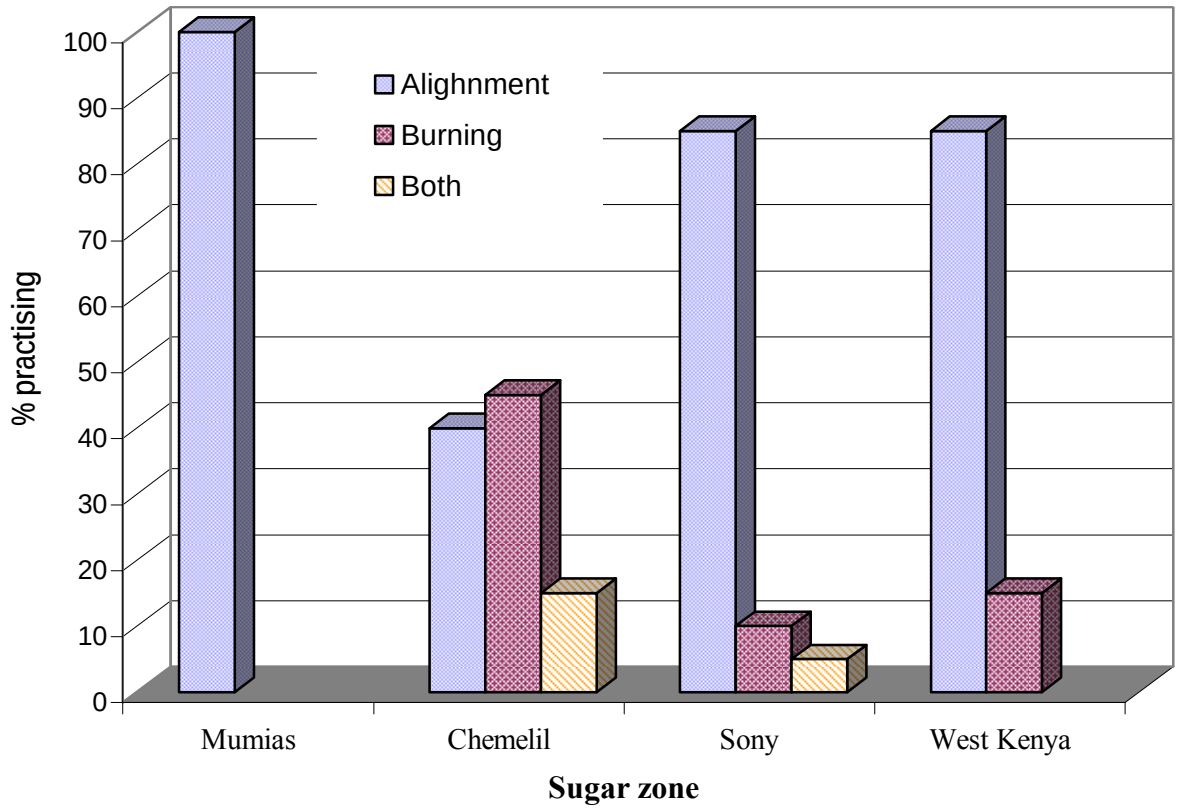

Figure 4: Trash management techniques used in different sugar zones

Table 14: Use of different trash management techniques

Technique	Mumias (%)	Chemelil (%)	Sony (%)	West Kenya (%)
All inter-rows	88	36.5	2.9	48.6
Alternate inter-rows	10	13.6	37.1	2.9
Every 2 or more inter-rows	2	50	60	-
Blanket	-	-	-	48.6

Ratoon Management

Chemelil and Mumias Sugar zone farmers maintained significantly high number of ratoons in comparison to Sony and West Kenya farmers (Table 15). Profit in cane farming lies in ratoon due to low input required as compared to plant crop. Table 28h indicates that majority of farmers keep 2 ratoons in Mumias (43%), 3 ratoons in Chemelil (40%), 2 ratoons in Sony (57%) and 2 ratoons in West Kenya (43%). Farmers should be encouraged to maintain more ratoons (i.e. at least 3 ratoons).

Table 15: Number of ratoons maintained across the zones

	Highest No. of Ratoons ever maintained		Average No. of Ratoons maintained	
	Mean	Std. Deviation	Mean	Std. Deviation
Mumias	5	2.4	3	2.2
Chemelil	6	2.6	4	1.6
SONY	3	1.5	2	0.6
West Kenya	3	1.2	2	1.1
Total	4	2.3	3	1.6

Table 16: Percentage distribution of ratoon maintenance

	Sugar zone			
Number of ratoons	Mumias (%)	Chemelil (%)	Sony (%)	West Kenya (%)
1	5.0	5.4	3.6	17.1
2	42.5	5.4	57.1	42.9
3	27.5	40.5	39.3	25.7
4	7.5	24.3	-	11.4
>5	17.5	24.3	-	2.9

Constraints

The two major constraints to adoption of new sugarcane varieties are lack of adequate knowledge dissemination methods and lack of seed cane (Table 17). With the exception of West Kenya, farmers in all the three zones used some form of fertilizer (organic or inorganic).

Table 17: Constraints to major sugarcane production technologies as reported by farmers

Constraints	Mumias (%)	Chemelil (%)	Sony (%)	WestKenya (%)
Varieties constraint				
Never heard of it	29	34	63	11
No seed cane	71	45	25	86
Used to Common Varieties	-	21	8	-
Problem with harvesting	-	-	4	3
Total	**100**	**100**	**100**	**100**
Fertilizer use constraints				
Lack of finance	-	-	-	61
Not cost effective	-	-	-	6
No credit facilities	-	-	-	6
Cane lodging	-	-	-	6
High soil fertility	-	-	-	22
Total	**100**	**100**	**100**	**100**

Logistic Models for varieties and fertilizer adoption

Adoption of improved cane varieties: This study was focused on farmers' uptake of new technologies, including improved cane varieties and production practices. The model is based on adoption of cane varieties that have been released in the last 10 years. These included CO 945, N14, CO1148, KEN 83-737, CB 38-22 and KEN 82-247. A farmer who was found to have planted any of these varieties was considered an adopter, otherwise a non-adopter, hence this dependent variable is dichotomous. The logit model has therefore been used. It is hypothesized that farmers' decisions

to adopt or failure to adopt new technologies is influenced by a simultaneous effect of a number of factors, both economic and social, as described below.
Following the logistic model:

Log (p/1-p) = $X_i \beta_i + e$ where X_i is the combined effect of independent X variables and β_i is the value (constant) of each explanatory variable. e is the error term.

$X_i = \beta_0 + X_1 \beta_1 + X_2 \beta_2 + \ldots + X_{11}\beta_{11}$, where:
X_1 = Sugar zone (Zone that farmer belongs to)
X_2 = Transport zone (Transport zone that farmer falls under)
X_3 = Gender (gender of the farmer)
X_4 = Education (Level of Education)
X_5 = Family size (Family size of household)
X_6 = Cane Experience (Sugarcane farming experience)
X_7 = Self land ownership status (Type of self land ownership)
X_8 = Title deed (Ownership of a title deed by the farmer)
X_9 = Labour use (Type of labour used by the farmer)
X_{10} = Finance farm activities (Financing of Farm Activities)
X_{11}=Member of organization (Membership in out grower company or a farmers' organization)
X_{12} = Access to Extension Services (Extension service)

Descriptions of the Variables and how they are Expected to Influence Adoption

Zone that farmer comes from (Sugar zone): Easy access of farmers to the sugar research institute is likely to influence farmers to take up new varieties after observing them in the experimental plots. It is therefore hypothesized that the closer the zone is to the research institute, the higher the likelihood of adopting new varieties.

Transport zone that farmer falls under (Transport zone): If a farmer belongs to a transport zone which is near the sugar factory, it is expected that he/she has easy access to the nucleas estate where improved cane varieties are tested, hence he/she is expected to have high chances of adopting. Transport zone is measured by considering the distance from the factory, the closest being zone A and the furthest being zone M. West Kenya and Chemelil have four zones, hence their furthest zone is zone D, while Mumias and Sony have thirteen zones with zone M being the furthest. These zones were coded from 1 - 13.

Gender:Culturally, in the Western region of Kenya, women are the ones who work in the farms while the men provide money for the farm inputs. It is therefore hypothesized that gender would influence adoption of improved cane varieties.

Level of Education*:* Farmers with a high level of education are expected to understand the benefits of growing improved cane varieties better than those who have low or no formal education at all. Hence higher level of education is expected to increase chances of adoption of new cane varieties. This variable was measured in four categories i.e. no formal education at all, primary education, secondary and tertiary, coded 1-4.

Family size of household: A large family is expected to provide labour for farm activities that may emanate from improved cane varieties, hence technology adoption is hypothesized to be high with increase in family size. The family sizes were measured in four categories i.e. number of spouses (family size 1), number of sons (family size 2), number of daughters (family size 3) and the total family size (family size 4). The four were found to be significantly correlated, but the number of sons was found to be significant in influencing the adoption when considered on its own before

other variables were introduced, hence it is the one considered in the model, referred to as Family size 2.

Sugarcane farming experience: It is expected that the more years of experience a farmer has in growing sugarcane, the higher the chances of adopting improved cane varieties, since he/she will have seen the performance of most varieties and would like to make comparisons. This variable was found to be positively correlated with the size of land owned by the farmer.

***Type of self land ownership status*:** This variable was in three categories, i.e. whether the farmer owns land as family land, if he purchased it or if he owns it through some other means. It is expected that self ownership would encourage the farmer to adopt new varieties.

***Ownership of a title deed by the farmer*:** If a farmer has a title deed for his farm, it is expected that he would be encouraged to adopt new varieties since he would be free to use his land the way he wishes. The title deed may also enable the farmer to obtain credit from financial institutions. This is a dichotomous variable, where the farmers either have or do not have a title deed.

Type of labour used by the farmer: A farmer can either use family labour, hired labour or any other. This is hypothesized to influence adoption positively or negatively. Family labour is cost saving, hence hypothesized to influence adoption positively, while hired labour is expensive hence expected to influence adoption negatively. The variable was coded 1-3.

Financing of farm activities: The source of funds for farm activities is expected to influence adoption of new varieties. It is hypothesized that the use of self-savings may negatively influence adoption since finances maybe limiting, while borrowed money (credit) may not be limiting and may enable a farmer to finance all tasks that come with adoption of improved varieties. Use of credit facility is therefore expected to influence adoption positively. A farmer could as well have other means of financing farm activities besides these two, hence this variable was measured in three categories, coded 1-3.

***Membership in outgrower or farmers' organization*:** Being a member in an outgrower company or in any farmers' organization is positively associated with adoption of improved cane varieties. This is a dichotomous variable, where a farmer is either a member or not a member.

Access to Extension Services: It is hypothesized that receiving of extension services can influence adoption of improved cane varieties positively. This is a dichotomous variable, where a farmer either receives extension services or does not.

Parameter estimation for adption of improved cane varieties: The logistic model explained 79% of the variation in the adoption of improved cane varieties. The correctly predicted adopters and non-adopters were 79% and 78% respectively. The variables included in the model were significantly different from zero at 1% level of significance, as indicated by the chi-square statistic. The sugar zone that the farmer belongs to, the possession of a title deed and membership in out growers' company or in a farmers' organization significantly influence the adoption of improved cane varieties.

The parameter estimates are shown in Table 18

Table 18: Parameter estimates for factors affecting adoption of improved cane varieties

Explanatory variable	β	Wald statistic	Exp(β)	95.0% C.I. for EXP(β)	
				Lower	Upper
Sugar zone	-.486**	4.338	.615	.389	.972
Transport zone	.227	2.372	1.254	.940	1.674
Gender	-1.076	1.830	.341	.072	1.621
Education	.331	1.232	1.392	.776	2.496
Family size (no. of sons)	.129	1.119	1.137	.896	1.443
Cane experience (yrs)	-.022	.646	.979	.928	1.032
Self land ownership status	.035	.228	1.036	.897	1.196
Title deed	1.425*	7.652	4.159	1.515	11.416
Labour use	.144	.171	1.155	.584	2.286
Finance farm activities	.029	.220	1.029	.912	1.162
Member of organization	1.628*	7.460	5.095	1.584	16.388
Extension service	-.280	.378	.756	.310	1.844
Constant	-2.509	1.086	.081		

Model $\chi^{2} =$ 45.839*
Overall cases correctly predicted were 79%.
Correctly predicted adopters were 79%.
Correctly predicted non-adopters were 78%.
Sample size was 162.
Note: * = significant at p = 1%; ** = significant at p = 5%.

The sugar zone that the farmer belongs to negatively influenced the likelihood of adopting improved cane varieties, where the odds of adopting decreased by 0.62. Farmers in any sugar zone are unlikely to adopt the improved cane varieties probably because of their location, and the odds of adopting are likely to decrease by even a higher factor of up to 0.97, indicated by the 95% confidence interval of exp β. From the descriptive analysis (Figure 1 and Table 9), there are more adopters in Sony and Mumias than the non-adopters, but the opposite is true for Chemelil and West Kenya. Majority of the farmers in Sony and Mumias grow varieties CO 945 and N 14 which are among those released in the last ten years, while Chemelil and West Kenya farmers grow CO 617 and CO 421 respectively, which were released in the 1950s. However, the overall effect is that the zone decreases the likelihood of adoption of the improved varieties. The reasons that farmers gave for this was that they have never heard of these varieties, while others have heard but they do not have access to the seed cane (Table 17).

The odds of adopting improved cane varieties increased by a factor of 4.16 at 1% significance level, for farmers who hold title deeds for their farms in comparison to those who do not hold. When farmers have title deeds for their farms, they feel secure to try new technologies since they have all the authority over the use of their farms. They feel encouraged to take farming more seriously, hence the increased likelihood of adoption of new cane varieties. At any one time, when farmers hold title deeds for their farms, the odds of adopting improved cane varieties increases by a factor of between 1.52 and 11.42 as indicated by the 95% confidence interval of exp β. From the descriptive analysis, 51.38% of the sample farmers across the zones have title deeds, while 48.63% do not have.

Being a member in an out growers company or in a farmers' organization increased the odds of adopting improved cane varieties by a factor of 5.10 at 1% level of significance. At any one time,

the odds of adopting improved cane varieties increases by a factor of between 1.58 and 16.39 for farmers who are members of either an out growers company or a farmers organization. Farmers are likely to meet with extension officers in these organizations who may inform them of the suitable characteristics and hence the benefits of growing the new varieties.

Adoption of fertilizer use:The use of fertilizers is a technology that farmers are supposed to adopt. Farmers use fertilizers for both planting and topdressing. The farmers who use fertilizers for either planting or topdressing are considered adopters, otherwise non-adopters. Several explanatory variables were expected to influence adoption of fertilizers, some of them similar to those that were expected to influence adoption of varieties as described below:

$X_i = \beta_0 + X_1 \beta_1 + X_2 \beta_2 + \ldots + X_7\beta_7$, where:

X_1 = Sugar zone (Zone that farmer belongs to)

X_2 = Transport zone (Transport zone that farmer falls under)
X_3 = Cane area (The area occupied by sugarcane in comparison to other crops)
X_4 = Plant time (The time farmers plant cane in terms of rain season)
X_5 = Alignment method (Method of aligning trash in the farm after cane harvesting)
X_6 = High ratoon (Highest number of ratoon ever maintained by the farmer)
X_7 = Finance farm activities (How farmers finance their farm activities in terms of whether self-savings or credit facilities)

Zone that farmer comes from: as described above in **varieties'** adoption.

***Transport zone that farmer falls under*:** as described above in **varieties'** adoption.

***The area of the farmer's farm occupied by cane*:**The area of a farmer's farm that is occupied by cane is expected to influence adoption of fertilizers positively. The larger the farm area allocated to cane, the higher the output (income) a farmer is expected to get, hence the higher the chances of adopting fertilizers. This variable was measured in acres.

***The time farmers plant cane in terms of rain season*:**The time farmers plant cane can either be in the short-rains, long rains or both. Therefore, fertilizer use is expected to be influenced by the season of planting due to effects of water on fertilizer in terms of the dissolving ability of the fertilizer and subsequent absorption by the cane crops. This variable was measured in three categories as already mentioned and coded 1-3.

***Trash alignment method after cane harvesting*:** When trash is aligned in the field after harvesting, it decomposes to organic matter which improves soil fertility. Therefore, farmers who align trash after cane harvesting may adopt fertilizers having seen the benefits that accrue from trash alignment. This variable is therefore expected to influence adoption of fertilizers positively. The variable was measured in four categories i.e. blanket, all inter-rows, alternate inter-rows and every 2 or more inter-rows, coded 1-4.

***Highest number of Ratoon maintained*:** Maintaining many ratoons is associated with adoption of fertilizer, since the fertilizers continually enrich the soil and such soils are expected to maintain a high number of ratoons.

Financing of Farm Activities: as described above in **varieties'** adoption.

Parameter estimation for adption of fertilizer use: The parameter estimates are shown in Table 19. The logistic model explained 93% of the variation in the adoption of fertilizer use. The correctly predicted adopters and non-adopters were 97% and 67% respectively. The variables included in the model were significantly different from zero at 1% level of significance, as indicated by the chi-

square statistic. The area occupied by cane in a farmer's farm in comparison to other crops, and trash alignment method were found to be significant in influencing the adoption of fertilizer.

Table 19: Parameter estimates for factors affecting adoption of fertilizer

Explanatory variable	β	Wald statistic	Exp(β)	95.0% C.I. for Exp(β)	
				Lower	Upper
Sugar zone	-.041	.005	.960	.325	2.834
Transport zone	.211	.285	1.235	.568	2.684
Cane area	.620*	6.769	1.858	1.165	2.964
Planting time	.416	.370	1.516	.396	5.800
Highest ratoon	.148	.320	1.159	.695	1.933
Financing farm activities	17.341	.000	$3.4 \chi 10^7$	.000	.
Alignment method	1.039**	3.493	2.826	.951	8.401
Constant	-22.593	.000	.000		

Model $\chi^{2 =}$ 45.835*
Overall cases correctly predicted were 93%.
Correctly predicted adopters were 97%.
Correctly predicted non-adopters were 67%.
Sample size was 162.
Note: * = significant at p = 1%; ** = significant at p = 10%.

Cane area had a positive significant influence on adoption of fertilizer, where the likelihood of adopting increased by 1.86 at the 1% level of significance. Large cane area implies a high output, more income and therefore farmers can afford fertilizers. More so, farmers with large cane areas would like to continually improve their yield, so they will use fertilizers to maintain high yields. At any one time, the likelihood of adoption of fertilizer increases by a factor of between 1.17 and 2.96. It appears that it is economical to use fertilizers with large size of cane area. Considering cane area alone, assessment was done to find out the extent to which the probability of adoption of fertilizer is related to cane area. The fitted relationship is shown in Figure 12 the outliers (cane area figures > 200 acres) were excluded from the plot.

The relationship indicates that farmers who have allocated a large area of their farm to cane growing are more likely to adopt fertilizers. The mean cane area per zone is shown in Table 20. The mean areas occupied by cane in the zones (Table 20) are significantly different as indicated by the F-statistic. Chemelil has a high mean, an indication of the large scale farms in the zone. The odds in favor of adopting fertilizer increased by a factor of 2.83 at 10% level of significance for farmers who were practicing various trash alignment methods. At any one time, the odds in favor of fertilizer adoption can increase by a factor of up to 8.40 for farmers practicing various trash alignment methods. The practice of trash alignment improves soil fertility when the trash decomposes, which in turn increases cane yield. Having seen the increased cane output, farmers who practice trash alignment will adopt fertilizers since they already know the benefits of improved soil fertility. On considering the trash alignment methods, the blanket method was significant in influencing fertilizer adoption, but it decreases the odds of adoption by a factor of 0.057. This can be attributed to the disadvantage this method has of covering the stools, hence hindering proper

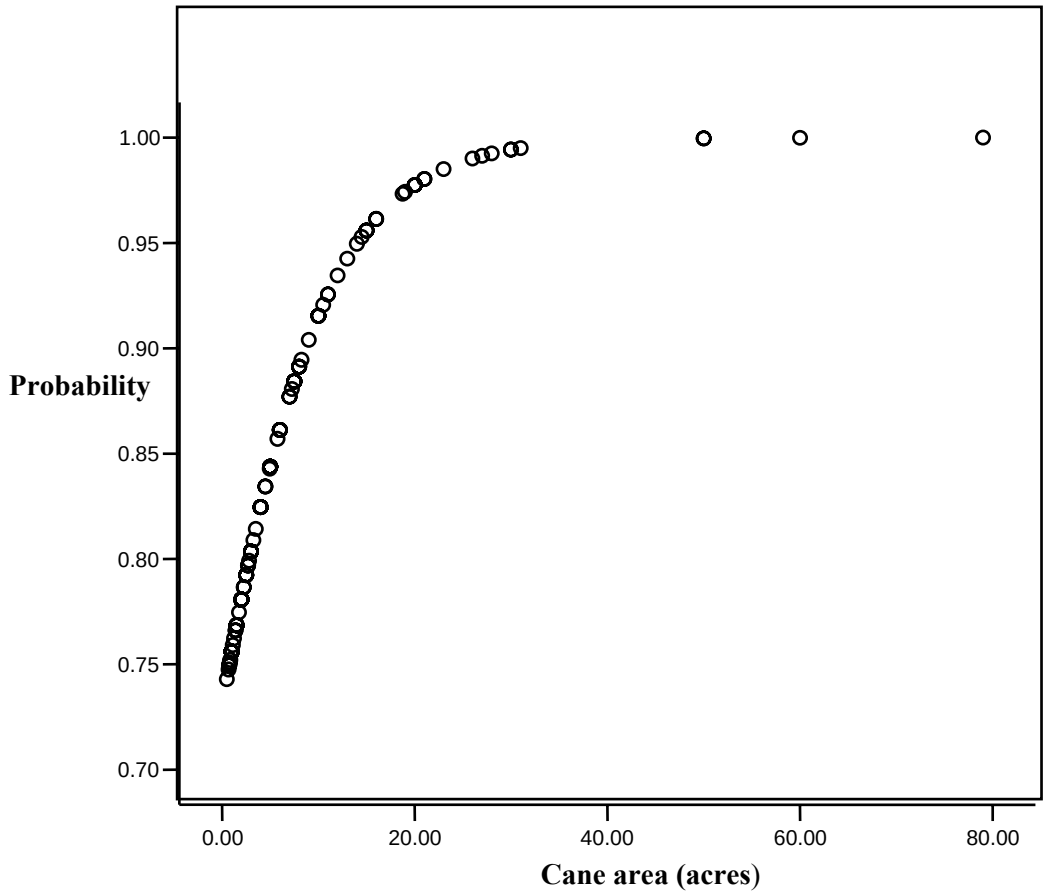

Figure 5: Predicted probability of adoption of fertilizer against cane area

Table 20: Area occupied by cane (acres)

Sugar Zone	Mean	N
Mumias	4.6488	42
Chemelil	148.0793	41
SONY	7.2397	39
West Kenya	6.1638	40
Total	41.9469	162
F statistic =4.031*		

* *Significant at p = 1%*

sprouting of tillers for ratoon crop. From the descriptive analysis, only West Kenya farmers (48.6%) use this method, with the other zones using the other three methods. Majority of Mumias farmers (88%) use the all inter-rows method, majority of Chemelil farmers (50%) use every 2 or more inter-rows method, and majority of Sony farmers (60%) use every 2 or more inter-rows method. Hence, the overall effect of all the four methods increases the odds of adopting fertilizers. Farmers should use the most appropriate alignment methods.

Implications for Research and Extension: The logistic regression results showed that the sugar zone that a farmer belongs to, possession of a title deed and being a member of an out-growers company or a farmers' organization were statistically significant factors influencing the adoption of improved cane varieties.

The sugar zone that a farmer belongs to negatively influence the likelihood of adopting improved cane varieties, i.e. in whichever zone the farmers belong to, they are unlikely to adopt the improved cane varieties. According to majority of the farmers interviewed in the four sugar zones (45.7%), lack of seed cane was the reason for not adopting improved cane varieties, and especially the latest ones, i.e. EAK and KEN series. 23.5% had never heard of these varieties, while 4.9% are used to their common varieties, implying they are resistant to change. Extension staff from the research institute that generates varieties needs to reach the farmers and inform them of the latest improved varieties. They also need to liaise with the factories out-grower managers to avail seed cane of the improved varieties to farmers in all sugar zones. The extension staff should also sensitize the farmers to make them change their attitude and try planting the improved varieties as they still retain the old ones.

The possession of title deeds positively influenced the adoption of improved varieties. Some farmers own land but they may not have managed to acquire title deeds. The policy makers in the sugar industry should facilitate acquisition of title deeds by cane farmers so that the industry can benefit economically from farmers' adoption of improved varieties.

Out grower companies and farmers organizations which already exist should be strengthened, and more farmers should be encouraged to become members so as to benefit from information on new technologies. The organizations are vital venues of technology transfer. More farmers' organizations should be formed through the initiation of the extension staff.

As far as of fertilizers are concerned, the area occupied by cane in farmers' farms in comparison to other crops was found to be significant in influencing fertilizer adoption. A large cane area implies a high cane yield in most cases. Farmers with large areas of cane would like to maintain high yield, hence the likelihood of adopting fertilizers. It is also economical to use fertilizers in large areas. Farmers should therefore be encouraged to expand the area of cane growing within their farms, so as to benefit from fertilizer use.

The alignment method was another determinant of fertilizer adoption. Extension staff should not only encourage farmers to align trash after cane harvesting, but they should show them the methods of doing so. The blanket method decreases the odds of adopting fertilizers, so farmers should probably be discouraged from using this method. Farmers should be discouraged from burning trash.

General Observations and Suggested Strategies

The observations and suggested strategies on the technology adoption process emanated from discussions held between the investigators, out-growers and sugar company representatives (see Table 21).

Chemelil Sugar Company

Varieties: CO 617 is said to be stress tolerant in water logging, it subdues weeds, does not require fertilizers and requires few operations unlike CO 421. Those farmers who are not financially able economically go for CO 617, however, there was need to caution farmers against growing a crop without proper management. Medium scale farmers planted CO 421 and EAK 70-97, while some farmers have picked up KEN 82-247 and KEN 82- 808 after observing them in the nucleus estate farm.

The zone requires a variety that is early maturing and which can be accommodated in the current harvesting schedule. CO 421 yields better than CO 617 although CO 617 ratoons become thinner and it is unappealing to cane cutters and that is why it is burnt. In addition, CO 617 is no longer resistant to smut. It was agreed that the agronomist and the breeder at KESREF should work together to get a varieties/clones suitable for the various agro-climatic zones in Chemelil.

Ratoon management: It was noted that most farmers maintain 3 ratoons. The plant crop is normally considered as an investment crop due to heavy investment required in land preparation and seed cane. On average, the nucleus estate yields 60 tch while marginal regions yield 50 tch, and the out growers realize 40 tch. Cane fires was said to be a problem. It was agreed that proper crop establishment and good management maintains more rations. CO 331 was said to be the best in ratoon sustainability, followed by CO 617, and the third is CO 421. The decision to extend rations rests on the productivity (yield). Since ratoons are more profitable than the pc, most farmers should be encouraged to maintain not less than three ratoons.

It was agreed that break-even studies should be done annually to give guidance on how many ratoons to maintain. It also emerged that there is a tendency to extend ratoons where mouldboard plough is used.

Weeding: KESREF's assistance is required to provide the right cocktail for herbicides which is cheap and effective for post-emergence, given that the current cocktail of Velpar and Diuron or Diuron and Gesapax Combi is quite expensive. Farmers are currently using Round-up for post-emergence combined with hand-weeding. From CSC staff, early Round up (Glyphosate) combined with proper land preparation makes weeding to be done only once before canopy formation. Round up is again needed towards harvesting.

It was noted that fallow fields encourage weeds since a lot of weed dispersal takes place. It was agreed that timely operations should be in place, since at times land is prepared too early and weeds start growing before planting is done, or sometimes it is too wet to do hand-weeding, hence a chemical combination is still necessary. Weeding can also be contracted. Late weeding seriously affects the cane yields and therefore the need for KESREF in collaboration with CSC to develop and demonstrate a cost effective weed control strategy.

Extension Services: Farmers need to be sensitized about the role of KESREF while the new varieties should also be tested in the highlands. A suitable extension system should be formulated to better enlighten on varieties and improved production practices through field demonstrations, seminars and workshops. The KESREF staff should collaborate closely with the company in this venture. This will help to harmonize the messages that are passed on to farmers through jointly planned extension programs between KESREF, CSC and out-grower companies.

Mumias Sugar Company

Varieties: Logistics of harvesting for the different varieties is difficult; blocking is a problem because farmers in the same block have different varieties, where some are harvested on time, while others too late. The factory should review its strategies to incorporate the time of planting and harvesting. The company should adopt a policy that incorporates the early maturing varieties in the harvesting programmes, where probably, the early maturing varieties are grown in blocks. Mumias is already doing something on the D-varieties and Ken-varieties. It emerged that CO-945 is an embraced variety because it is secure in the sense that it does not deteriorate easily.

It was agreed that farmers need to be educated on blocking so that they benefit from early maturing varieties, and logistics of harvesting should be streamlined. Varieties that are suitable for specific regions should be supplied, in accordance to soils and climatic characteristics.

Extension: It was agreed that extension should be separated from general operations/supervision. The extension methodology should be improved. The school type method of just talking to the farmers should be stopped, with more alignment to participatory approaches where farmers make suggestions of what they require.

It emerged that KESREF staff has been joining hands with Ministry of Agriculture and Miller on extension programs, but since they have been only 3, they are not recognized/known by the farmers. Hence it was agreed that the 3 parties should be holding meetings in turns such that each party is in

charge at a particular time. KESREF should hold its own meetings on research and development and invite MOA and Miller so that they (KESREF) can be recognized.

Billboards should be erected at KESREF's offices and demonstration plots to show that it is KESREF's work. In addition, smaller boards bearing the technology descriptions should also be erected besides the plots. There should be planned occasional visits by farmers at the demonstration plots where KESREF staff explains to them what they are demonstrating. It is important to emphasize that the demos should be well maintained and more practices should be demonstrated, all the way up to harvesting. KESREF field staff should have uniform (coats) inscripted KESREF on the back so that farmers can recognize them.

As a way forward, collaboration between the miller, MOCO and KESREF should be improved so that farmers can be encouraged to take up the new technologies.

Ratoon management: It emerged that the miller must maintain ratoons 1 and 2, while advanced ratoons depend on the area of replough. There is normally reconciliation between plant crop and ratoon crop because the miller wants to maintain some level of production. KESREF should also guide on this issue, especially on the economic factor. The compulsory fallowing should be encouraged to improve on soil nutrient and productivity.

Quality Seed Cane: From the staff of MSC, cane fires have been a havoc, and there has been lack of harmonization on seed cane supply and land prepared for planting. The plan for availing seed cane has not been well done as B-nurseries are not available while seed cane supply has been contracted but contractors cannot move more than 15 km away. It emerged that when the seed cane is poor, then there is a poor crop for the next 5 years. It was therefore agreed that KESREF and Mumias Sugar Company should come up with a well planned scheme of seed cane supply.

Farmers advance: It emerged that when farmers advance was stopped, they could not manage their cane well due to lack of money to finance the operations, and hence the yield declined. Farmers Advance System (FAS) was stopped in 2002; it was agreed that KESREF should check on the productivity before and after 2002 to assess the efficiency after the stoppage of FAS.

Sony Sugar Company

Varieties: N14 is the most preferred variety followed by CO945, CO1148 and CO617. Adoption of KEN series has been minimal in the zone (KEN 82-247); probably other KEN series could be introduced. Some farmers still think that CO421 is still a better variety. KEN 82-247 performed exceptionally well in the nucleus estate during varieties trials but its performance presently both in the outgrowers and the nucleus has been dismal. N14 was preferred by both the miller and the farmer due to its high sugar content and high yields respectively. CO617 is being phased out in the outgrowers nucleus although a small percentage of the same will be kept to cater for future needs. CB 3822 performed well in poorly drained soils. EAK 70-97 was introduced but its maturity coincided with excess cane in the zone hence over maturity. EAK 70-97 could not with stand overmaturity and in most cases it dried up, this discouraged many farmers from planting it.

Crop establishment: Crop establishment in the zone ranged from moderate to poor, this is because the soils and rainfall are good for most areas though in some sectors the soils are poorly drained.

Ratoon management: Farmers keeps at most 2 ratoons, this scenario of less ratoon cycles was attributed to miller's policy on ratoon. The miller re-plough the land after 2 ratoon this policy was implemented during the smut epidemic, it was agreed that the policy need to be reviewed given that some new varieties have moderate to high smut resistance.

Extension: The issue of usefulness of demonstration plots was raised because most of the farmers who have given out land for demonstration do not adopt the technologies they see on the demo plots. It was agreed that for demonstration plots to be effective, they should be easily accessible to farmers and only the highest standard of management should be displayed so that the demos are

unique and attractive. The need for a combined effort between Sony and KESREF extension staff could not have been over emphasized. Sony has a monthly farmers training programme although its outreach is limited.

West-Kenya Sugar Company

Seed cane: According to WEKSCOL staff, scientific basis is required to convince farmers to change to setts because as per the current situation, the yields are still high. Farmers use cane tops for seed because the tops do not carry smut disease and also smut levels are low due to crop rotation. On the issue of setts vs cane tops, it was agreed that economics should come in to evaluate which one is better. Trials comparing the two are on and KESREF should generate information on this where the establishment of the crop should also be considered.

New technology: From WEKSCOL, any new technology has to be looked at critically. There is less compaction in the fields due to the method of loading, hence no need to do ripping or sub-soiling, while the ox-ploughs that the farmers use are said to have better penetration than the disc ploughs.

Varieties: The tradition has been to grow CO 421 for it can withstand over-maturity and it is not prone to smut. New early maturing varieties might not fit in because planting and harvesting are not synchronized for the miller to be able to take up the varieties when they have over mature cane in the fields.

Bulking seed cane should be done to promote the new varieties. KESREF should assist in the supply of seed cane to farmers. The cost of A- material/nurseries should be sorted out in terms of who funds it between KESREF, KSB, WEKO or WEKSCOL. It was suggested that KSB may be requested to fund farmers' seed cane development program, while KESREF could assist in supervising this program.

Fertilizers: According to WEKSCOL, the yields are still relatively good even without the use of fertilizers, and therefore the need to validate the benefits arising from use of fertilizers. Soil sampling and analyses may also be necessary before fertilizers application.

Ratoonability: From WEKSCOL, ratoonability is a matter of tradition than a fact. Ratoons are not maintained and hence perform poorly, which explains why very few ratoons are maintained in West Kenya.

Extension Services: This was said to be slow due to the way it started, but it was reported that it is now being reformed. It was also agreed that extension cannot be there, especially with farmers, without availability of improved technologies.

Table 21: Stakeholders comments on the commercial varieties by zone

Variety	Characteristics			
	Sony Sugar Zone	**Mumias Zone**	**Chemelil Zone**	**West Kenya Zone**
KEN 82-247	➢ One of the most recently released varieties ➢ The surface area is small ➢ The testing was only done in the nucleus estate ➢ The yields obtained in the commercial plots were low, contrary to what was obtained in the trials- PC, 95t/ha and R1 54t/ha ➢ Yields observed from trials were higher than from the commercial fields. This was attributed to good management practices. ➢ Delayed harvesting affected the yields in the outgrower's fields. ➢ KEN 82-247 observed to be poor than CB 38-22 and could do better on poor soils.		➢ Highly potential in the zone ➢ High fibre ➢ Not drought resistant ➢ Yield is 120 tch in PC.	The tradition has been to grow CO 421 for it can withstand over-maturity and it is not prone to smut; new early maturing varieties might not fit in because planting and harvesting are not synchronized for the miller to be able to take up the varieties when they are mature.
KEN 82-808			➢ Not tolerant to smut, whole stool dies off ➢ Not tolerant to water-logging. EAK series and KEN series covers 9% in the nucleas estate.	
KEN 83-737		➢ It grows fast and does well ➢ They did not have much information about it on productivity.		
KEN 82-216	-		➢ Susceptible to smut Grows straight forming no canopy hence it is weeded more times ➢ Tillers tend to grow at the same time ➢ Yield was 95 tch at 18 months.	
CO 58-20		➢ It is heavy ➢ Self-detrashing.		
CO1148	➢ It's a poor yielder ➢ More susceptible to stress than CB38-22 ➢ Has less future in the sugar zone ➢ It's susceptible to Rust and White scales.	➢ Does well but cane cutters complain that it is too hard and it has no weight ➢ It has a lower tch that CO 945 ➢ It is affected by leaf rust but it seems to come out of it.		
CO617	➢ Has low sugar content 12% ➢ Not planted in the outgrower zone ➢ It's hard, hence difficult to mill			
CO945	➢ High rainfall requiring variety ➢ It's a poor germinator ➢ Has high tillering a ability ➢ Has high sugar content ➢ Better ratooning ability than others	➢ it was said to be the best due to high weight and high ratoonability;	➢ Quickly deteriorates in ratoons ➢ Smutted by 4th ratoon, but in some areas it has gone to 6th ratoon ➢ Yield is 145 tch for PC and 80 tch RC.	

CO421	➢ Late maturing ➢ Susceptible to smut		➢ It is ideal if it can survive the conditions ➢ It appears better in smut than CO 945 ➢ Yield is 140 tch in nucleas, pol 12.5% ➢ Lowest fibre; good germination.	
EAK 70-97	➢ Early maturing variety ➢ It's the only EAK in the nucleus estate ➢ Better ratooner than N14 ➢ Grown mainly in sector 1 ➢ Grows well on well drained soil ➢ Average at forming the canopy ➢ Farmers rejected it because of cases of late harvesting ➢ Poorer performer in shallow soils ➢ 12R has been reported in the nucleus estate		➢ It did well in the nucleas estate ➢ It has high tonnage ➢ Good ratoonability ➢ Early maturing ➢ Pol is 13%.	
EAK 73-335		➢ It has thin stalks ➢ Requires good soils ➢ Medium in terms of harvesting age ➢ Susceptible to smut.		
CB 38-22	➢ Not liked in the nucleus estate ➢ Requires good management practices ➢ 143 t/ha has been achieved in the outgrowers ➢ A lot planted in sector 2 ➢ Where grown in shallow soil and harvested late results into performance	➢ It is suited to murram soils ➢ Early maturing ➢ It flowers ➢ Susceptible to human pest ➢ Lodges ➢ Less tch ➢ Mumias is phasing it out because of flowering when stressed.	➢ Forms canopy very early, hence there is less weeding; ➢ It dries when it over matures ➢ A lot of trash with too sharp spikes ➢ Lodges early ➢ Compares with CO 617 in yields ➢ Can sustain more ratoons which are productive ➢ Yield is 89 tch at 4th ratoon ➢ Pol is comparable to CO 421 ➢ Moderate in smut; highly susceptible to *striga*.	
N14	➢ Has high TCH ➢ Most preferred variety in the zone ➢ Susceptible to moisture stress ➢ Poor performer in shallow soil ➢ Medium maturing ➢ Forms canopy faster ➢ Slightly poor in rationing ability than CO945	➢ Poor ratoonability ➢ Susceptible to RSD and water stress	➢ highly resistant to smut ➢ Thick stalks ➢ Sensitive to drainage ➢ Poor ratoonability ➢ Late maturing ➢ 160 tch with filter mud ➢ Sucrose is 12%.	
D 84-84		➢ It grows fast ➢ It has few tillers so the weeding is frequent ➢ Its tch is almost at the same level as that of CO 1148 but lower than that of CO 945 ➢ It requires fertile soils ➢ Susceptible to human pest ➢ Mumias is ready to promote it.		

Conclusions

The demographic and socio-economic characteristics did not differ significantly across the zones. In the family characteristics, the number of sons was significantly different among the zones, but there were no significant differences between the levels of education and the farmers' occupation/profession.

As far as land ownership is concerned, farmers who own land under self ownership status still do not have title deeds for them. In Mumias, 90.5% of farmers own land solely but only 42.1% have title deeds for them. Similarly, in Sony, 87.2% own land solely, but only 33.3% have title deeds. Majority of farmers in Chemelil and West Kenya have title deeds for their farms. Possession of title deeds is vital for adoption of improved cane varieties.

Farmers were found to be growing other crops besides sugar cane, but the area allocated to cane was of more concern. The mean area allocated to cane was significantly different across the zones, with Chemelil farmers allocating the highest proportion (59.23 ha) and Mumias the lowest proportion (1.86 ha). Area under cane was found to be one of the factors significantly and positively influencing adoption of fertilizers, hence farmers who still have un-utilized land should be encouraged to put it under cane to benefit economically from use of fertilizers.

The assets for farmers varied across zones, but the most common ones were livestock i.e. local poultry, local cattle and small ruminants (sheep and goats). Farmers with small farms should be encouraged to use farm yard manure in their cane farms, and probably supplement it with inorganic fertilizers.

In as far as sugar cane production technologies are concerned, varieties seems to be the only technology that KESREF solely owns. The rest are co-generated by the sugar companies. In this study, technology adoption was considered by regarding only two technologies i.e. varieties and fertilizer use. For fertilizers, farmers seem to use different rates for both planting and topdressing across the zones. A package on use of fertilizers in terms of type and rates should be developed for each zone, taking into consideration the types of soils in the different zones.

KESREF should also develop packages for the other technologies that were of concern during the study, since all of them seem to vary with even no proper standardization within the zones. The technology packages should however be economical in terms of cost. These technologies include:

- Land preparation which should address the implements to be used, number of ploughings and harrowings.
- Planting and seed rates which should address appropriate planting method economical seed rate.
- Weed management which should give the most economical Integrated Weed Management (IWM).
- Ratoon management which should address how to maintain a high number, and the benefits of this.
- Trash management which should address the appropriate methods and their advantages.

Recommendations and Way Forward

In order improve technology adoption by farmers the following recommendations were made:

- KESREF extension staff needs to reach the farmers and inform them of the latest improved varieties. They also need to liaise with the factories out-grower managers to avail seed cane of the improved varieties to farmers in all sugar zones. The extension staff should also sensitize the farmers to make them

change their attitudes and try planting the improved varieties as they still retain the old ones, to benefit from early maturing factor.

- Farmers should be encouraged and helped to acquire title deeds for their farms. This should probably be a government policy of issuing title deeds to all farmers who own land solely.
- Farmers should be encouraged to join either out-growers' organizations or farmers' organizations, since these are avenues of information from the extension staff.
- Proper utilization of land by farmers should be encouraged, by utilizing it for cane production. KESREF extension staff should advice farmers on the economic use of fertilizers when they have large areas under cane. Food security should however not be compromised.
- Trash alignment after cane cutting should be encouraged. Extension staff should show the farmers the appropriate methods of doing so.
- KESREF will come up with packages for cane production besides varieties. The packages should be specific for each sugar zone so as to take care of the different environmental factors. The packages should be for land preparation, planting methods and seed rates, fertilizer use, weed management, trash management and ratoon management.
- KESREF will consider coming up with a technology transfer model that is able to change the heavy influence the milling companies have on the technologies used by the farmers especially the varieties. Many millers give to the farmers the seedcane of their preferred varieties, uproot the ratoons at their preferred time and give their preferred fertilizers at their preferred time.
- More forums should be created where KESREF scientists meet with the millers and farmers to review progress on technologies adoption and exploring on expected trouble shooting areas

Acknowledgements

We would like to appreciate the staff of the sugar companies (West Kenya, Mumias, Chemelil and Sony Sugar) for their contribution in technology adoption study. In addition, the staffs of the outgrowers sections and outgrower companies are appreciated for both their contribution in discussion on issues emanating from the study and for recruiting farmers who were interviewed during the survey, and ensuring the interviews went on smoothly. We would also like to appreciate all KESREF scientists who were vital in development of the questionnaire, more so the plant breeders and agronomists who also participated in collection of data through agronomist/breeder datasheets. Thanks to the farmers who willingly and enthusiastically gave us information making the interview process enjoyable and valuable.

The authors would also like to appreciate the Director, KESREF, for providing financial and logistical support, and for permission to publish this report.

Last but not least, the authors greatly appreciate the constructive comments and suggestions by the KESREF Editorial Committee, headed by Dr. J. K. Rono on the initial draft.

IDENTIFICATION AND RANKING OF ZONAL SUGARCANE PRODUCTION CONSTRAINTS IN THE KENYA SUGAR INDUSTRY

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Abstract

Various sugarcane production constraints have been reported to threaten the survival of the sugar industry in Kenya. There has been a marked decline in productivity at the farm level over the last ten years due to a conglomeration of constraints ranging from technological to policy issues. A clear understanding and ranking of these constraints is needed to define opportunity for identifying and developing strategies that can assist in the management of these constraints. According to KSB (2003), the average sugar cane yield for the period 1992-2002 stood at 74.87 tch, while that of 2002 and 2003 was 70.67 and 69.12 tch, respectively. The continued decline in yield and poor performance of the sugar industry is worrying. It therefore, requires serious attention from researchers and all stakeholders.

KESREF scientists undertook a study to identify major sugarcane production constraints by zone in the sugar industry. In addition, the study undertook to prescribe appropriate intervention measures to the constraints. The study covered sugarcane productions areas of Mumias, Busia, West Kenya, Nzoia, Miwani, Muhoroni, Chemelil and Sonysugar. Depending on the size of each zone, a sample of 25-50 farmers was drawn and invited to a central place where KESREF scientists guided them into discussions that resulted into identified and ranked major sugarcane production constraints, and a catalogue of appropriate interventions measures. The constraints were ranked using a paired matrix and high cost of farm inputs, lack of capital, accessibility to credit facilities among others were some of the production constraints identified as consistently ranking highly in the sugar industry

Introduction

Sugarcane cultivation in Kenya dates back to early 1920s when the first factory was established at Miwani in the current Nyando sugar zone. The sugar industry in Kenya started with the establishment of Miwani (1922) and Ramisi (1927) sugar mills. After independence new factories were put up in Muhoroni (1966), Chemelil (1968), Mumias (1973), Nzoia (1978), SONY sugar (1979) and West Kenya (1986). All these factories rely on independent farmers (Outgrowers) and nucleus estates for the supply of sugarcane except West Kenya which wholly relies on the out growers farms.

Sugarcane farming has since then been done by small scale farmers accounting for more than 90% of total cane production. In all the cane growing zones a part from the nucleus estate of Chemelil where limited irrigation is done, sugarcane is produced under rain-fed conditions. In most sugar zones farmers are funded by outgrower companies for field operations and cane maintenance. There are currently over 211,000 small scale farmers in the sugar industry (KSB 2005).

The Kenya sugar industry is threatened with declining productivity especially at farm level. The return per shilling invested by the farmer is also on the decline. This has been caused by various problems facing the farmers in their attempt to increase cane production with available resources. Previous studies have been undertaken to identify problems facing farmers but none of them involved the farmers' direct participation nor has there been any follow up to ensure the recommendations made are implemented.

In view of this, KESREF reviewed sugarcane production constraints in the Kenyan sugar industry for the periods; 1999, 2001 and 2003. Those that consistently appeared in the three years were ranked. The major resolution was that constraint identification and ranking is an important exercise, which should be done routinely. For this exercise to be more meaningful for research and policy formulation, farmers should be involved in the whole process of identifying and ranking of constraints in their specific zones.

The current study was participatory as farmers and other stakeholders were involved in the identification and ranking of sugarcane production constraints in various sugarcane zones and ultimately suggesting possible intervention measures.

An Overview of Previous Studies on Sugarcane Production Constraints

Various studies have been conducted in the past to identify constraints limiting sugarcane production in Kenya. This has been part of a concerted effort to make sugarcane production more profitable. An intercropping systems study in Western Kenya reported that lack of finance, delayed payments, irregular and untimely supply of farm inputs as well as declining land size are the major constraints in the sugar industry (Wawire *et al,* 1999). Other constraints by then included unreliable weather, poor infrastructure, limited choice of varieties by farmers, high cost of production and weak extension services. Researchable constraints identified then were poor choice of varieties by farmers, poor crop husbandry, high cost of cane production and declining land sizes. The rest were policy related constraints.

In the year 2001, another survey was conducted in the sugar industry aimed at identifying sugarcane production constraints (Wawire *et al,* 2001). This survey was necessitated by the fact that despite earlier studies, cane yield generally was still on the declining trend. There was therefore need to identify the existing constraints so that research programmes can be tailored towards generating appropriate intervention measures. From this study, the additional constraints identified were accidental fire, lack of farm records, lack of market for intercrops, poor farmers' attitude towards cane contracts, lack of adequate farm machineries, cane losses in transit to the factory, food insecurity, HIV/AIDs pandemic, sugarcane pests and diseases, low sugarcane prices, poor maintenance of ratoons and lack of quality seedcane. Most of these additional constraints require research interventions while a few like low sugarcane prices require policy intervention. In this study, causes of these constraints well as intervention measures were identified. Some of the constraints, however were specific for particular zones like delayed payment for Nzoia sugar zone, while others were observed across the sugar industry, for instance poor infrastructure, lack of finance as well as unreliable weather.

KESREF extension officers have reported several sugarcane production constraints during the 2002-2003 periods (KESREF 2002, 2003). Most of these constraints were similar to those reported in 1999 and 2001 with the exception of cane stool destruction during loading and transportation and lack of market for sugarcane. The latter was reported in Miwani zone due to the indefinite closure of Miwani sugar factory in February 2001. A frequency of the identified problems was done for three periods and those constraints which persisted in all the three periods were ranked and interventions recommended.

These studies however, were done based on reports by extension officers and sugar/outgrower companies. This study being reported herein is the first to include farmers' participation in constraint identification, ranking and suggesting of appropriate intervention measures. It was also participatory to ensure that it brings out the real issues from the farmers' perspective.

The objectives of the study were:

- To identify and rank the major sugarcane production constraints with the help of farmers in their respective zones
- To identify and recommend possible intervention measures

The expected output was to report on the zonal ranking of constraints and recommended appropriate intervention measures in the various sugarcane production zones.

The expected impact was to better formulation of research and policy interventions for each sugar zone by all the relevant stakeholders.

Methodology

A multi-disciplinary team of scientists from KESREF consisting of socio-economists, senior extension officer, an agronomist and a plant breeder, accompanied by zonal extension officers visited different sugarcane growing zones in June 2005. The outgrower and Sugar companies, in collaboration with the respective sugar zones identified farmers for this exercise. These farmers were then invited to the study meetings. In the meetings, farmers identified sugarcane production constraints in their sugar zones. The farmers with the assistance of the research team then ranked these constraints using a paired matrix (not presented in this report) and finally identified possible intervention measures. A total of 450 farmers drawn from 9 sugarcane production zones participated in 15 group meetings during the exercise. The zones included Busia, Mumias, Nzoia and West Kenya in Western Province; Muhoroni, Chemelil, Miwani and Sonysugar in Nyanza Province. One group meeting was held in each sugar zone except Mumias (4), Busia (3), Chemelil (2) and Sonysugar (2) due to their large sizes, logistic considerations as well as non-uniformity of the zones.

Results and Discussion

The findings presented herein are the output from the discussions and conclusions arrived at during the group meetings attended by representative sugarcane farmers, sugar/outgrower company staff with KESREF scientists playing the lead role. The identified and ranked constraints as well as recommended interventions (Tables 1-16). The ranking of the constraints was based on the method adopted from Lelo *et. al*. 2000.

West Kenya sugar zone

Constraints

West Kenya sugar zone is unique from other sugar zones as it has no nucleus estate and does not give loans/credit to farmers for cane development. The major (Table 1) problem was poor public relations between company field staff and farmers leading to haphazard and delayed harvesting followed by poor harvesting programme and inadequate extension services.

The problem that ranked least was unproductive soils in some areas followed by destruction of cane stools during transportation.

Table 1: Ranked Sugarcane production constraints in West Kenya zone

Rank	Problem Description
1.	Poor public relations between farmers and the miller (field staff) (PPR)
2.	Poor harvesting programme leading to delayed harvesting up to 35 months (PHP)
2.	Inadequate extension services (EC)
4.	Lack of capital and access to credit facilities for cane development (LC)
4.	Poor crop husbandry practices (PCH)
4.	Poor land preparation methods (PLP)
4.	Inappropriate use of cane proceeds (ICP)
8.	Planting of poor quality seedcane (use of cane tops for planting) (PSC)
9.	Lack of confidence in handwritten receipts at weighbridge (CW)
10.	Lack of cane planting programme (LPP)
11.	Infield destruction of cane stools by tractors during transportation (LDT)
12.	Poor/unproductive soils in some areas (US)

Interventions Measures

Through discussions, various suggestions were made to address the constraints that had been identified. The proposed solutions ranged from policy, research to administrative (Table 2). It is important to note that most of the proposed interventions were administrative since a majority of the constraints were also managerial in nature. As identified, the biggest problem in West Kenya zone was poor public relation between farmers and the sugar company field staff. This was made worse by the fact that in this zone, the miller uses a permit system for cane to be harvested. For a farmer to acquire this permit, the field staff is very important in reporting the correct age of the cane. This gives room for some farmers to be favoured against others with cane of similar cane. Cases of bribery enter at this point making it difficult for some farmers to harvest their cane at the correct age. As a way of eliminating this, it was suggested that seminars for field assistants be intensified as well as establishment of a suggestion box at West Kenya. West Kenya management was also asked to hold monthly meetings to address farmers' complaints. Table 2 contains the details of the proposed interventions for all identified constraints.

KESREF is required to address the issues of strengthening extension services and undertaking research on utilization of filter press mud as fertilizer coupled with soil sampling and analysis.

Tables 2: Showing Production Constraints and recommended Remedial strategies in West Kenya

Constraint Description	Proposed interventions
Poor public relations between millers and farmers.	-Supervision of field assistants by management to improve public relations - Suggestion box to be put up at West Kenya sugar company factory (WEKSCOL) - Seminars for field assistants and tractor crews on improving public relations. - WEKSCOL to hold monthly meetings to address farmers' complaints
Poor harvesting programme	- Develop and follow a planned harvesting programme -Corrupt field assistants and supervisors should be disciplined by the management
Inadequate extension services	-Improve communications to inform farmers on meetings by WEKSCOL and WEKO -Field officers to intensify extension programmes through regular meetings/seminars -Use farmers' pay days to extent information and technology. -Increase planned field or farmers visits -KESREF to intensify field days and demonstrations of new technologies
Lack of capital/credit facilities for cane development.	- Farmers to be educated on alternative credit facilities. - Explore possibilities to revive loaning by Outgrower Company (WEKO) and WEKSCOL. - Develop procedures to deal with loan defaulters.
Poor crop husbandry practices	- Farmers should be educated on ways of managing sugarcane crop - Farmers be given advances to carry out timely farm operations
Poor land preparation	- Contractors should be well supervised while ploughing by owners and field supervisors - Contractors should be penalised where they do shoddy work
Inappropriate use of cane proceeds	-Farmers in consultation with their spouses to make wise investments decisions
Planting of poor quality seedcane (use of cane tops)	- Farmers to use 12 – 14 months old clean seedcane from their fields. - On-farm demonstration /trial by KESREF to be undertaken on use of cane tops.
Lack of confidence in weighbridge	- Weighbridge needs to be inspected by the Weights and Measures Department on a regular basis - Avoid overloading of tractors from the field - Computer to be provided soon
Lack of planting programme	- planting programme to be developed by both millers and farmers
In field losses due to tractor trampling	-Drivers not to give tractor to loaders -Discourage overloading of tractors -Cane to be grown in wider spacing at least 1.2 metres
Unproductive soils in some areas	- Studies be made by KESREF on use of filter mud for unproductive soils - Soil sampling and analysis to determine nutrient status (KESREF)

Nzoia Sugar Zone

Constraints

The major problem production constraint in this zone was poor keeping of farmers' records by the company. This has led to farmers losing payment because of mix-up in farmers' records. Supply of inputs is also interfered with under such circumstances. Farmers are also charged wrongly for farm

operations like land preparation and seedcane supply. This problem was followed low cane prices and high cost of inputs which seriously eroded farmers' profits (Table 3). Poor public relations between the miller and farmers initially thought to be a major issue was ranked last.

Table 3: Ranked Sugarcane production constraints in Nzoia zone

Rank	Problem Description
1.	Poor keeping of farmers records (PPR)
2.	Low cane prices (LCP)
3.	High cost of farm inputs (HCI)
4.	Lack of finance/credit for cane maintenance (LF)
5.	Lack of and delayed supply of quality farm inputs (DSI)
6.	Poor timing and supervision of farm operations (PTSO)
7.	Poor land preparation standards (PLP)
8.	Inadequate knowledge/ information on new cane varieties (LKT)
8.	Cane losses due to poor harvesting, loading and transportation (CLH)
8.	Cane losses due to pests, fire and poaching (CLPF)
11.	Poor management of cane varieties especially CO 945 (PMV)
12.	Poor public relations between miller and farmers (PPR)

Intervention Measures

As reported above the major constraint identified was poor keeping of farmers, records by the miller. To avoid this situation, it was suggested that all farmers' records be computerised something which the management promised to work on immediately. To improve profitability of cane production it was recommended that the sugarcane price should be reviewed upwards. In addition, costs of production should be reduced through bulk sourcing of inputs such as fertilizers and minimising of the number of field operations including the frequency of harrowing and ploughing.

KESREF has to actively initiate educational programs for farmers on sugarcane varieties suitable for this zone and proper crop husbandry practices as well as strengthening extension linkages in the zone. Table 4 gives a comprehensive list of proposed interventions for each identified problem.

Tables 4: Constraints and recommended Remedial strategies in Nzoia Sugar Zone

Constraint Description	Proposed interventions
Poor keeping of farmers records	-Computerization of farmers' records recommended
Low cane prices	-Cane prices to be reviewed upwards regularly based on the pricing formula
High cost of farm inputs	-Number of farm operations be minimized where possible e.g. one ploughing and harrowing -Cheaper sources of fertilizer be explored by KSB -Farmers to be encouraged to develop cane using their own resources. -Bulk sourcing of fertilizer
Lack of finance/credit for cane maintenance	-Farmers' advance system to be introduced by Outgrower/Sugar Company
Lack of and delayed supply of quality farm inputs	-Timely supply of fertilizers and seedcane by the outgrower/sugar company. - Proper planning of supply of inputs by the outgrower/sugar company
Poor timing and supervision of farm operations	-Joint planning of activities by farmers, millers and outgrower companies.

	-Encourage private cane development with coordination by Nzoia Sugar Company.
Inadequate knowledge/ information on new varieties	-Farmers to seek appropriate information on new varieties from NSC and KESREF. -Establish more demonstration plots
Poor land preparation standards	-Improve supervision by farmers and millers. -Improve supervision of land preparation by contractors.
Cane losses due to pests, fire and poaching	-Farmers need to be supplied with pesticides to control pests by the sugar company -Farmers and supervisors to improve supervision to curb poaching
Cane losses due to poor harvesting, poor loading and transportation	-Supervision of cane cutters be improved -Overloading of transport units should be discouraged -Appropriate trailers for transportation be designed and introduced
Poor management of cane varieties, especially CO 945	-Farmers be educated on the importance of good crop husbandry
Poor public relations between miller and farmers	-Management to introduce in-service training of staff on importance of handling farmers with courtesy.

Busia Sugar Zone

Constraints

Busia Sugar Zone was sub-divided into 3 sub-zones for this purpose: North, Central and South. One meeting was held in each sub-zone. In all the three sub-zones of Busia sugar zone, high cost of transport was ranked first due the long distance between Busia Sugar zone and Mumias sugar factory (over 40 km) (Table 5). The other problem that ranked highly was biased contracts between farmers and miller. Farmers strongly felt that they were hurried to sign contacts without clearly understanding the implications. In addition, delayed supply of inputs and poor supervision of the field operations including land preparations, planting, harvesting and transportation have led to reduced cane productivity in the zone.

Table 5: Ranked Sugarcane production constraints in Busia zone

Rank	Busia Central	Rank	Busia South
1.	High transport costs (HTC)	1.	High transportation costs (HTC)
2.	Lack of capital for cane establishment (LC)	2.	Biased contract between miller and farmer (BC)
3.	Lack of education to farmers before signing contract with miller (LE)	3.	High cost of inputs i.e. fertilizer (HCI)
		4.	Low cane prices (LCP)
4.	Inadequate and untimely supply of farm inputs. (TSI)	5.	Cane loss due to poor harvesting, spillage and poaching (C Loss)
4.	Prevalence of pests mainly termites and moles (PD)	6.	Declining soil fertility (DSF)
		7.	Delayed supply of inputs (DSI)
6.	Farmers not involved in decision making by miller (DM)	7.	Inadequate extension services and supervision (IES)
6.	Arson incidences on cane (ARC)	9.	Lack of farmers' advance services (FAS)
8.	Cane losses due to poor harvesting, poaching and chewing (CLH)	10.	Poor choice of variety and seedcane quality (PVC)
8.	Poor supervision of farm operations by miller and farmers (PS)	11.	Prevalence of pests and diseases (PD)
10.	Low cane yields (LCY)		
11.	Low profits from cane farming (LP)		
12.	Declining land sizes (DLS)		

Rank	**Busia North** **Problem description**		
1. 2. 3. 4. 5. 5. 7. 8. 9. 11. 11.	High cane transport cost (HTC) Low cane prices (LCP) Inaccuracy at weighbridge (IW) High cost of input (fertilizer) (HCI) Lack of farmers advance services (FAS) High minimum acreage for contracting (1 Ha) (HMC) Cane losses due to poor harvesting, loading, spillage and poaching (C Loss) Delayed payment of Retention funds (DPR) Sugarcane pests and diseases (DP) Inadequate extension services and poor supervision (IES) Duplication of service between BOCO and BSC (DS) Indiscipline cane cutters (IDCS)		

Interventions Measures

The high cost of cane transportation could be addressed though the construction of the proposed Busia sugar factory (Table 5). This would reduce the distance covered and ultimately the cost involved in order to deliver cane from the zone to Mumias sugar mill. As is the case for Nzoia sugar zone, delayed supply of inputs mainly seedcane and fertilizer by Mumias Sugar Company also ranked highly. It was recommended that Busia Sugar Company take over this role instead of Busia Outgrowers Company (BOCO). Farmers felt that they should be given more education on the contracts before signing them. They further recommended (Tables 5) that constraints and recommended remedial strategies in Busia Sugar Zone was that the minimum acreage for cane contracting should be one acre (0.4ha) of land since most farmers in the zone fall in this category.

Busia Sugar Company and KESREF should address the issue of pests and diseases and provide appropriate information on the controls through enhanced extension services.

Tables 6: Constraints and recommended remedial strategies in Nzoia Sugar Zone

Constraint Description	**Proposed interventions**
High transport costs	-Construct factory at Busia because it is over 40 km from Mumias -Mumias sugar company to continue subsidising the transport cost for farmers
Lack of capital	-Involve AFC and other financiers with low interest rates in cane funding. -Encourage farmers to seek loans from other lending institutions
Biased cane contracts between miller and farmer	-Educate farmers before signing contract -Simplify the contract document -Circulate a copy for farmers to read in advance before signing. -Negotiation should consider the farmers' opinions

	-Minimum acreage for contracting be lowered to one acre (0.4 ha).
Delayed supply of farm inputs	-BSC be involved instead of BOCO -Timely supply of seedcane and fertilizer -Encourage farmers to source inputs privately.
Pests and diseases (moles, termites, scales, Striga, smut)	-Company to avail pesticides for control of termites. - Farmers to be educated on KESREF's recommendations on the control of major pests and diseases. - Explore possibility of controlling moles using traditional means
Involvement of farmers in decision making	-Policy makers or decision makers should consult farmers on crucial issues concerning them.
Burnt cane/arson cases	-Severe penalties set on cane burning/arsonists. -Improve supervision -Establish fire breaks
Cane losses due to poor harvesting, theft and spillage	-Improve harvesting systems/programmes -Establish mobile weighbridges -Ban cane transportation at night - Improve supervision on cane cutters and transporters - Jaggery owners should not be awarded cane transportation contracts
Poor supervision	-Farmers should supervise operations on their farms -Telephone farmers should treat cane farming as a business -Enhance supervision of cane harvesting
Low cane yields	-Increase use of fertilizers -Adopt improved cane varieties. -KESREF and sugar company to identify causes of low cane yields -Soil sampling and analysis to be encouraged -Crop rotation -Use cheaper alternative sources of fertilizer e.g. farm yard manure and filter press mud
Low profit	-Address the issue of transport and other production costs -Improve cane husbandry practices -Review the cane price regularly based on the cane pricing formula.
Declining land sizes & silent farmers	-Farmers recommended individual contracts of up to 0.4 ha.
High cost of farm inputs	-Reduce taxes and interest rates. -Millers to import fertilizer direct in bulk -Encourage farmers to finance own operations (self-financing)
Inadequate extension services	-Increase frequency of training programmes by KESREF and Busia Sugar Company -Publicity of meetings to be improved -Farmers should develop a positive attitude towards extension meetings
Inaccuracy at weighbridge in Mumias	-Introduce mobile weighbridges -Sugar Company management should discipline weighbridge staff to root out craft
Lack of farmers' advance system (F.A.S.)	-Provide F.A.S. for farmers -Farmers to join SACCO to attract loans
Poor choice of variety and seedcane quality	-KESREF to look into tasselling of cane variety CB 38-22 -Use of recommended varieties

Delayed payment of Retention funds	-Retention funds should be paid promptly to farmers as per the contract terms
High min. acreage for contracting	-Minimum acreage for contracting should be reduced to 1 acre (0.4 ha).
Indiscipline cane cutters	-Educate contractors and cane cutters on importance of courtesy -Cane cutters should be given rules and regulations of working. - Motivate cane cutters

Mumias Sugar Zone

Constraints

This is the largest sugar zone in the sugar industry. For this reason, the zone was sub-divided into four sub-zones: North, East, South and West. Mumias had the highest number of group meetings (4) and consequently the highest number of reported constraints. Although no single problem ranked first in all zones, cane fires, biased contracting, poor harvesting programme and high costs of inputs were identified as major constraints in the zone (Table 7).

Intervention Measures

Various intervention proposals were given for each identified problem (Table 8). This included proper education to be given to farmers before signing contracts with the miller to avoid cases such as what the farmers termed 'exploitation'. Most farmers do not understand their role as spelt out in the contract. They attribute this to the manner in which the contract is designed. Sugarcane losses at the farm was associated with theft of stacks, spillage and cane fires which could be reduced if supervision by the both the miller and farmer were enhanced. Proper and timely undertaking of operations and activities like land preparation, seedcane supply, harvesting and transportation of cut cane will improve farmers' morale and improve productivity.

It was also recommended that KESREF and collaborators should enhance technology transfer services on varieties, assess the level of pest and disease prevalence and provide appropriate cane management practices for increased cane productivity at the farm level.

Table 7: Ranked sugarcane production constraints in Mumias sugar zone

Rank	Mumias North zone	Rank	Mumias East Zone
1.	Cane fires and biased contracts (CFC)	1.	Cane fires and poor harvesting programme (CFDH)
2.	Cane losses (C Loss)	2.	Low cane prices and high cost of farm inputs (LCPHI)
3.	Poor variety choice (PVC)	3.	Inaccuracies and cheating at the weighbridge (ICWB)
4.	Delayed transportation of cane (DTC)	3.	Poor land preparation standards (PLPS)
4.	Inaccuracies at the weighbridge (IW)	5.	Cane loss due to poor harvesting, theft of stacks, loading and
4.	Poor timing of planting (PTP)		spillage (CPH)
7.	Poor land preparation standards (PLP)	6.	Delayed supply of farm inputs especially fertilizer (DSFI)
8.	Delayed supply of inputs (DSI)	7.	Lack of proper education on new transport zones and proper
9.	Poor marginal soils (PMS)		communication between farmers and the miller (IEC)
9.	Delayed cane harvesting (DCH)	7.	Poor variety choice (PCV)
11.	Diversion of inputs (DI)	9.	Poor farmers' record keeping by the Sugar Company (IFR)
12.	Delayed crediting of farmers account	10.	Delayed transportation of cut cane (DTC)
	(CRF)	11.	Inaccuracies in surveying (IS)
		12.	Prevalence of pests (termites) and weeds (PW)
	Mumias West Zone		**Mumias South Zone**
1.	Non-adherence to contracts (NAC)	1.	High cost of production i.e. high cost of fertilizer and other
2.	Poor soil fertility (PS)		farm inputs (HCP)
3.	Poor weed management (PWM)	2.	Poor supervision and extension services (PSE)
4.	Poor quality of seed cane and variety	2.	Poor estimate of distance/plot size (EDS)
	choice (PVC)	4.	Inaccuracy at weighbridge (IW)
5.	Poor treatment of private farmer (PTPF)	5.	Poor variety choice (PVC)
6.	Poor determination of distance and size	6.	Delayed harvesting of early maturing variety (DHEMV)
	of farmers plots (PDE)	6.	Poor land preparation (PLP)
6.	Cane losses during harvesting,	8.	Cane losses due to high cutting and poaching (C Loss)
	transport, pest or disease (CLPH)	9.	Delayed supply of inputs (DSI)
6.	High cost of inputs (HCI)	9.	Diversion of inputs (DI)
9.	Poor land preparation standards (PLP)	11	Prevalence of pests (moles) and weeds (*Striga)* (PW)
10.	Diversion of inputs (DFI)	12.	Stool destruction during transportation of cane. (SD)
11.	Delayed supply of inputs and services		
12.	(DSI)		
	Inadequate supervision/extension (ISE)		

Tables 8: Showing Constraints and recommended Remedial strategies in Mumias Sugar Zone

Constraint Description	Proposed interventions
Cane contracts between miller and farmers	-Farmers should be educated on the contract and roles of MOCO and MSC. - Contract be revised in consultation with MOCO, MSC & KSB e.g. include effect of cane losses. - The concerned parties should ensure adherence to contract terms. - Contracts be issued to farmers in advance before signing for acquaintance
Cane losses due to poor harvesting, transport, stack theft and fire	-Cane cutting contractors should reduce the cane cutters tasks. -Cane cutters payment rates be reviewed upwards -Improve supervision -Cane cutting contractors/supervisors be in serviced regularly -Enhance surveillance and collective responsibility by farmers and Outgrower Company. -Judiciously licence jaggery plants -Discourage over-loading of trailers by having weld mesh on the trailers -Cane should not leave the farmers field without the records of the tractor on the delivery note.
Poor variety choice	-Establish more demo plots, by KESREF on new varieties and technology. -KESREF should carry out more on-farm trials before release of varieties. -Farmers should have a right in choice of varieties planted - Soil sampling be done before change of cane varieties - Identify high ratooning varieties
Delayed transportation of cane.	-Ensure cane is transported in time (within 72 hours) to the mill. -Company to acquire more tractors for cane transportation -Roads should be well maintained to reduce spillage and delay in transportation -Cess money to be retained by Sugar Company instead of County Council for proper utilization
Inaccuracies at the weighbridge	- Company is in the process of computerizing the system - Discourage cane transportation at night to allow the farmer to accompany the tractor. -Establish possibilities of having mobile weighbridges. - Corrupt weighbridge officers to be sacked - Farmers be allowed to verify tonnage at weighbridge - Farmers be vigilant in supervising cut cane to avoid stack and tonnage theft
Poor timing of planting	-Plant between March and October in uplands, and Nov and Jan in lowland areas.
Poor land preparation	-Improve supervision -Contractors who do shoddy jobs should be blacklisted -Contractors be phased out and be replaced by Sugar Company machinery for land preparation - Introduction of job completion certificates (JCC)
Delayed supply of inputs	- Timely supply of farm inputs - Farmers' complaints be addressed timely
Poor marginal soils	-KESREF and MSC to carry out further analysis for nutrient availability -Increase fertilizer use if necessary -Organic farming – possibility of MSC supplying farmers with filter mud -Deep ploughing by mould board recommended - KESREF to provide analytical services
Delayed cane harvesting	-Company to stick to the contract agreement -Mumias Sugar Company to implement the proposed new harvesting programmes.
Diversion of inputs (fertilizer)	-Supervise application of fertilizer in blocks -Able farmers to buy their fertilizer (self-financing) - Enforce law to offenders -Timely supply of fertilizer -Farmers' advance scheme be reinstated
Delayed crediting.	-MSC should adhere to the Sugar Act recommendations on cane payment terms. -Interest on services and inputs should stop immediately once cane reaches the weighbridge
Poor harvesting programme	- Planned harvesting programme should be followed strictly
Low cane prices and high	-Cane price be improved

cost of farm inputs	-Transportation rates be reviewed realistically -Ways of reducing fertilizer prices like bulk sourcing be encouraged -Reduction of taxes on inputs -Direct importation of inputs -Review of seedcane prices/costing.
Cane loss due to poor harvesting, theft of stacks, loading and spillage	- Supervision during harvesting be improved - Cane cutters be assigned reasonable tasks to avoid poor cane cutting - Farmers should report cases of poor cane harvesting and collection immediately - Farmers be made to sign job completion certificates especially after harvesting -Any left over cane be reported to the company and remedial action taken. -Transport – Mobile weighbridge be enforced -Both contractors and cutters be paid based on tonnage -Incompetent contractors be blacklisted -Proper supervision be enforced -Cane be harvested by MSC not contractors -Jaggery factories should be licensed
Lack of proper education on new transport zones and proper communication between farmers and the miller	- Company should educate farmers on current zoning system - Field demonstrations by KESREF and MSC be increased - Company management be courteous to farmers - Farmers' representatives be consulting farmers before making crucial decisions - Farmers be invited to attend exhibitions and visit other sugar zones and KESREF
Inaccuracies in farmers record keeping	- Farmers' records at the Sugar Company be computerized
Prevalence of pests (termites) and weeds	-Research into ways of controlling pests and diseases prevalent in this zone be done -Insecticides be supplied to farmers by MOCO/MSC -Weed scientist from KESREF visit the area and identify some noxious weed prevalent in the area.
Poor determination of distance, plot size and mill cane	-Review of the transport distances with farmers' involvement. -Farmers to be present during the survey of their cane plots to ensure accurate determination of plots and if necessary cross checking to be permitted. -Survey section acquire more manpower -In case of change in acreage of land under cane, farmers should officially inform the company -Field offices be assigned a surveyor
Inadequate supervision/extension	-Refresher courses to be offered for extension staff. -Correct placement of the field staff by zones.

Chemelil Sugar Zone

Constraints

Chemelil sugar zone is the only zone with distinct small and large scale farmers. The study team therefore held separate meetings with each category of farmers. High cost of farm inputs and general lack of money for cane establishment were identified as the major constraints in the zone (Table 9).

Table 9: Ranked sugarcane production constraints in Chemelil zone

Rank	Large Scale farmers	Rank	Small Scale farmers
1.	Lack of money for operations (LM)	1.	High cost of farm operations especially land preparation
2.	Declining soil fertility (DSF)	2.	Poor harvesting programme
3.	Poor land preparation (timing and drainage) (PLP)	3.	Lack of finance for cane establishment and maintenance
4.	Lack of labour for large scale farmers (LL)	4.	Cane loss due to spillage
5.	Poor quality of services – weeding, spraying and harvesting (PQS)	5.	Inadequate extension services
		6.	Poor weeding because of low rates

6.	Weed control and maintenance (WCM)	7.	Inadequate machinery for land preparation
7.	Cane loss through chewing, fire and spillage (C Loss)	8.	Poor quality seedcane
8.	Limited variety choice (PVC)	9.	Pending loans
9.	Lack of extension services (LES)	10.	Adverse weather conditions
10.	Poor harvesting programme (PHP)	11.	Limited choice of cane varieties

Intervention Measures

In view of the high costs of inputs and inadequate capital for cane development, it was suggested that alternative sources of funds for cane development to be identified to complement the existing sources. The problem of high costs of cane production in the Nyando zone should be addressed through identifying appropriate and cheaper land preparation methods, cheaper fertilizer sources/sourcing and reducing the farm machinery levies (Table 10).

Table 10: Constraints and recommended Remedial strategies in Chemelil Sugar Zone

Constraint Description	Proposed interventions
Lack of money for operation	- SDF loans to be channelled through O.Gs and factories so that it is advanced to farmers - All other funding institutions to consider advancing money to farmers to alleviate poverty. - Outgrower organisations to intensify the source of funds from CSC, KSB, e.t.c. to give to farmers as credit
Declining soil fertility.	-Elaborate soil survey in the area recommended -To encourage crop rotation practices
Poor land preparation (timing and drainage)	-Proper timing of land preparation -Use of appropriate land preparation implements and supervision by CSC -Vetting of contractors by the company is necessary
Lack of labour for large scale farmers	-To educate the people to minimize the level of drinking to increase work output. -Further investigations to be done why we have insufficient labour. -To introduce labour saving practices for large scale farms e.g. herbicides
Poor quality of services – weeding and spraying.	-Elimination of cheating in spraying -Use of recommended rates -Supervision and penalty for those engaged in bribery - Proper timing of weeding operations - CSC to harmonize weeding rates -Proper crop maintenance to be encouraged -KESREF to determine current weed status in the zone and recommend appropriate control strategies.
Cane loss through chewing, fire and spillage	-Arsonists to be arrested -Spillage needs to be reduced -Strict policing -Cess funds should be well utilised to ensure roads are well maintained - Certificates of job completion be introduced - Legal framework needed on compensation for the losses
Limited variety choice	-KESREF, CSC and OGCs to set up more demonstration plots in the area to create awareness of new varieties
Inadequate extension services	- Extension and supervision to be strengthened by KESREF and CSC - Establish more demonstration plots - Intensify farmers' meetings
Poor harvesting programmes	-KESREF to investigate and provide suitable irrigation technology. - Synchronize harvesting programmes with available crushing capacities - Eliminate corruption in harvesting section - Farmers should sign contract with millers
High cost of farm operations	-Reduce cost of diesel, fertiliser and chemicals through bulk sourcing

especially land preparation	-Farmers organisations to source fertilizer and other inputs in bulk -More research be done on heavy ploughing -Franchise on machinery leads to high costs
Poor quality seedcane	-High quality seedcane should be acquired through bulking in outgrower section -Education to farmers be intensified -Seed inspection should be done by CSC before being released to farmers
Inadequate machinery for land preparation	-Outgrower Company and CSC to procure more land preparation machinery through SDF
Interest on pending long term loans	-The government should explore possibilities of writing off these loans
Adverse weather conditions	- Choose suitable varieties for drought and flooding condition - Drainage channels be enhanced

Other interventions include setting up comprehensive programmes for land preparation and harvesting which are practical and can be adhered to.

KESREF should intensify its extension services in this zone through more demonstration plots on new varieties; weed control and general appropriate crop husbandry practices.

Muhoroni Sugar Zone

Constraints

The eleven problems identified and ranked in Muhoroni Sugar zone are listed in Table 11. The major problem identified was high cost of farm inputs while the least ranked was poor crop husbandry practices.

Table 11: Ranked Sugarcane production constraints in Muhoroni zone

Rank	Problem Description
1.	High cost of inputs i.e. fertilizer and interest on farm operations like land preparation (HCT)
2.	Poor planning and coordination of planting and harvesting programmes (PPC)
2.	Pests and diseases (Striga, Smuts, Humans) (PD)
4.	Soil exhaustion (DSF)
5.	Burden of interests on past loans (farmers) (IL)
6.	Inadequate extension services (IES)
6.	Unsuitable varieties and poor quality seedcane.(PSV)
6.	Poor crop husbandry practices (PCH)
9.	Lack of and untimely supply of farm inputs (DSI)
10.	Soil erosion, water logging and drainage (WLDE)
11.	Poor record keeping by farmers (PRK)
11.	Cane loss due to high cutting and spillage (LSC)

Intervention Measures

High cost of farm inputs such as fertilizer was identified as a major constraint in Muhoroni zone (Table 12). It was hence suggested that cost of cane production be reduced through zero rating of taxes on farm inputs such as fertilizer and farm machinery. Sugar cane productivity could be enhanced in Muhoroni through development of efficient planting and harvesting programmes by millers in collaboration with the relevant farmers' organisations.

KESREF is required to address the question of declining soil fertility and improve extension services.

Table 12: Constraints and recommended Remedial strategies in Muhoroni Sugar Zone

Constraint Description	Proposed interventions
High cost of inputs	- Reduction of taxes on farm inputs - Prices of inputs be adjusted downwards - Price of cane be reviewed upwards
Poor planning and coordination of planting and harvesting programmes	- Cane should be harvested at optimum age. - Company to develop and follow clear planting and harvesting programmes - Joint planning of activities between miller and farmers.
Pests, diseases and cane fire	- Outgrower companies should supply farmers with pesticides to control pests - Use of filter press mud by farmers to control pests such as *String* - KESREF to provide control measures for smut disease. - Fire breaks be established - Trash burning be discouraged - Arsonists be identified and prosecuted - Factories should acquire appropriate fire fighting equipment
Soil Exhaustion	- Crop rotation especially with legumes - Soil sampling and analysis to determine nutrient status -Use of filter mud
Accrued interest on past loans affecting current farmers	-The government should consider writing off previous long-term loans
Unsuitable varieties and poor quality seedcane	- Improve extension services & education on varieties - Establish nurseries to supply high quality seedcane - Establish demonstration plots for new varieties.
Inadequate extension services	-KESREF to enhance farmers' educational meetings, seminars etc - Establish more demonstrations for new technologies
Lack and untimely supply of farm inputs	- Ensure timeliness in the supply of fertilizer and seedcane. - Crash programmes on farm operations i.e. ploughing & harrowing be discouraged
Soil Erosion/drainage	- Proper methods of soil conservation to be availed to farmers for adoption. - Farm operations to be done in line with slope & contour - Cess money to be retained by factory for maintenance of water drains.
Cane losses due to poor harvesting techniques and spillage.	- Grade and maintain cane roads. -Supervision of cane cutting be improved - Cess funds to be retained and used for maintenance of sugar roads
Poor record keeping	- Educate farmers on importance of keeping records (KESREF and sugar company)

Miwani

Constraints

Miwani sugar factory was closed in February 2001. Despite this, farmers in this zone still plant cane. This cane is taken to Muhoroni Sugar Mill, over 40 km away (Table 13).

Table 13: Ranked Sugarcane production constraints in Miwani zone

Rank	Problem Description
1.	Poor roads in the sugar zone (PRSZ)
2.	High cost of transportation and cheating in rates (HCIC)
3.	Cane loss due to chewing, poor harvesting, untimely harvesting, poor collection, loading, spillage and delayed transportation (CLHS)
4.	Delayed payment and inadequate capital sources (DPICS)
5.	Poor land preparation methods especially ploughing (PLP)
6.	Low and unreliable rainfall (LUR)
6.	Prevalence of weeds (Striga) (PWES)
6.	Inadequate extension services (IES)
9.	Destruction of cane stools during loading (DCSL)
10.	Inaccuracies at the weighbridge (IW)
11.	Poor choice of cane varieties (PCV)
12.	Declining soil fertility (DSF)

Poor roads and high transport charges were identified as the major constraints affecting cane production.

Intervention Measures

The most highly ranked problem in the zone is poor roads. Most parts of Miwani zone are inaccessible, especially during rain season. It was suggested that funds from the cess kitty should be utilised to reverse this situation (Table 14). The Acts governing cess and CDF funds should be changed to empower farmers to have more say on utilization. The other major problem in this zone is the long distance between the farmers and the miller (Muhoroni) where farmers currently deliver their cane. The distance between Miwani and Muhoroni factory is over 40 kilometres. This makes farmers to lose a lot of money through transportation costs. Over 35% of farmers' payment is taken up by transport cost. The most ideal solution is to revive Miwani sugar factory. It is important to note that Miwani Sugar mill is the only sugar factory in Kenya with a sugar refinery which could be used to produced refined sugar and hence save the country's needed foreign exchange.

KESREF should will focus on improving technology transfer mechanisms and developing cost effective management practices. In addition more research should be geared towards the control of *Striga* weed.

Table 14: Constraints and recommended Remedial strategies in Miwani Sugar Zone

Constraint Description	Proposed interventions
Poor roads	-Cess funds to be used on roads -Act need to be amended so that farmers can manage the cess funds. -1% sugar levy meant for roads need to be channelled to the roads by KSB. -The petroleum levy meant for classified roads to be extended to sugar roads. -Constituency Development Fund should be used for road construction and repair. -Farmers must be represented in CDF committees.
High & cheating on transportation rates.	-Revival of Miwani Sugar Company

	-The miller should subsidize for farmers in far zones as is the case in Busia zone -Information on change of zones to be availed to farmers. - Cane transporters to be contracted especially by Chemelil to avoid doctoring of transport rates. -The miller should intervene on controversies between contractor and farmer. -Factories should computerise farmers' records. -Harvesting permits be issued and enforced. -Farmers be contracted by millers -Fraudulent contractors be prosecuted
Cane loss due to chewing, poor harvesting and untimely harvesting.	-Supervision by miller, farmer and transporter to be improved -Cane chewers to be prosecuted. -Cane to be harvested at recommended age. -Chemelil Sugar Company should improve on planting programmes. -Transportation units to be increased through loans to O.G and societies. -Kenya Wildlife Services should intervene to control monkeys.
Delayed payment and inadequate capital sources	-Chemelil SC should improve on cane delivery payment -Chemelil SC should change their negative attitude towards Miwani farmers
Poor land preparation	-Farmers be advised on ploughing in relation to different soil types by KESREF
Low and unreliable rainfall	-Introduction of resistant varieties by KESREF -Enhance irrigation research by KESREF
Weeds (*Striga)*	-KESREF to advise farmers on best weed control practices through demonstrations. -CSC and KESREF to advise farmers on use of suitable herbicides and pesticides
Inadequate extension services	-Employ, more extension officers (KESREF). -In-service agricultural staff in sugar companies on new production practices.
Destruction of cane stools during loading	-Reduce cane harvesting during wet season - Manual labour be used to remove cane from wet fields before loading on tractors -Cane stacking be introduced as done in Mumias zone
Inaccuracies at the Weighbridge.	-Farmers be represented at weighbridges -Farmers be allowed to verify their cane weight -The weighbridges to be subjected to standard measures by KEBS. -Millers practice utmost good faith -Mobile weighbridge be introduced
Poor choice of cane varieties	-KESREF should intensify demonstration of cane varieties
Declining soil fertility	-Crop rotation to be encouraged -Soil sampling and analysis be done by KESREF -Farmers to be educated on the importance of fertilizer use. -Use of filter mud (75 tons per ha).

Sonysugar Zone

Constraints

Sonysugar zone was sub-divided into two zones (Table 15). Farmers in Trans-Mara zone ranked low cane prices and high cost of inputs as a major problem, while in Awendo delayed payment for delivered cane was ranked high. Delayed harvesting of cane featured as a major problem in the two zones. Cane harvesting age was estimated at 35months instead of 18-24 months for plant crop and 16-18 months for ratoon crop.

Table 15: Ranked Sugarcane production constraints in Sonysugar zone

Rank	Awendo	Rank	Trans Mara
1.	Delayed payment for delivered cane (3 months) (DP)	1.	Low cane prices and high cost of inputs (LCP)
1.	Biased contracts which favour millers (BC)	2.	Delayed harvesting (35 months) and transportation (DHT)
1.	Delayed harvesting (35 months), transportation and prolonged interest rates (DH)	2.	Poor road maintenance (PR)
4.	Lack of finance for cane establishment (LF)	2.	Delayed payment for delivered cane (DP)
5.	Poor timing of farm operations (PTFO)	4.	Interest rates on inputs and farm operations
5.	Poor supervision of farm operations (PS)	4.	charged beyond recommended cane harvesting age (PIR)
7.	Cane loss due to poor loading, spillage and stack theft. (CLLS)	6.	High transportation costs (HTC)
7.	Corruption and abuse of Job completion certificates by contractors (CJCC)	7.	Poor land preparation standards by contractors (PLP)
9.	Low yielding varieties (LYV)	7.	Poor seedcane supply programme (PSS)
10.	Poor quality and quantity of supplied seedcane (PQS)	9.	Charging for repeated operations by contractors (DC)
11.	Inaccuracy in land survey and erroneous deductions (ILS)	9.	Farmers not involved in decision making at factory level (FIDM)
12.	Inadequate extension services (IES)	11.	Cane loss due to spillage (CLS)
		12.	Corruption and abuse of Job completion certificates by contractors (JCC)

Intervention Measures

In view of the problem of delayed harvesting and transportation of harvested cane, it was proposed that the expansion of the factory to 6,500 tonnes of cane per day would go along way in alleviating this problem (Table 16). Most cane farmers are now demoralised because the return per investment has reduced given the long duration of waiting before cane is harvested and or paid for. It was recommended that payment for cane delivered should be made within the stipulated 30 days period instead of the current delay of up to six months.

Low cane price and high cost inputs should also be addressed through a review of cane price upwards and lowering of interest on inputs. The introduction of job completion certificates will help in improving the services and therefore minimize on losses through poor harvesting, loading, spillage, stack theft and corruption.

Tables 16: Constraints and recommended remedial strategies in SONY sugar zone

Constraint Description	Proposed interventions
Delayed payments	- Cane delivery payment to be done within the stipulated 30 days -Enforce provision in the agreement - Records should be properly kept or be computerised. - Favours should not be there during payments - Filing system to be improved.
Biased contract between farmer and miller	- Parties concerned to agree and abide by the contract terms.

Delayed harvesting, transportation and prolonged interest rate.	- Expansion of Sony sugar factory to increase the crushing capacity to 6500tcd - Proper planning for planting and harvesting programmes - Company to purchase more tractors with the help of SDF and other financial institutions - Road improvement by utilising cess funds appropriately - Incentives needed to attract more transporters - Farmers should try to buy their own tractors - Prudent financial management - Payments that stay with company after 30 days should earn interest. - Harvesting programme should be harmonized - The farmer should appoint authorised agent - No interest rate should be charged for months past stipulated harvesting date. - Sonysugar Company should adhere to contract with farmer - Farmers to be encouraged to self develop their fields - Company should harvest all farmers' cane, whether contracted by SONY or self developed.
Lack of finance for cane establishment	- Finances to be made available through other financial institutions like AFC. - SDF to be sourced by miller to assist farmers
Poor timing of farm operations	-Proper planning -Farmer education
Poor supervision of farm operations	- Supervisors to relate positively with farmers - Organise field days - The sugar company should give farmers who perform well motivation in form of bonuses.
Cane losses due to poor loading, spillage and stack theft.	- Losses due to overloading and spillage should not be charged on the farmer - Proper supervision during cane loading tractors encouraged to reduce spillage - Securing stacks by chaining to avoid spillage - There should be properly designed trailers for carrying cane -Job completion certificates (J.C.C) should be signed in the field - Transporting cane at night should be discouraged to stop thefts and laxity - Repair roads to minimise cane spillage - Maximum tonnage for each tractor should be determined to curb overloading. - Contractor should hire workers to collect cane left behind (rogota) by the loader
Corruption and abuse at Job Completion Certificates	- Zero tolerance to corruption, necessary - J.C.C. should be signed only after job has been satisfactorily completed. - Job Completion Certificates should be given to supervisor and not contractor - No one should sign J.C.C. other than the farmer - Signature where there is a complaint should be cancelled. -Supervisor to be trustworthy. -Supervisor to certify work and get J.C.C to the farmer to sign
Low yielding varieties	-Researchers to come up with suitable varieties for each zone. -Varieties should be well managed by farmers
Poor quality and quantity of seedcane.	- Supplier of seedcane to adhere to recommendations. - Farmers who can grow seedcane be identified to be seedcane suppliers - Supervisors to be more vigilant. - Honesty on the part of block members. - Sonysugar staff to supervise distribution of seedcane among silent farmers.
Inaccuracy in land survey and erroneous deductions	- The company should employ a qualified surveyor(s). - Build capacity and have equipment in the department -Surveyors should not work at night -Let the farmer be given statement before payment - Proper record keeping/computerisation.
Inadequate extension services	-Sonysugar, KESREF and other stakeholders to work out a programme to educate farmers.
Poor land preparation	- Company should take the responsibility of land preparation - Supervision to improve - Farmer to choose contractor - Poorly ploughed land should be re-ploughed at contractor's cost.

Poor roads	- Construct and repair bad roads - Cess should be used to construct and repair roads - SDF road levy to be made available for road repair
High transportation costs	- Transport rates should be reviewed regularly - Proper zoning to be done (proper records of distance to be kept) - More direct routes would reduce costs (construction of bridges).
Double charging for repetition of operations	-Farmers should write requesting for re-plough instead of 2nd ploughs in case plots were poorly ploughed.
Farmers not involved in decision-making.	-Farmers should be involved in some decision-making - Farmers should have representatives in various forums at factory level.
Low cane prices and high cost of inputs	- Cane prices should be increased. -Prices of inputs should be reduced - Interest on inputs to be reduced
Poor seedcane supply programme	- Programme should be improved through planning involving Sonysugar and farmers

Conclusions

This study aimed at determining the sugarcane production constraints and listing possible intervention measures as perceived by farmers. A cost–benefit analysis of sugarcane production by KESREF socio-economists shows that the return per shilling invested by the farmers is low. This is attributed to the various constraints as identified by the farmers during this survey. Highly ranked and most frequently occurring constraints across the sugar industry have been discussed below.

High cost of farm inputs was consistently ranked highly in all sugar zones. Inputs in this case include land preparation cost, seedcane and fertilizer. In all zones visited, farmers felt that the cost of establishing cane is too high because of the various operations required. The cost of fertilizer has increased by at least 25% between January and June 2005. This has seriously affected the returns in both plant and ratoon crops.

Poor planning, coordination of farm operations and activities by various sugar and outgrower companies came out strongly as another major constraint in the sugar industry. Poor planning for example, leads to poor timing of crucial farm operations like ploughing, planting, delayed supply of farm inputs and harvesting. It consequently contributes to substantial reduction in cane yields. In most zones farmers complained of delayed supply of seedcane, fertilizer and harvesting. Delayed harvesting adversely affects the yield of early maturing varieties like CO 945, N 14 and CB 38-22. In zones like West Kenya and Trans Mara, harvesting has been delayed by up to 15 months above the recommended harvesting age. Under such circumstances most cane varieties are likely to give low yields due to flowering, loss of tonnage and sucrose.

Lack of capital and accessibility to credit facilities featured as a crucial constraint in the various zones. Delayed payment was reported to be severe in Sonysugar and Miwani sugar zones. Cane farmers therefore find themselves in financial problems either for subsistence or for important farm operations like weeding. The problem is worsened by delayed harvesting of cane. When operations like weeding are delayed because of lack of finance, cane yields are severely affected.

Farmers in all sugar zones, except West Kenya, complained of low cane prices. The existing average cane price was KShs. 1,850 per tonne. Sugar prices and that of other inputs like fertilizer have hit an all time high during the period March to June 2005. Low cane prices translate into reduced profit margins. Farmers felt that as prices of sugar and farm inputs rise there should be an equal adjustment in cane prices. ***All sugar companies have however adjusted their cane prices upwards (effective 1st July 2005).***

The cost of cane transportation accounts for 40% of the total costs according to surveys conducted earlier. In some sugar zones, farmers complained of an unfair zoning system introduced by the millers (4 km band). They demanded a return to the old system (10km band). Millers however argue that the previous system is unfair to transporters. In most sugarcane zones transport rates had been increased. This affected farmers adversely. Some sugar zones are more than the recommended economical distance between a farmer and a miller (32 km). Such zones include Busia, Miwani, Soin and Trans Mara. These are areas where more than 40% of payment per tonne goes towards cane transportation costs. Mumias and Sony Sugar Companies have tried to lessen this problem by giving transport subsidy to farmers in far off zones.

Poor supervision of farm operations by both farmers and millers is another constraint raised in most sugar zones. Poor supervision leads to cane losses due to poor harvesting and loading where a lot of cane is left in the farm, stack theft, particularly in Mumias and Sonysugar and cane spillage as a result of overloading. Land preparation standards are also severely affected because contractors are not adequately supervised. Poorly prepared land is re-ploughed at farmers' expense; a phenomenon very common in Trans Mara zone. This seriously affects the farmers' yield and hence profit from cane. Poor supervision also leads to crucial operations like weeding being done poorly by contracted workers. This is a big problem in Muhoroni and Chemelil zones where these operations are contracted. A lot of cane tonnage is therefore lost due to poor weed control arising from poor supervision.

Poor keeping of farmers' records is an issue of grave concern in Nzoia and Mumias sugar zone. Farmers complained that they lose a lot of money because of errors in their records in terms of acreage, distance estimation and tonnage. This was attributed to dishonesty among staff handling farmers' records. Mumias farmers complained of deliberate changing of names and transfer of stacks from one farmer to another. In Nzoia, some farmers are not paid for cane delivered because of what the farmers termed deliberate change of personal information in their records.

Extension services in the sugar industry are generally weak. Farmers do not have adequate information on various cane varieties and their management. Demonstration plots, farmers' extension meetings and field days are not adequate. KESREF and various sugar/outgrower companies have been requested to come out more strongly on this aspect.

Lastly, the condition of roads in the sugar industry is bad. Some sugar zones like Trans Mara, West Kenya and Miwani are inaccessible. Farmers complained of lack of accountability with the cess money deducted from their cane payment. Sugar companies have left road maintenance to county councils, a role which is currently not well performed. Poor roads lead to cane losses through spillage and delays leading to fluctuation in cane supply to the sugar factories.

Recommendations and Way Forwad

The constraints discussed above should be fully addressed by the relevant stakeholders if the sugarcane productivity has to improve and hence contribute to the sugar industry becoming competitive by the year 2008. The following recommendations have been made to address the most outstanding constraints in the sugar industry:

High cost of farm inputs

- Agricultural inputs to be exempted from Value Added Tax (VAT)
- Price of cane to be reviewed realistically on a regular basis
- Number of farm operations be minimized where possible e.g. ploughing and harrowing
- Farmers be encouraged to self finance cane development

- Cane transportation rates be reviewed based on realistic surveys
- Direct importation of inputs in bulk (could be done by KSB for the sugar industry)
- Review of seedcane prices based on realistic estimates of rates and cost.
- Reduce cost of diesel, fertiliser and chemicals through bulk sourcing
- More research be done on heavy ploughing

Poor planning and coordination of farm operations

- Cane to be harvested at the recommended age for each given variety.
- Each sugar company to follow a clear planting and harvesting programme
- Joint planning of cane development and harvesting activities by the millers and farmers
- Proper planning of supply of inputs by millers and farmers organisations

Lack of capital and accessibility to credit facilities

- Farmers to be educated on alternative credit facilities e.g. AFC
- Explore possibilities to revive Farmers' Advance System (FAS)
- Develop agreements to deal with defaulters

Poor keeping of farmers records

- Computerization of farmers' records
- Deploy well trained and honest personnel

Low sugarcane prices

- Cane prices to be reviewed regularly based on sugar price sensitivity
- Accurately monitor and review cane production costs or rates on regular basis

High transportation costs

- Establish new factories in areas far from existing cane factories i.e. Busia, Soin, Miwani and Trans Mara
- Sugar Companies should subsidise transport rates for farmers beyond economic distance from miller

Delayed payment for delivered cane

- Payment for cane delivered should be within the 30 days as stipulated in the Act
- Sugar companies should be vigorous in marketing their sugar
- Farmers records should be well kept for ease of payment

Poor supervision of farm operations

- Supervisors should relate positively with farmers
- Farmers as well as millers should be fully involved in supervising operations in the farms
- Proper standards to be established and farmers and supervisors enlightened.
- Job completion certificate (JCC) should be initiated in all sugar zones

Weak extension services

- Improve communications to farmers on educational programs to increase their participation
- Research-Extension-Farmer-linkages to be strengthened up.
- All relevant key stakeholders to plan for more sugarcane production educational fora
- Field days and demonstrations of new technologies to be enhanced

Poor roads

- Sugar factories should retain cess money so that they take over the task of sugar road maintenance since county councils are unable to do this.
- The Act pertaining to administration should be reviewed to empower the sugar companies to collect and utilise these funds.

Acknowledgements

The study team would like to thank the Management of all Sugar and Outgrower companies for their support and information availed during the study. In particular, we wish to thank staff of Outgrowers Departments of all the sugar companies for mobilizing farmers and ensuring that the meetings went on smoothly. We also greatly appreciate the constructive comments and suggestions given by the KESREF Editorial Committee headed by Dr. J.K. Rono.

Last but not least, great appreciation goes to the Chief Executive Officer, KESREF for providing financial and logistical support and for permission to publish this report.

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