FIELD EVALUATION OF CONCENTRATED MOLASSES STILLAGE AS A NUTRIENT SOURCE FOR SUGARCANE IN SWAZILAND

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Abstract

Stillage or vinasse, which is a byproduct of ethanol production, is produced from the fermentation of molasses and is used as a source of potassium on cane fields at Simunye-Royal Swaziland Sugar Corporation. Due concern regarding its high salt content and Chemical Oxygen Demand (COD), a trial was established on an S set soil (Mayo form) to study the effect of increasing levels of concentrated molasses stillage (CMS) on cane and sucrose yield, recovery of ash in the mill and the impact of CMS on soil quality and the environment. The results of two crop harvests indicated no significant differences in cane and sugar yields when the K source was either muriate of potash or CMS, provided the recommended amount of K was adhered to. The low CMS treatment of 3 t/ha banded on the row initially produced the highest sucrose yield and this provided approximately 160 kg/ha K. Doubling the CMS rate to 6t/ha impacted negatively on cane growth and sucrose yield but no evidence of salt accumulation or pH change was found. The results suggested that the application of CMS at the recommended rate to supply K, would maintain sugar productivity and soil fertility and cause no environmental contamination.

Keywords: alcoholic slops, vinasse, potassium, environment

Introduction

The byproduct of alcohol production from the distillation of molasses, called distillery slops, stillage or vinasse has been used in Australia, Brazil and many other countries mainly as a source of potassium fertilizer in sugarcane fields (Korndorfer and Anderson, 1997). Yield responses varying from 5 to 30% have been reported on ratoon cane treated with 150 t/ha vinasse in Brazil on sandy and clay soils (Silva 1982). Although vinasse has been used on cane lands since the early 1920s, it was not until the fifties that a comprehensive chemical assessment was made by Almeida (1952) as referred to by Nadir and Da Gloria (1977). He described it as an organic liquid residue comprising about 93% water, 5% organic matter (mainly unfermented sugars and other carbohydrates) and about 2% of inorganic dissolved solids. Although it contains neither pathogenic viruses nor bacteria this high organic matter content causes a high chemical oxygen demand (COD) with levels ranging from 10 000 to 60 000 ppm as reported by Kujala (1976) and Jackman (1977) for various factories in Brazil (the COD of normal dunder water is of the order 100-200 ppm). Other potential drawbacks often cited are the salinity aspect and the potentially harmful effects of adding large amount of degradable sugars (Korndorfer and Anderson, 1997).

Despite these drawbacks, there are numerous published reports of the safe application of vinasse to ratoon cane, at rates varying from 50 to 100 t/ha without endangering surface or ground waters(Yang, 1968; Samuels, 1982; Chang and Li, 1989; Wang *et al*., 1996; Kee Kwong and Paul, 1999). However, there are also reports of environmental contamination in Brazil where high rates of vinasse were continually discharged into waterways (Korndorfer and Anderson, 1997). More recent developments have centered on reducing the moisture content of vinasses through evaporation to produce a concentrate that is referred to in the South African sugar industry as concentrated molasses stillage or solids (CMS). An assessment of the composition of CMS shows that it contains between 44 to 46% moisture and 38 to 40% organic material on an as received basis. The total mineral fraction comprises 27.5 to 31.5% on a dry mass basis of which potassium is the dominant nutrient followed in decreasing order of concentration by chloride, sulphur, calcium, magnesium and phosphorus (see Appendix 1). Of the trace elements copper appears to be the most abundant followed by manganese, zinc and cobalt.

Since the establishment of an ethanol plant at Royal Swazi Sugar Corporation, vinasse and more recently CMS have also been applied to estate fields in compliance with guidelines from an environmental impact assessment conducted by CSIR (CSIR, 1995). Soils were ranked according to suitability into three classes: high, moderate and low, based on soil properties such as clay, depth and drainage. The selection of fields suitable for stillage application was subsequently reviewed by Murdoch (1997). He felt that the low suitability rating given in the CSIR report to cane fields on S set soils, which comprised about 10% of the estate, was too harsh and that a 'moderate suitability' rating would be justified because the rock underlying S set soils was generally very permeable. Murdoch recommended a follow-up programme of field experiments. As a result a trial was established on a shallow S set soil to evaluate the use of CMS as a nutrient source and for its long term effect on a Somerling soil. Specific objectives were to assess the:

- nutritional value of the product on this soil
- effects on cane and sucrose yields
- long term physical, chemical and biological effects on the soil
- effects on mill recoveries (ash% in juice).

Methods and Materials

A site was selected at Royal Swazi Sugar Corporation as being representative of the shallow S set soils (less than 500 mm depth). The soil was a sandy clay loam (33% clay) classified as having a moderate to high N mineralizing potential, with an adequate P status (51 ppm) but a marginal level of K (121 ppm). The standard FAS recommendation for cane growing on this soil was 140 kg/ha N and 150 kg/ha K. Because some of the plots sampled were marginal in P, it was decided to include 20 kg/ha P as part of the standard treatment for this trial.

Treatments were as follows:

1. Standard inorganic fertilizer according to FAS recommendations.
2. Standard inorganic fertilizer for N and P (Zero K).
3. CMS fortified stillage – rate to apply standard K (as for T1) plus standard inorganic N and P.
4. CMS stillage/fertilizer – rate to apply standard K (as for T1) plus inorganic N and P balanced to take account of that in stillage.
5. CMS stillage/fertilizer – rate to apply 1.5 x standard K. Standard N and P balanced.
6. CMS stillage/fertilizer – rate to apply 2 x standard K. Standard N and P balanced.

Notes on treatments:

- Urea (46% N), single superphosphate (10.5% P) and potassium chloride (50% K) were used as inorganic granular fertilizers.
- A sample of stillage was analysed to provide a measure of the nitrogen, phosphorus and potassium content so that equivalent rates of N, P and K could be applied in stillage. The values of N, P and K that were used to calculate rates were: N 1.15% by weight; P 0.15% by weight and K 5.5% by weight. Densities of 1.25 g/ml and 1.6 g/ml were used for stillage and phosphoric acid respectively when calculating rate equivalents.
- Phosphoric acid was used where extra P was required in the stillage treatments.

Trial layout
The plot size consisted of 6 rows x 9 m x 1.5 m with 6 replications of 6 treatments in a Latin Square design. Cane rows were on a ridge approximately 50 cm wide with sloping sides 20 cm wide and a base in the interrow of 60 cm width. Irrigation was by overhead sprinkler and was conducted as part of the field operation. The site was on a slight slope and sited 40 m from the field edge, which was bounded by a road and waterway. Cane lines ran down the slope towards the field edge.

Soil sampling
Samples were taken prior to treatment application at 0-200 mm depth from all plots, and 8 interrow cores were composited with 1 row core in three lines per plot. Depth samples 0-200 and 200-400 mm were taken in six positions in the row and interrow separately from selected plots only. Plots were selected for their position at the top and bottom of the slope of the trial site.

Soil sampling was repeated two months after application of stillage treatments and at harvest of the fourth and fifth ratoon crops.

Treatment application
Granular fertilizers urea (46% N), single superphosphate (10.5% P) and potassium chloride (50% K) were weighed out for each row and applied in a band over the cane row to treatments 1 and 2. No potassium was applied to treatment 2.

For stillage treatments the volume required to apply the standard rate of 150 kg K/ha was calculated, based on stillage analysis, to be 17.67 litres per plot. To this were added the relevant quantities of prilled urea and phosphoric acid to balance these nutrients according to treatment requirements. These were mixed in a stainless steel drum and decanted into knapsack sprayers. The knapsack sprayers were fitted with PVC piping extensions as used by Nutri-Flo for liquid fertilizer application in parts of the South African sugar industry. A single pipe without nozzle was used and the liquid allowed to flow by pointing the pipe downwards and stopped by lifting the pipe. A suitable walking speed was used to allow two passes per row and in this way achieving contact on the cane row of 50-200 mm. Volumes were adjusted to achieve the different rates of application.

At application samples of fortified stillage were taken from each stillage treatment and analysed to obtain the actual nutrient content of the treatments.

Crop measurements
Leaf sampling was conducted on two occasions in the first crop and on one occasion in the second. All plots were sampled using the standard leaf sampling procedure. Stalk length was measured to the top visible dewlap of six randomly selected stalks per plot on each occasion. Stalk populations were calculated from counts in one row per plot. Measurements were conducted at various intervals in each crop. At harvest of each crop the trial was burnt, plots harvested and net areas of 4 rows x 7 m per plot were weighed. A sample of 12 stalks per plot was taken at random and sent to the mill laboratory for sucrose determinations. Yield and quality data are summarized in Tables 1 and 2.

Results

Cane and sucrose yield
There were no statistically significant differences in yield between treatments in either crop. However there was a tendency for treatments with high stillage rates to yield less than other treatments in the fourth ratoon crop. This was also the case in the fifth ratoon for the medium and low rates of stillage but not for the highest stillage rate. In terms of sucrose % cane, there was a trend towards higher quality from higher potassium rates in the fifth ratoon crop and lower quality from higher rates in the fourth ratoon crop. In regard to sucrose yield there were no statistically significant differences between treatments but the trend towards lower cane yields associated with

higher stillage rates in the fourth ratoon and higher yields associated with the highest stillage rates in the fifth ratoon was evident for sucrose yields as well.

Nutrient rates applied

In general nutrient rates applied agreed closely with the rates recommended for potassium and treatments therefore represented the desired range. However, in the case of nitrogen, the levels of N in the stillage treatments were less than recommended in both crops, which resulted in treatments with high stillage rates supplying less nitrogen than intended. This was particularly evident in the fourth ratoon crop (see Table 3). Phosphorus was higher than recommended in all stillage treatments in both crops; this difference was substantial in the second crop. However non-stillage treatments still received adequate phosphorus.

Table 1. Yield data of the fourth ratoon crop

Treatment	Cane (t/ha)	Sucrose % cane	Sucrose (t/ha)	Brix % cane	Non-pol % cane
1	94.9	16.0	15.2	17.6	1.65
2	97.0	15.5	15.0	17.2	1.76
3	96.8	15.9	15.3	17.2	1.33
4	95.4	16.2	16.1	17.7	1.46
5	92.5	15.8	14.6	17.4	1.57
6	90.9	15.0	13.6	16.9	1.87
S/NS	NS	NS	NS	NS	
CV%	10.9	5.3	11.8	4.5	
Sediff	6.0	0.5	1.0	1.6	
LSD (0.05)	12.5	1.0	2.1	3.3	

Table 2. Yield data at harvest of the fifth ratoon crop

Treatment	Cane (t/ha)	Sucrose % cane	Sucrose (t/ha)	Brix % cane	Non-pol % cane
1	97.2	16.5	16.1	18.5	2.02
2	94.5	15.9	15.1	18.1	2.20
3	95.3	16.0	15.2	18.3	2.36
4	92.5	16.2	15.0	18.5	2.36
5	91.3	16.5	15.1	18.7	2.22
6	102.1	16.8	17.2	19.1	2.27
S/NS	NS	NS	NS	NS	
CV%	10.2	4.7	11.0	4.0	
Sediff	5.6	0.4	1.0	1.5	
LSD (0.05)	11.8	0.9	2.1	3.1	

Table 3. Actual nutrient rates applied as calculated from sample analysis.

Treatment	N (kg/ha)		P (kg/ha)		K (kg/ha)	
	R4	R5	R4	R5	R4	R5
1	140	160	20	20	150	150
2*	140	160	20	20	0	0
3	194	156	25	49	176	120
4	140	153	25	48	163	135
5	131	147	23	59	230	207
6	121	147	25	78	301	282

* Standard FAS recommendation

Figures 1 and 2 compare cane yields with nitrogen and potassium rates applied. It is apparent that yields in both crops tended to follow nitrogen rates except for the highest rate in the fifth ratoon. In regard to potassium, the association of high rates with low cane yield was less consistent but nevertheless apparent. There were no treatment effects on flowering or pith formation.

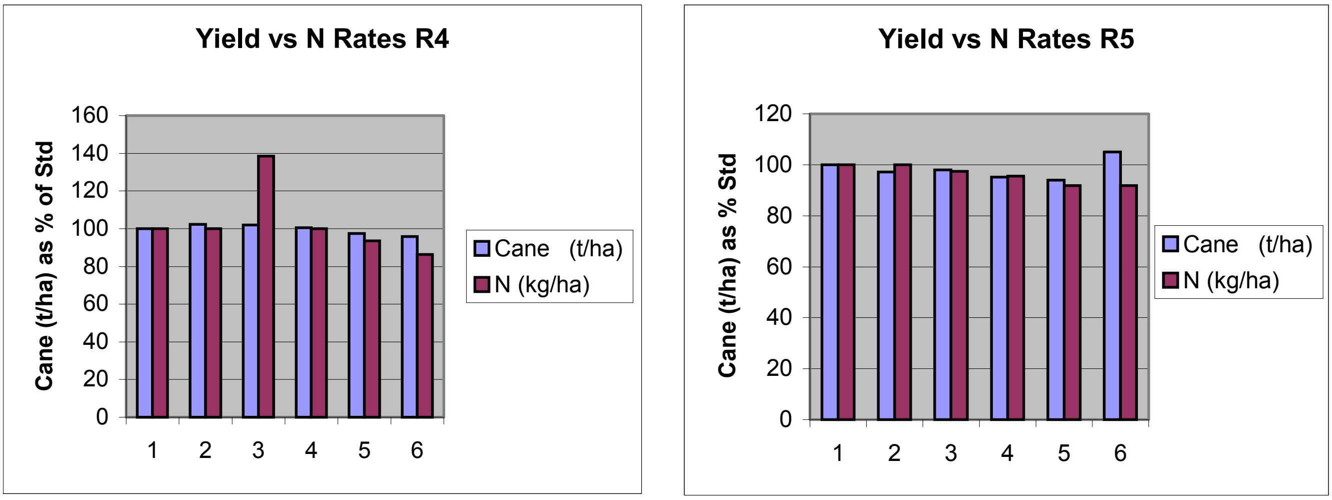

Figure 1. Cane yield as a percent of treatment 1 in relation to nitrogen rates in two ratoon crops.

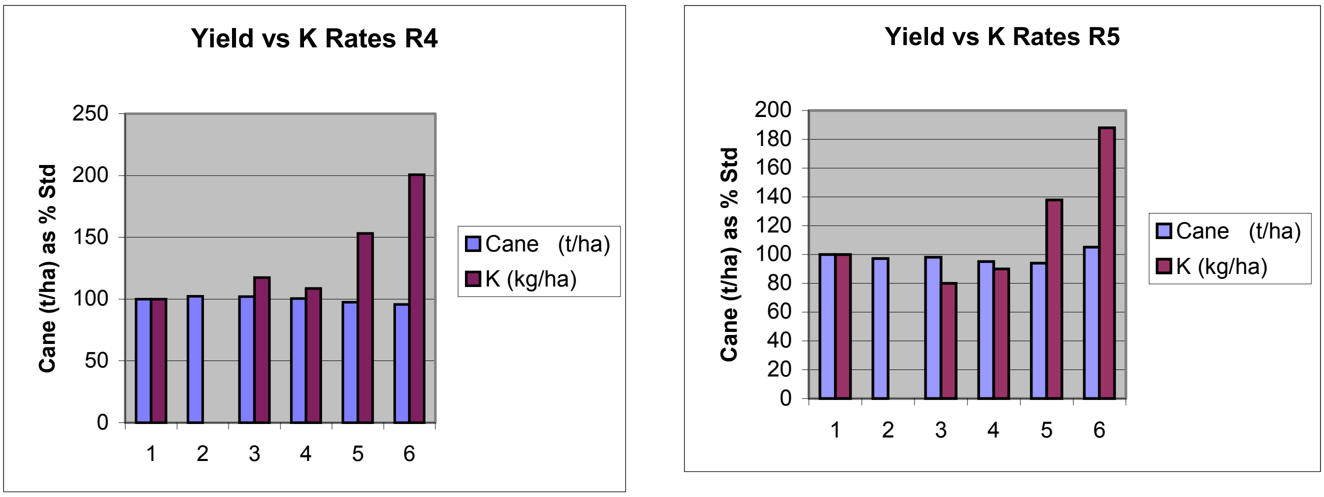

Figure 2. Cane yield as a percent of treatment 1 in relation to potassium rates in two ratoon crops.

Treatment effect on leaf nutrient uptake

Nitrogen levels in the leaf were above threshold for all treatments at three months of age in the first crop. However at six months there were statistically significant differences between treatments with lower leaf N levels from plots treated at the high stillage rate (see Tables 4 and 5). This was to be expected as the N level in the applied stillage was found to be below the recommended rate. However, these differences were not apparent in the fifth ratoon crop.

Phosphorus was well above the threshold at all sampling ages in both crops and from all treatments. There were no treatment differences in leaf P levels in spite of large differences in amounts of P supplied by the various rates of stillage.

Potassium was clearly in short supply in three month old cane in the first crop in treatment 2 where no K had been applied. There was also a statistically significant increase in leaf potassium after application of high rates of stillage when compared with the granular potassium chloride application. At six months of age these differences were less pronounced and all analyses were above the threshold K value.

Treatments showed similar trends in the fifth ratoon crop, although the differences were not statistically significant. Calcium and magnesium were well above threshold in both crops and tended to be higher where no potassium had been applied particularly in the fifth ratoon crop.

Table 4. Third leaf nutrient analyses at 3 and 6 months in the fourth ratoon crop

Treatment	N%		P%		K%		Mg%		Ca%	
	3 m	6 m	3 m	6 m	3 m	6 m	3 m	6 m	3 m	6 m
1	2.31	2.008	0.31	0.27	1.07	1.24	0.27	0.20	0.33	0.26
2	2.28	2.023	0.31	0.28	0.97	1.15	0.27	0.20	0.32	0.28
3	2.27	2.008	0.31	0.28	1.11	1.15	0.25	0.20	0.37	0.26
4	2.25	2.007	0.31	0.27	1.18	1.25	0.26	0.20	0.38	0.28
5	2.26	1.983	0.32	0.27	1.21	1.19	0.28	0.20	0.34	0.27
6	2.24	1.998	0.31	0.27	1.15	1.33	0.25	0.20	0.30	0.29
S/NS	NS	S	NS	NS	S	S	NS	NS	NS	NS
CV%	3.00	0.800	5.10	3.20	5.80	7.30	12.90	11.80	21.70	12.70
Sediff	0.04	0.010	0.01	0.01	0.04	0.05	0.02	0.01	0.04	0.02
LSD (0.05)	0.08	0.020	0.02	0.01	0.08	0.11	0.04	0.03	0.09	0.04

Table 5. Third leaf nutrient analysis at 8 months in the fifth ratoon crop

Treatment	N%	P%	K%	Mg%	Ca%
1	2.01	0.25	1.14	0.22	0.23
2	2.01	0.25	1.08	0.24	0.26
3	2.02	0.24	1.08	0.23	0.24
4	2.01	0.24	1.11	0.23	0.23
5	2.01	0.25	1.13	0.22	0.22
6	2.02	0.24	1.12	0.22	0.22
S/NS	NS	NS	NS	S	S
CV%	1.30	3.50	5.50	4.00	8.30
Sediff	0.01	0.00	0.03	0.01	0.01
LSD (0.05)	0.03	0.01	0.07	0.01	0.02

Treatment effects on soil properties

The highest stillage treatment increased soil potassium levels significantly over the standard potassium chloride treatment based on samples taken at the end of the fifth ratoon crop. There were no statistically significant differences in pH, phosphorus, calcium or magnesium between treatments (see Table 6). However, at the end of the fourth ratoon crop there was some evidence of a slight increase in soil pH from the high stillage treatment but this had disappeared by the fifth ratoon (see Table 7). There was no indication from the results of a build-up in salinity or sodicity nor an increase in cation exchange capacity (CEC) from the application of the high rate of stillage. Although the results are not shown, treatment with CMS had little or no effect on the soil organic matter and heavy metal content.

Table 6. Mean soil analyses following harvest of the fifth ratoon crop

Treatment	pH	P (ppm)	K (ppm)	Mg (ppm)	Ca (ppm)
1	6.70	61	261	1218	4977
2	6.58	52	172	1222	5062
3	6.72	62	229	1219	4832
4	6.77	63	226	1242	5041
5	6.60	75	276	1173	4909
6	6.67	66	330	1294	4801
S/NS	NS	NS	S	NS	NS
CV%	1.9	19.4	9.4	6.2	3.4
Sediff	0.07	7.07	13.5	44	97.5
LSD (0.05)	0.15	14.7	28.1	91.7	203.3

Table 7. Salinity/sodicity analyses after harvest of the fourth ratoon crop

Treatment	Depth cm	pH	Na meq/L	EC ms/m	SAR %	CEC meq%
T6	0-20	6.9	1.2	39	1.2	29
	20-40	7.13	1.1	35	1.1	30.2
	40-60	7.15	1.2	24	1.7	42.1
Mean	Mean	7.06	1	33	1.3	33.8
T1	0-20	6.51	1.7	59	1.4	32.2
	20-40	6.81	1.4	38	1.4	30
	40-60	7.19	1.1	21	1.7	36.9
Mean	Mean	6.84	1.4	39	1.5	33.0

Discussion

In general the yields of cane and sucrose for both ratoon crops were similar irrespective of whether the potassium source was muriate of potash or CMS. The lack of a response to applied K was surprising given the fact that the mean K level of 121 ppm K was below the threshold value of 150 ppm. The improvement in leaf K status of the treatment without K (treatment 2), from a marginal state at three months to an adequate level suggests the presence of significant reserves of K in the subsoil and the saprolite. If this is so then it will also explain the lack of any significant response to the CMS at this site.

As expected soil potassium levels have been increased by stillage applications and future crops should clarify the responses to K. The residual effect of the 3 t/ha CMS treatment on soil K (226 ppm) conformed very closely to the residual effect of the equivalent standard FAS K treatment (229 ppm). The 4.5 and 6 t/ha CMS treatments increased residual K levels to 276 and 330 ppm respectively. Leaf analysis corroborated the increased residual effects but at no stage did the K content of the TVD exceed the luxury upper threshold value of 1.45%. Repeated application of CMS at 3 t/ha will provide sufficient K for crop removal without causing a build-up of K. Doubling the rate of CMS to 6 t/ha will result in a rapid build-up of K which will not only lead to luxury uptake of K but also enhanced K levels in cane juice. Various researchers have shown that extreme uptake of potassium reduces cane quality by increasing the ash content of cane (Kingston, 1982). K also forms a complex with sucrose and tends to be retained in solution. The net effect is that the solubility of sucrose is increased when K levels in juice, syrup or molasses increase. This means that when high K syrups are boiled, the crystal yield will be smaller than usual and much more sucrose will remain in solution and end up in the molasses (Irvine 1978; Clark, 1981). This results in high purity molasses and high molasses exhaustion values.

Despite the high acidity of CMS (pH approximately 4.5) and high conductivity (>15 000 mS/m), no significant adverse effects were observed on the yield of the two ratoon crops. However, cane growth in the fourth ratoon crop appeared to be slightly surpressed with increasing application of CMS probably because of the combined effect of high electrolyte concentration of salts and COD from the high organic matter. Cane quality was also slightly reduced due to an increase in the non-sucrose content. Similar results have been reported by several investigators under different climatic conditions (Wang and Li, 1957; Yang, 1968). Any potentially negative effects from the CMS treatment were dissipated by the end of the fifth ratoon crop.

Cane yields appear to have been affected more by the nitrogen rate than stillage rate and the differences in third leaf nitrogen in the fourth ratoon crop also support this. However some influence from higher stillage rates would seem possible as the leaf N levels were still above threshold. Future ratoon crops may provide a clearer assessment.

Of interest is that the highly acidic CMS treatment initially tended to increase rather than decrease soil pH values in the fourth ratoon crop (see Table 7) but they reverted to their original values at the end of the fifth ratoon crop (see table 6). This observation is in agreement with the results from elsewhere. According to Rao (1983), the organic acids in CMS undergo rapid microbial decomposition in the soil leaving an excess of bases, which hydrolyse causing an increase soil pH.

No changes were observed in calcium, magnesium or phosphorus levels in the soil during the two crops harvested and although the data are not shown, there was no indication of any build up in heavy metals such as Cu, Zn, Fe or Mn.

Although the trial did not include any detailed analyses of the quality of the drainage water, regular monitoring of the water quality of four boreholes in areas that could be affected by seeping stillage, have shown that although poor prior to commercial CMS application, water quality has not deteriorated further. Lysimeter investigations conducted in Taiwan showed that an application of 300 t/ha vinasse (equivalent to about 30 t/ha CMS) had no significant effect on the chemical quality of drainage water. The increased nitrate N, COD, EC and pH were well within the safety regulations prescribed by the EPA (Wang *et al*., 1996).

Conclusions

The results generally support Murdoch's recommendation that the Swaziland S set soils should be accorded a 'moderate' instead of a 'low' suitability rating in terms of CMS disposal. Cane yields were not detrimentally affected by repeated CMS application over two crops and there was no indication of any build up salts. This is perhaps not surprising as these soils although shallow (300-400 mm) are well drained as they are underlain by 900-1200 mm of soft porous highly weathered saprolite which in turn overlies fissured basalt.

The results confirm that CMS can substitute for K in muriate of potash and that this could save the sugar industry huge sums of foreign exchange when it is considered that a ton of CMS is currently valued at about R260 in terms of its nutrient content. Although the application of 6t/ha CMS appears safe in the short term, it is recommended that 3 t/ha CMS would be effective as a source of K on the shallow S set soil and that the long term rate should not exceed 4 t/ha.

As a rule of thumb CMS is likely to be cost effective when the FAS recommendation indicates that at least 100 kg/ha of K is needed, the grower is within 15 km of the mill, and it is fortified with N and P if needed.

Additional precautions that should be taken when applying CMS in the field with respect to environmental protection and reducing the risk of soil degradation include:

- Avoid application to soils with restricted drainage problems such as duplex or valley bottom soils.
- Maintain vegetated buffer strips and grassed waterways between cane fields and streams.
- Control CMS application rates.
- Where large scale application is envisaged use tankers with flotation tyres to minimize infield compaction.

Apart from testing the sensitivity of other soils such as the vertisols to CMS application, research is needed in on timing and rates of CMS application to ratoon cane cut in the early part of the season. There have been concerns that cane treated with a single application of CMS supplemented with N, between April and June may be deficient in N at the onset of the rains in September/ October. There may be merit in splitting fortified CMS according to the N demand curve for the particular time of the year.

REFERENCES

Chang, SR and Li, SW (1989). The disposal of alcoholic slops on sugarcane fields. *Proc Int Soc Sug Cane Technol* 20: 551-557

Clarke, MA (1981). Potash: Potential profits or problems. *Sug J* 43(10): 18.

CSIR (1995) Environmental Impact Assessment of the Proposed Distillery at Simunye Sugar Estate. Swaziland-Final Report. CSIR, Pretoria.

Irvine, JE (1979). Variations in non-sucrose solids in sugarcane: Potassium. *Sug J* 41(5): 28-30.

Jackman, E (1977). Distillery effluent treatment in the National Alcohol Programme. *Chemical Engineer* April 1977, p 239.

Kingston, G (1982). Ash in first expressed cane juice at Rocky Point: Factors affecting the inorganic composition of juices. *Proc Qld Soc Sug Cane Technol* 52: 11-17.

Korndorfer, GH and Anderson, DL (1997). Use and impact of sugar alscohol residues vinasse and filtercake on sugarcane production. *Sug y Azucar* 92: 26-35.

Kujala, P (1976). Alcohol from molasses as a possible fuel. *Sug y Azucar* March 76, p 29.

Murdoch, G (1997) Review of Stillage Application at Simunye. Unpublished Report.

Nadir, A; Da Gloria (1977). Study on the application of Vinasse for fertilization. Published by Codistil Translation Service.

Ng Kee Kwong, KF and Paul, JP (1999). Vinasse as a Potassium Fertiliser for Sugarcane. *Revue Agricole et Sucriere* 76: 34-37.

Samuels, G (1982). Possible agricultural and industrial uses of distillery waste in Puerto Rico. *J Am Soc Sug Cane Tech* 1: 62-67.

Wang, SC and Li, YK (1959). The development of liquid nitrogenous fertilizers in Taiwan sugarcane agriculture. *Proc Int Soc Sug Cane Technol* 10: 424-432.

Wang, PL, Li, SW, Chan, Y, Tsai, CS and Chang, SJ (1996). Nutrient recycling of the alcoholic slops by land furrow and sprinkle irrigation in sugarcane fields. *Proc Int Soc Sug Cane Technol* 22: 56-62.

Yang, SC (1968). The effect of alcoholic slops application upon the soil properties and cane yield. *Report Taiwan Sugar Exp Station* 46: 35-51.

Appendix 1. Chemical and Nutritional Specification of CMS

	As fed	**Dry Material Basis(per/kg)**	
ITEM	**(per kg)**	**Average**	**Typical range**
Moisture (g/kg)	440-460	1000	--
Organic material (kg)			
Total Organic Material (g)	380	690	685 - 725
Volatle Fatty Acids, Pectins, etc (g)	115	210	200 - 220
Total Reduced Sugars (g)	66	120	110 - 130
Fructose (g)	13	25	23 - 25
Sucrose (g)	7.5	14.5	14 - 16
Glycerol (g)	35	63.5	55 - 70
Nitrogen Containing Substances (g/kg)			
Nitrogen	10	18	14 - 28
Crude Protein	63	115	88 - 175
Amino Acids:			
Aspartic Acid (Asp)	1.1	2	
Glutamic Acid (Glu)	1.2	2.2	
Serine (Ser)	0.5	0.9	
Glycine (Gly)	1.1	2	
Histidine (His)	0.05	0.1	
Arginine (Arg)	0.05	0.1	
Phenyl Alanine (Phe)	0.3	0.2	
Lysine (Lys)	0.1	0.2	
Methionine (Met)	0.07	0.13	
Threonine (Trh)	0.4	0.7	
Alenine (Ala)	1.3	2.4	
Proline (Pro)	0.7	1.3	
Tyrosine (Tyr)	0.8	1.5	
Valine (Val)	0.7	1.3	
Isoleucine (lle)	0.4	0.7	
Leucine (Leu)	0.5	0.9	
Vitamins (mg/kg)			
Thiamine (B1)	1.2	2.2	
Riboflavin (B2)	7.9	14.3	
Pyridoxine (B6)	39	70	
Cobalamine (B12)	0.05	0.09	
Nicolinate (Niacin)	61	111	
Choline (mg)	670	1220	1210 - 1230
Minerals (g/kg)			
Total Ash (g)	170	310	275 - 315
Macro minerals (g) :			
Calcium (Ca)	10	18	16 - 19
Phosphorus (P)	1.6	2.9	2.5 - 3.2
Magnesium (Mg)	8	14.5	12.7 - 16
Chloor (Cl)	38	69	62 - 78
Potassium (K)	55	100	95 - 120
Sulphur (S)	11	20	18 - 35
Micro minerals (mg)			
Manganese	95	172	107 - 309
Copper (Cu)	220	400	360 - 550
Zinc (Zn)	52	95	22 - 125
Cobalt (Co)	3	5.5	3.5 - 20
Energy (ME/kg)			
ME (in vitra)	5.1	9.3	
ME (true for broilers)	3.3	5.97	