THE EFFECT OF CANE VARIETY AND OTHER AGRICULTURAL FACTORS ON JUICE COMPOSITION

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Abstract

Juice extracts from clean, fresh cane stalks from nineteen runs of the 1999 South African Sugar Association Experiment Station varietal trial program have been used. Twenty-six varieties from seven geographical locations in South Africa were involved. In addition, factors such as cane age, ratoon number, burnt or trashed, rainfed or irrigated were available. The extracts were analysed for brix, colour, phosphates, silica, gums, calcium, potassium and sulphated ash. The paper presents these results and discusses the impact of the factors, particularly variety and location. The concentration of gums, which influences processing and sugar quality, is shown to be highly dependent on location and on variety, while colour is predominantly a varietal effect.

Keywords: Variety, location, colour, gums, sulphated ash, silica, potassium.

Introduction

Characteristics such as cane variety, geographical location, cane age, months of harvest, irrigated or rainfed and burnt or trashed, impact on sucrose levels, yield per hectare, disease resistance and many other agricultural factors. The South African Sugar Association Experiment Station (SASEX) carries out varietal trials every year. This programme makes available cane extracts, the origin of which are clearly known. The Sugar Milling Research Institute (SMRI) and SASEX carried out a joint project to investigate the effect of the agricultural parameters mentioned above on some factors which impact on factory processing, namely colour, gums, inorganic phosphate, sulphated ash, calcium, potassium and soluble silica.

Colour impacts on sugar quality and on refining costs. There is some confusion with regards to the types of gums found in cane juices and on their effects on processing. Vegetable gums, that is natural cane polysaccharides, have given no evidence of causing serious processing problems but microbial gums, such as dextrans are known to effect factory operations and sugar quality adversely. The analytical method used for the determination of gums does not differentiate between the two types. Since only very fresh, clean cane stalks were used, this work yields levels of natural cane polysaccharides as dependent on the agricultural factors mentioned above. This type of data is not readily available. Phosphate impacts on clarification, soluble ash affects recoveries and silica is associated with evaporator scaling.

Experimental

The Direct Analysis of Cane (DAC) extracts were from clean, fresh cane stalks obtained from 19 agronomy trials conducted by SASEX during 1999. All samples and replicates were made available to the SMRI (samples were preserved using mercuric chloride and frozen). Replicates had to be composited to reduce the analytical load. This unfortunately reduced the database and made rigorous statistical evaluation more difficult.

All analytical work was conducted by the SMRI based on standard analytical procedures (Anon, 1985). Deviations from standard methods are described below.

- Inorganic Phosphate (P_2O_5) -Analyses on filtered samples. Previous work reported total phosphate (Lionnet, 1997).
- Sulphated ash -The filtrate obtained as for brix analysis was used for the determination of sulphated ash, by gravimetric analysis. The sample was ashed at 650°C.
- Soluble silica, calcium, potassium, brix and pH analyses were performed on filtered samples.

All results, with the exception of colour and sulphated ash, are expressed in the units of mg/kg bx (i.e. ppm on brix). Sulphated ash is in % bx (mass/mass) and colour in ICUMSA colour units.

Results

Colour

Varietal and geographical location effects on colour

The effect of variety was found to be highly statistically significant (5% level) on colour, using the ANOVA (Analysis of variance) technique (Goodman, 1974; Anon, 1998; Walpole and Meyers, 1990). A maximum difference of 94% was observed between N19 (lowest colour) and N12 (highest colour). These results appear in Table 1.

The effect of geographical location was found to be statistically significant (5% level) when tested by the ANOVA one factor method on all samples. However, the effect of unbalanced varietal distribution, (where a large number varieties having a high colour were sampled in a particular region) which is present in this project, was not considered. Table 2 shows the varietal distribution (divided into low, medium, high and very high colour varieties) for each of the seven geographical locations.

Table 2 shows that the sampling is biased resulting in an unbalanced varietal distribution. This will impact on the location effect. In an attempt to remove the varietal effect, varieties with a balanced number of samples in each region were analysed (ANOVA). This showed no statistically significant differences in colour between regions. Therefore, colour is predominantly a varietal effect.

Effect of harvest month, ratoon and age on colour

The effect of harvest period was significant at the 10% level. Unbalanced numbers of samples were again experienced between months and therefore the season was divided into periods, namely period 1 (April and May, 35 samples), period 2 (June and July, 32 samples), period 3 (August and September, 34 samples) and period 4 (October and November, 39 samples). These results appear in Figure 1.

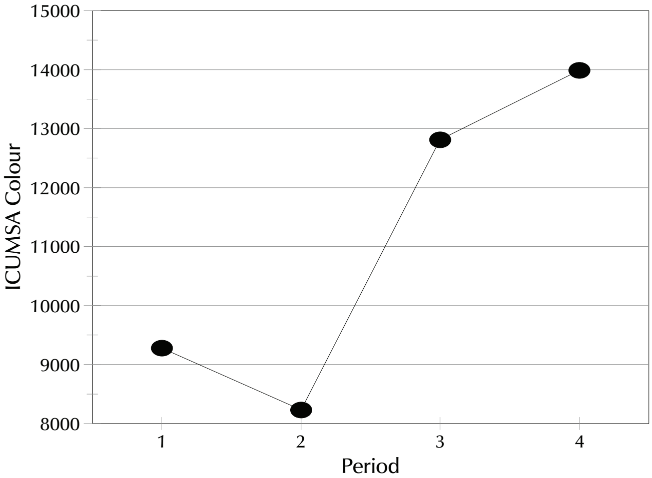

Figure 1. Effect of month of harvest on colour.

The effects of ratoon and age at harvest were not statistically significant when tested at the 10% level.

Effect of burnt or trashed and of rainfed or irrigated on colour

The effect of burning or trashing was not statistically significant, as expected since colour is predominantly a plant characteristic and is determined by growth conditions. However, the effect of irrigated or rainfed was weakly statistically significant (10% level). The average colour in rainfed cane was 28% higher at 12480 ICUMSA units.

Table 1. Effect of variety on colour

Variety	Colour (ICUMSA units)
N19	7705
N26	8515
N27	8415
N22	9430
N29	9675
N23	9695
N24	10060
N14	10660
N25	11100
NCo376	11850
N17	11970
N16	12835
N21	14200
N12	14925

Gums

Effect of Variety and Geographical location on gums

Variety was highly statistically significant (5% level). A maximum difference of 84% was calculated between N14 at 6460 mg/kg bx and N28 at 11920 mg/kg bx. Figure 2 shows these results.

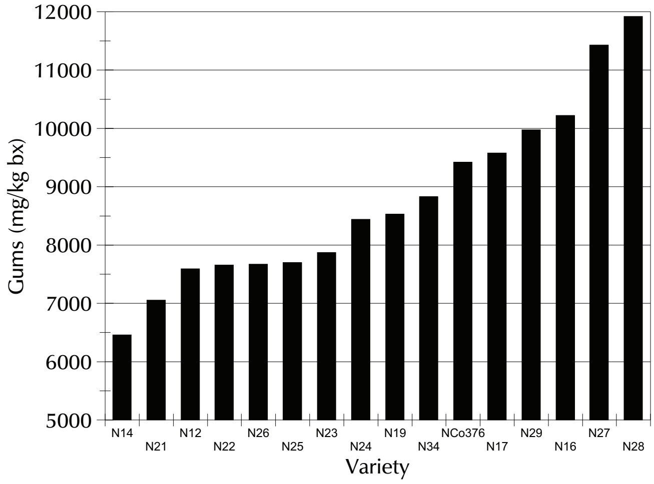

Figure 2. Effect of variety on gums.

The distribution of low, medium, high and very high gum varieties was balanced across the regions (maximum difference in the number of samples between any two cells was 30%). The location effect was statistically significant at 5%. Table 3 show these results. South Coast has the lowest gums levels at 7190mg/kg bx and Zululand the highest average gums concentration at 10320 mg/kg bx. This represents a maximum difference of 44%. These results were confirmed statistically on a few selected varieties, sampled at all locations, by the ANOVA technique.

Effects of harvest month, age and ratoon on gums

Gums follow a parabolic profile with respect to month of harvest. The lowest gums levels were recorded during the month

Table 2. Number of low, medium, high and very high colour varieties sampled on a regional basis.

Region	Low	Medium	High	Very High
Eastern Transvaal	3	3	2	0
Midlands	5	6	8	6
Mtubatuba	6	4	4	2
North Coast	7	6	9	8
Pongola	5	8	3	0
South Coast	0	0	6	4
Zululand	5	2	8	5

of July (7323 mg/kg bx) and the maximum occurred in October. The maximum difference was 42%. These results appear in Figure 3.

It was found that ratoon and cane age are not statistically significant at the 10% level.

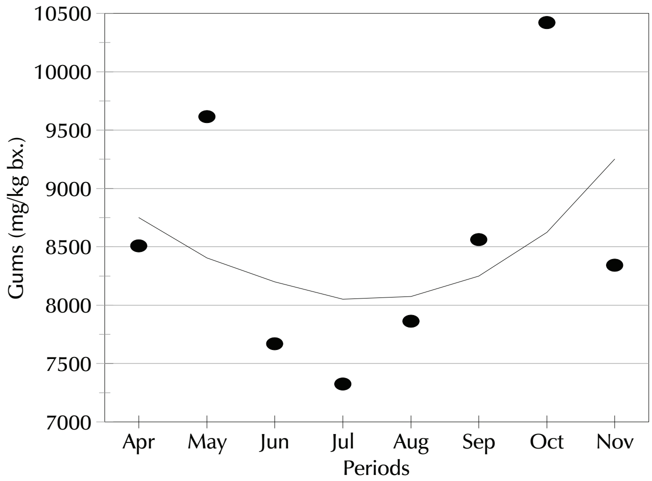

Figure 3: Effect of harvest month on gum concentration.

Effect of burnt or trashed and of rainfed or irrigated on gums

There was no statistically significant differences in the gums concentration between burnt and trashed samples. However, rainfed or irrigated showed a weakly statistically significant effect (10% level), with a maximum difference of 9%. Irrigated cane had the lower gums levels.

Inorganic Phosphate

Effect of variety and geographical location on inorganic phosphate

Variety was found to be highly statistically significant (5% level). A maximum difference of 157% was calculated between varieties. These results are shown in Table 4.

Location was significant at the 1% level. This was evident from analysis of variances on all samples. However, varietal distribution of low, medium, high and very high phosphate varieties was not balanced. Thus, location effects were tested on a few varieties, sampled at all locations, and found to be statistically significant at the 5% level. A maximum difference of 178% was calculated between Zululand and Mtubatuba. Table 5 shows these results.

Effect of harvest month, age and ratoon on inorganic phosphate

Harvest month was weakly statistically significant (10% level), the maximum difference being 86%. Age was also weakly statistically significant (10% level), with a maximum difference of 74%.

Effect of burnt or trashed and of rainfed or irrigated on inorganic phosphate.

The effect of burnt or trashed was not statistically significant while that of irrigated or rainfed was only weakly statistically significant (10% level) with a maximum difference of 40%. Rainfed samples showed a lower phosphate content of 1400 mg/kg bx than irrigated cane of 1972 mg/kg bx.

Sulphated Ash

Effect of variety and geographical location on sulphated ash.

Variety was weakly statistically significant (10% level) with a maximum difference of 78%. Location, with a balanced varietal distribution, was found to be very highly statistically significant (1% level). The location effect was confirmed statistically (ANOVA) for a few main varieties. The maximum difference was 42% between the South Coast and the North Coast. Figure 4 and Table 6 show these results.

Table 3. Effects of geographical location on gum concentration.

Region	Gums (mg/kg bx)
South Coast	7190
Pongola	8010
Midlands	8100
North Coast	8470
Mtubatuba	9570
Eastern Transvaal	9780
Zululand	10320

Table 4. Effect of variety on inorganic phosphate.

Variety	Inorganic phosphate (mg/kg
N16	1204
N12	1329
N28	1423
N19	1446
N21	1513
NCo376	1529
N17	1535
N24	1552
N25	1596
N14	1601
N23	1694
N27	1878
N29	1887
N26	2088
N22	3099

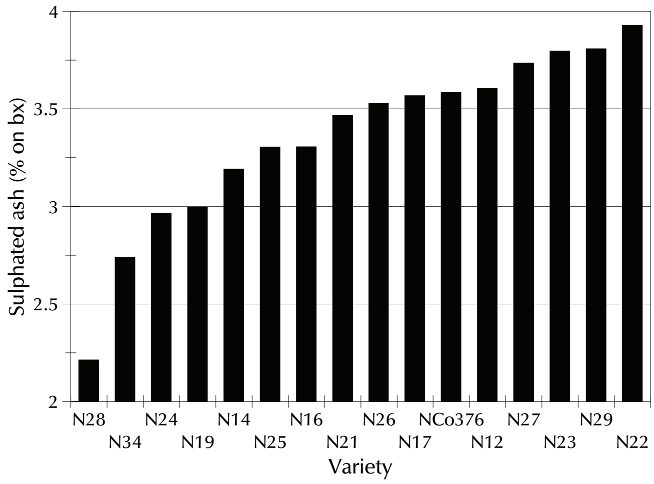

Figure 4. Effect of variety on sulphated ash content.

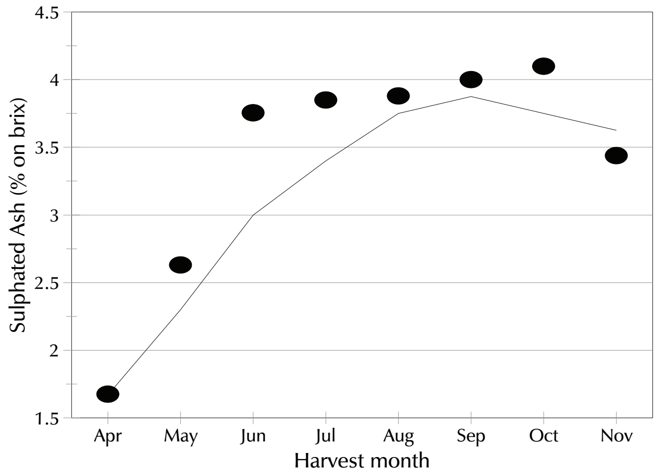

Figure 5. Effect of harvest month on sulphated ash content.

Effect of harvest month, age and ratoon on sulphated ash.

Harvest month was weakly statistically significant (10% level) and age was highly significant (5% level) with a maximum difference of 115%. Ratoon was not statistically significant. The effect of harvest month on sulphated ash is shown in Figure 5. A maximum difference of 165% was calculated.

Effect of burnt or trashed and of rainfed or irrigated on sulphated ash.

The effects of both burnt or trashed and rainfed or irrigated were not statistically significant at the 10% level.

Potassium and Calcium

Effect of variety and geographical location on potassium and calcium.

Variety was weakly statistically significant (10% level) and location was highly statistically significant (5% level), in both cases. The maximum difference of 40% on potassium and 110% on calcium with respect to variety, was calculated. Potassium accounts for approximately 26% of the sulphated ash and calcium for about 4%.

Location differences were 28% for potassium and 180% for calcium.

Table 5. Effect of geographical location on inorganic phosphate.

Region	Inorganic phosphate (mg/kg bx)
Zululand	857
South Coast	1352
Pongola	1418
North Coast	1527
Midlands	1791
Eastern Transvaal	1947
Mtubatuba	2382

Effect of harvest month, age and ratoon on potassium and calcium

Harvest month was weakly statistically significant (10% level) to both analytical factors. However this significance must be treated with caution due the interactive effects of location, cane age and ratoon.

Age was highly statistically significant (5% level) while ratoon was lower, but still statistically significant (10% level). Potassium and calcium content decreased as the plant matured, having a maximum difference of 154% for potassium and 68% for calcium.

Effect of burnt or trashed and of rainfed or irrigated on potassium and calcium.

The effect of burnt or trashed was not significant while that of rainfed or irrigated was only weakly statistically significant (10% level). A maximum difference of about 28% was observed for both potassium and calcium between rainfed and irrigated samples.

Soluble Silica

Only location and cane age showed a statistically significant effect on silica content (10% level). The maximum difference due to age is 63% and due to location (between South Coast

Table 6. Effect of location on sulphated ash content.

Region	Sulphated ash (% on bx)
South Coast	2.92
Mtubatuba	3.04
Eastern Transvaal	3.05
Midlands	3.08
Pongola	3.30
Zululand	3.50
North Coast	4.13

and Eastern Transvaal) is 175%. This shows a decrease of silica in mature cane. These results are shown in Tables 7 and 8.

Interactions of factors

Two factor analysis of variance was attempted. However, due to the large number of interactive factors and insufficient data the results of these analyses were not entirely conclusive. The determination of two way interactions, using ANOVA, was therefore not possible without violating some of the conditions inherent for ANOVA (Milliken and Johnson, 1984). Very basic variety-location interactions were however investigated for colour, gums and silica.

The investigation was simplified by dividing the varieties into four groups (low, medium, high and very high), this grouping being independent of location, e.g. the low group for colour consists of varieties N19, N26, N29 etc. The grouped varieties were then sorted into their respective locations and average values for each of the variety-location groups were calculated and plotted. Table 9 shows the grouping for the low group variety into their respective locations.

Figure 6 shows the interactive effect of variety and location on colour. Colour is not dependent on location. However the variations in colour between locations could be attributed to more complex interactions which were not considered in this study.

The same procedure of dividing and grouping varieties was followed to determine the variety-location effects for gums and silica. Figures 7 and 8 show these interactions respectively. Both factors are dependent on location.

Comparison to previous work

The results obtained in this work compared favourably to previous work (Lionnet,1997) for some factors. It was found that some varieties followed similar trends for colour, sulphated ash and silica (only varieties with number of samples greater than five were compared). Colour in both works showed a parabolic profile for month of harvest.

Although the previous work reported total phosphate the varietal and location effects were found to be similar. Total phosphate is approximately 60% greater than inorganic phosphate.

Due to the many interactive factors, such as climate, soil type, soil composition, age and variety, large variations between the

Table 7. Effect of location on soluble silica.

Region	Soluble silica (mg/kg bx)
South Coast	303
Zululand	337
Midlands	397
Pongola	424
Mtubatuba	549
North Coast	570
Eastern Transvaal	832

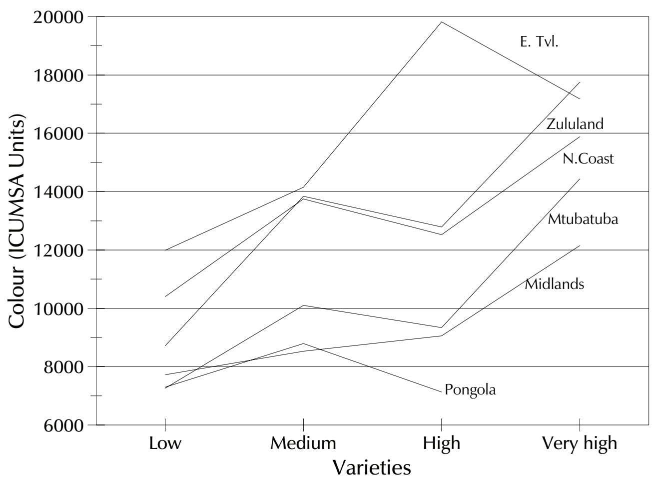

Figure 6. Interaction between variety and location on colour.

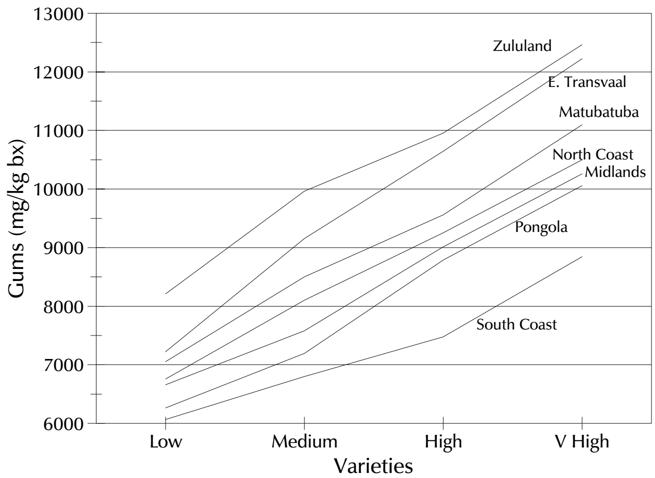

Figure 7. Interaction between variety and location on gums.

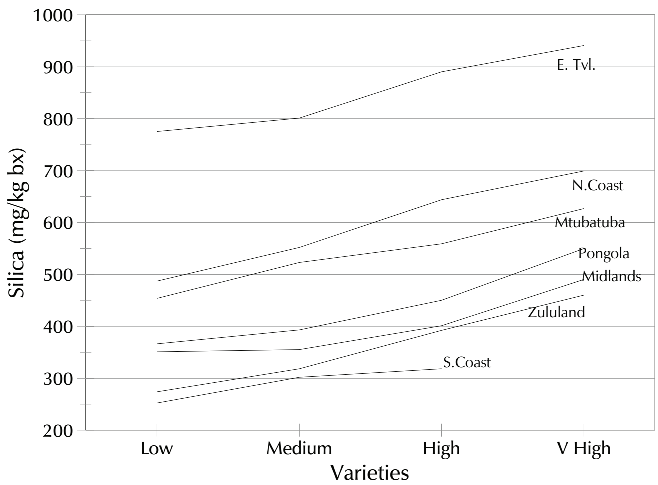

Figure 8. Interaction between variety and location on silica.

Table 8. Effect of age on silica.

Age (months)	Soluble silica (mg/kg bx)
6 to 12	590
12 to 18	432
18 to 24	363

two works were also noted. This occurred especially in factors that are largely dependent on soil and climatic conditions such as potassium, silica and ash.

Conclusion

The interactive effects of the many factors studied influence the statistical analysis. The effects should therefore be regarded with caution.

Burning or trashing (clean stalks) was not significant for any of the factors while ratoon was only weakly significant on potassium and calcium, therefore these factors are not discussed further.

Rainfed or irrigated was only weakly statistically significant for colour, gums, phosphate, potassium and calcium. Only colour, gums and calcium were lower in irrigated samples.

Cane age was weakly significant (10% level) for phosphate, potassium and calcium and highly significant for ash (5% level).

Harvest month showed a highly statistically significant effect on gums and weakly statistically significant effects on colour, inorganic phosphate, ash, calcium and potassium.

The effect of location was very highly statistically significant (1% level) on sulphated ash and highly statistically significant (5% level) on gums, phosphate, potassium and calcium. It was weakly significant for silica and not significant for colour.

Variety was significant with respect to all factors except silica.

Table 10 summarises these effects.

Insert Table 10.

* -weakly statistically significant (10% level)

** -highly statistically significant (5% level)

*** -very highly statistically significant (1%level)

This data is currently being used to look at the cane quality effects in South Africa (Lionnet, 2000).

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Table 9. Location-variety grouping for the low group colour variety.

Locations	Low colour group varieties				Location-variety average
	N19	N26	.....	N29	
Pongola	6870 4220	6960	.....		7295
Mtubatuba	6930 6230	8040 6850	.....	7760 6890	6920
	. .	. .	....	. .	. .
Eastern Transvaal	9090	12500	.....		11980

Table 10. Summary of statistically significant effects with maximum differences.

Analytical factor	Agricultural factors			
	Variety	Location	Harvest month	Rainfed / Irrigated
Colour	94%**	62%	118%*	28%*
Gums	84%**	44%**	42%**	9%*
Inorganic Phosphate	157%**	178%**	86%*	40%*
Sulphated ash	78%*	42%***	165%*	---
Potassium	40%*	28%**	226%*	26%*
Calcium	110%*	180%**	104%*	30%*
Soluble Silica	60%	175%*	186%	15%