CHARACTERISATION OF CANE VARIETIES BASED ON SUGAR PROCESSING PARAMETERS

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Abstract

Cane varieties that form part of the South African Sugarcane Research Institute's (SASRI) variety trial programme were used in these investigations. More than 30 varieties were tested including factors such as seven geographical locations, age, ratoon number and whether rainfed or irrigated. Juices were extracted from shredded clean fresh stalks, and analysed for brix, colour, phosphate, silica, potassium, sodium, calcium, magnesium, and conductivity ash. The shredded cane was analysed for pith and fibre content. The paper collates data from these investigations with data from SASRI to attempt to characterise varieties suitable for both agricultural (i.e. yield and sucrose content) and processing (i.e. colour) requirements. The results of these investigations are presented and the impacts of the different factors discussed.

Keywords: cane variety, location, colour, phosphate, fibre

Introduction

The South African Sugarcane Research Institute (SASRI) carries out variety trials every year to determine the cane varieties most suitable for growing in certain areas. The impact of factors such as cane variety, geographical location, age, ratoon number, month of harvest, irrigated or rainfed, and burnt or trashed at harvest on sucrose levels, yields and disease resistance were investigated. The Sugar Milling Research Institute (SMRI) collaborated with SASRI during 2004 to assess the impact of the above factors on factory processing characteristics, namely colour, inorganic phosphate, soluble silica, conductivity ash, cations (calcium, magnesium, sodium and potassium) and pith/fibre ratios. Shredded cane was made available from the variety trials done in the southern and northern rainfed areas and cane extracts were made available from the far northern irrigated areas (Mpumalanga, Pongola).

Varieties are selected for high ERC yield and adequate resistance to diseases and pests. However, some varietal characteristics also impact on the processing quality of the cane. The colour in cane impacts on sugar quality and refining costs, phosphates on clarification, ash on recovery, silica on evaporator scaling and pith/fibre ratios on juice extraction. The objective of this work was to analyse the varieties for the factors that have an impact on processing, and to use the data obtained to assist in selection of appropriate varieties for different mills. The results from these trials were compared with the results from a previous cane characterisation trial, which was carried out during the 1999/2000 season (Naidoo and Lionnet, 2000).

Experimental

The information and results shown in this report are based on 21 agronomy trials conducted by SASRI during 2004 at seven different geographical locations in the strategic cane growing areas. The details of where the trials took place, as well as the nearest mills and most common varieties that are crushed in these areas, are shown in Table 1. However, a large amount of mixed and unknown varieties were delivered to some factories, so some are only estimates.

Table 1. Locations where the trials took place, corresponding factories and common varieties crushed.

Location	No. of trials	Closest mill	Most common varieties crushed
Mpumalanga	2	ML	N14, N19, N25
		KM	N14, N19, N25
Pongola	4	PG	N14, N19, N25
Umfolozi	1	UF	N19, N27, NCo376
Zululand	6	FX	N19, N27, NCo376
		AK	N12, N27, NCo376
North Coast	3	DL	N12, N27, NCo376
		GH	N12, N27, NCo376
		MS	N12, N16, NCo376
Midlands	3	UC	N12, N16, N21
		NB	N12, N16, N29
		ES	N12, N16, N29
South Coast	1	SZ	N12, N16, NCo376
		UK	N12, N16, NCo376

Shredded cane from 14 of these trials was collected from the millroom at SASRI in Mount Edgecombe and taken to the SMRI. These samples of shredded cane were kept frozen at SASRI and composited at the SMRI immediately before extraction. The cane extracts were obtained using a cold digestor at the SMRI. The remaining trials were done at the SASRI research farm in Pongola, and cane extracts were made available to the SMRI for analysis. Samples and replicates needed to be composited to reduce the analytical load.

All analytical work was conducted at the SMRI, based on standard analytical procedures (Anon, 1985). The analyses performed are shown in Table 2.

Table 2. Details of analyses performed on samples.

Analyses	Units	Method
Colour	ICUMSA	Colorimetric
Inorganic phosphate	mg/kg Brix	Colorimetric
Soluble silica	mg/kg Brix	Colorimetric
Conductivity ash	g/100g Brix	Conductometric
Cations	mg/kg Brix	Ion exchange chromatography
Pith/fibre	ratio	Pith/fibre apparatus

Gums were not included as it was felt that the method of sampling may have led to small amounts of deterioration which may have masked other effects such as geographical location and whether green or burnt. The effect of age was not investigated due to the very small number of trials done for cane 18 months and older. In most of the cases when investigating the effects of time of harvest, the trials from the Midlands area were removed, as these were the only trials done in the middle of the season. The apparatus and method used to determine the pith/fibre ratio of the cane was obtained from a method developed by Chinsamy *et al.* (2004).

Results and Discussion

One-way analysis of variance (ANOVA) was conducted on the results using a statistical package, Statistica version 6 (http://www.statsoft.com/uniquefearures/general.html [Accessed March 2005]. In this paper 'highly significant' refers to statistical significance at a 1% level, and 'significant' refers to statistical significance at a 5% level. Except where otherwise stated, results were pooled for all factors other than those being considered. For example, when considering the effect of variety on colour, the average colour of a variety was determined across all samples received for that variety.

Colour

Varietal and geographical effects

There was a large variation in varietal colour for these trials. The variety with the highest colour was N33 and the lowest colour variety was N11, with a maximum difference of 318%. The maximum difference between the varieties was calculated by taking the difference of the highest colour variety and the lowest colour variety divided by the lowest colour variety. The effect of variety on colour was highly significant. Figure 1 ranks the varieties in terms of colour.

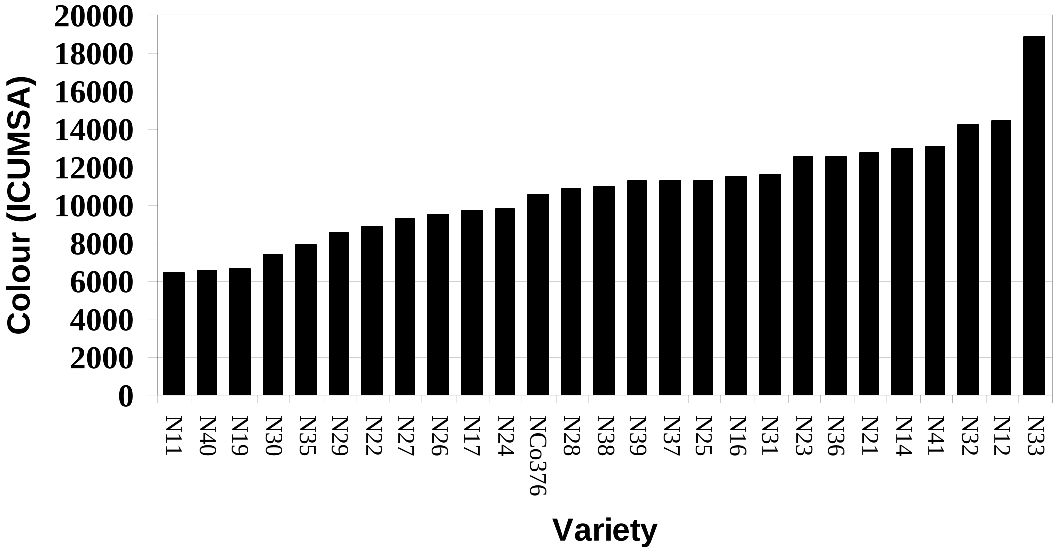

Figure 1. Effect of variety on colour.

The effect of overall geographical location was not found to be significant. However, it was highly significant when the locations were separated into individual farms. The comparisons between the farms are shown in Figure 2 as a box and whisker plot. The results show that there is large variation in colour within locations. On average, the Midlands showed the lowest colours, with Kearsney on the North Coast experiencing high colours.

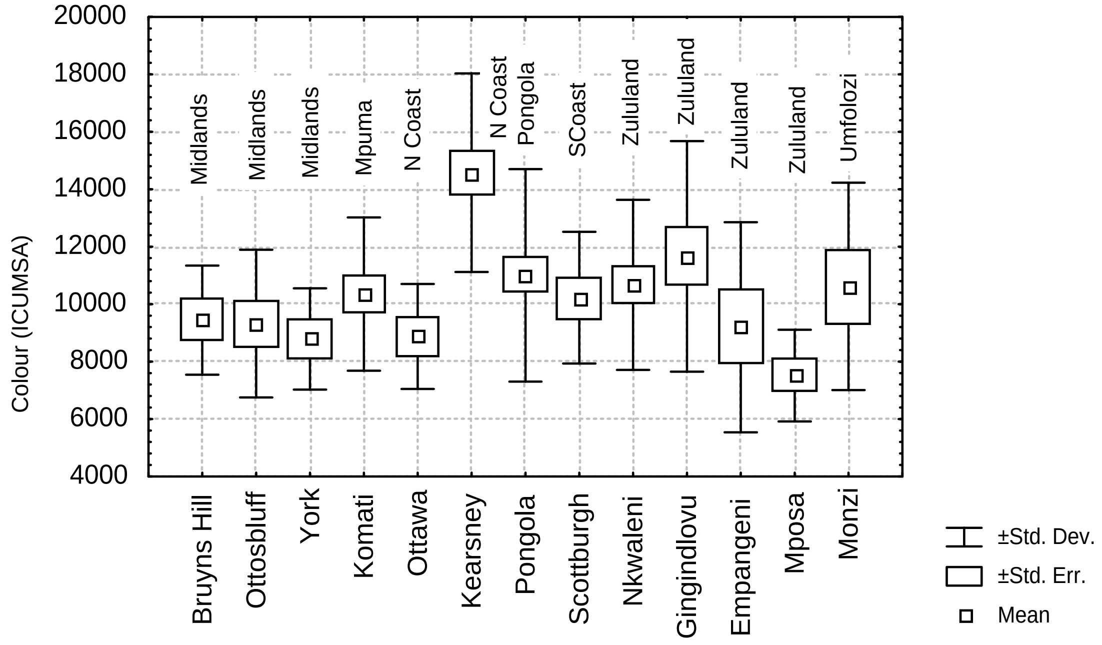

Figure 2. The effect of geographical location on colour.

Effect of harvest month and ratoon number

When investigating harvest month, samples were grouped into three parts, namely early (April to June), middle (July to September) and late (October to December). The effect of harvest month is not significant if the trials in the Midlands, the only location for which cane was harvested in mid-season, are removed, but is highly significant if they are included in the statistical analysis. Figure 3 illustrates the results. A parabolic trend is followed where the lowest colour occurs in the middle of the season. However, the effect of location impacts on the results so it is difficult to draw firm conclusions.

The effect of ratoon number was not significant at the 5% level.

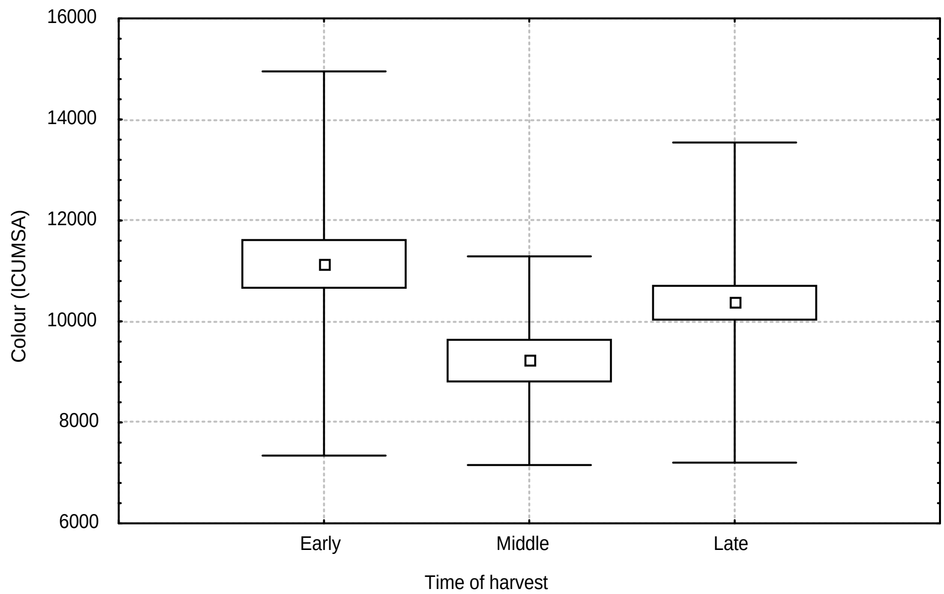

Figure 3. The effect of time of harvest on colour.

Effects of burning versus trashing and of rainfed versus irrigated
No statistically significant effects were found.

Inorganic phosphate

Varietal and geographical effects
Both variety and location were highly significant. There was a maximum difference of 197% between the varieties, and a maximum of 123% between locations. Table 3 ranks the varieties in terms of phosphate levels. Figure 4 illustrates the effect that area has on phosphate levels, with the North Coast having the highest levels.

Table 3. Effect of variety on inorganic phosphate.

Variety	Inorganic phosphate (mg/kg Bx)	Variety	Inorganic phosphate (mg/kg Bx)
N24	1021	N30	1930
N19	1241	N29	1985
N36	1248	NCo376	2024
N16	1257	N22	2091
N25	1288	N27	2163
N28	1289	N38	2284
N14	1315	N31	2334
N21	1349	N41	2373
N32	1485	N35	2386
N40	1505	N33	2394
N26	1506	N12	2584
N17	1601	N16	2739
N23	1792	N39	3035
N37	1925	-	-

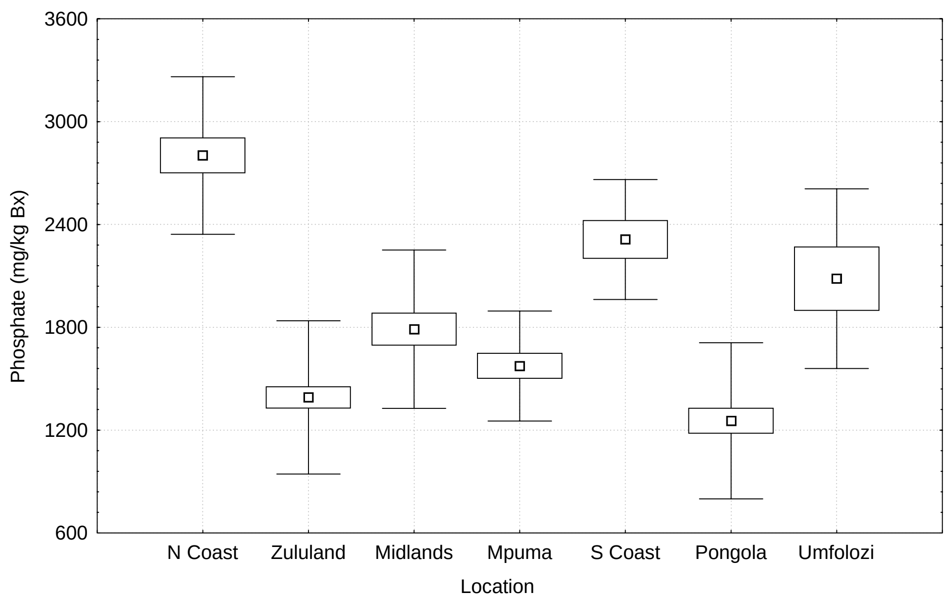

Figure 4. The effect of geographical location on phosphate.

Effect of harvest month and ratoon number

There was no significant difference between the time of harvest and phosphate levels. The effect of ratoon number was highly significant. Figure 5 shows the phosphate levels for each ratoon.

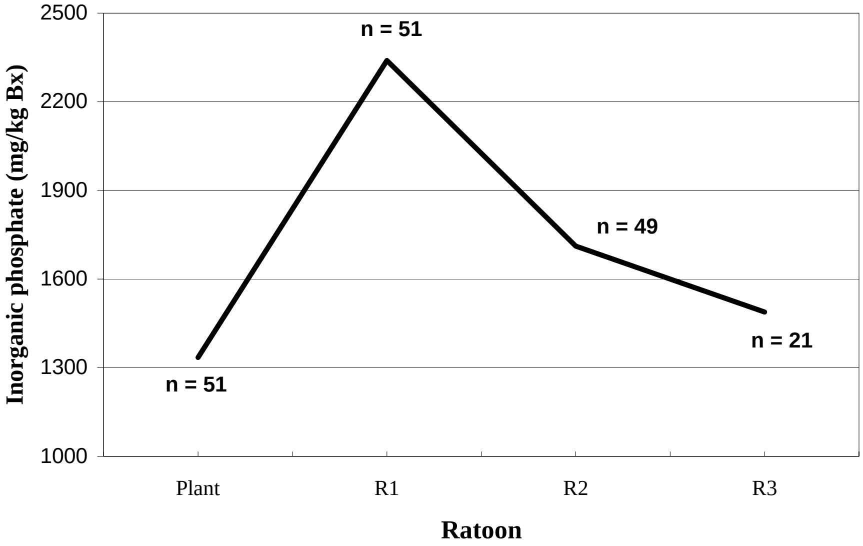

Figure 5. Effect of ratoon number on phosphate levels.

Figure 5 shows that there is an increase in the uptake of phosphate in the first ratoon and decreases with further ratooning. There may be some influence of area and variety, and more data are required to confirm these results.

Effect of burning versus trashing and of rainfed versus irrigated

Trashing or burning the cane was not statistically significantly different, while rainfed versus irrigated was highly significantly different, with rainfed areas having an inorganic phosphate content of 21% higher.

Soluble silica

Varietal and geographical effects

Variety did not have a significant effect on soluble silica levels for this trial, while geographical location was highly significant. The effects of location are illustrated in Figure 6 as a box and whisker plot. The graph shows that the Midlands has a higher silica content, while the South Coast tends to have lower silica concentrations.

Effect of harvest month and ratoon number

The time of harvest had a significant effect on the silica levels, where levels dropped from higher levels at the beginning of the season to lower levels at the end of season. The effect of ratoons was not significant.

Effect of burning versus trashing and of rainfed versus irrigated

The effect of burning versus trashing on the amount of soluble silica in the cane was highly significant. The results show that burnt cane has higher silica levels than trashed cane (data not shown). The effect of rainfed or irrigated was not significant.

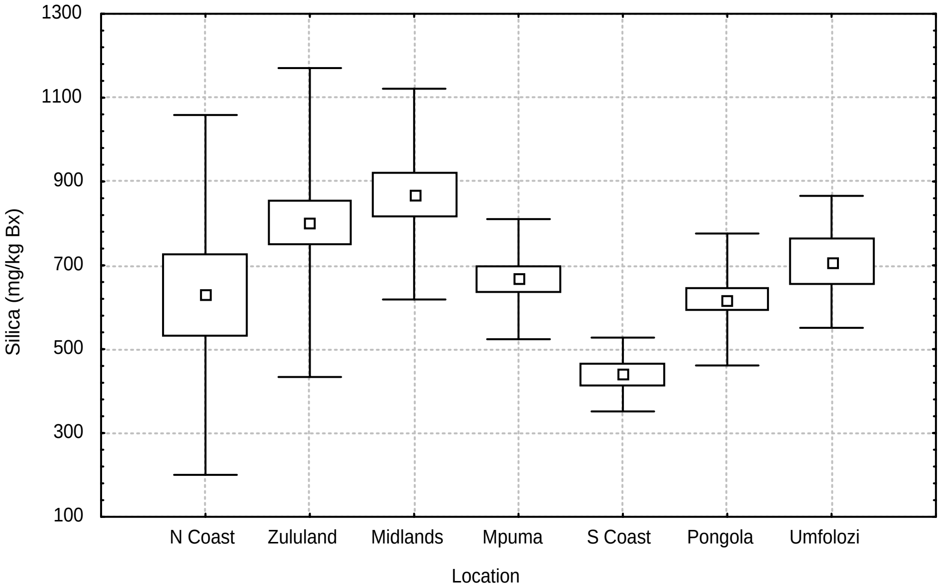

Figure 6. The effect of geographical location on soluble silica.

Conductivity Ash

Varietal and geographical effects

The effect of variety on conductivity ash was significant, with a maximum difference of 195% being shown between varieties N11 and N12. Figure 7 ranks the varieties in terms of their conductivity ash levels. Geographical location was highly significant and Figure 8 shows the effects. The Midlands have higher ash levels than the other regions, with the North Coast and Umfolozi having lower levels.

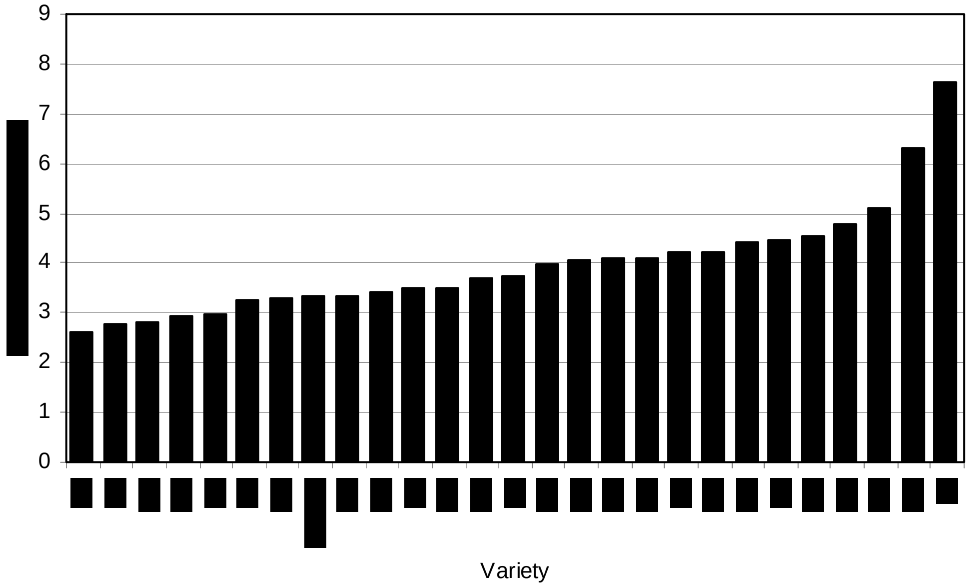

Figure 7. The effect of variety on conductivity ash.

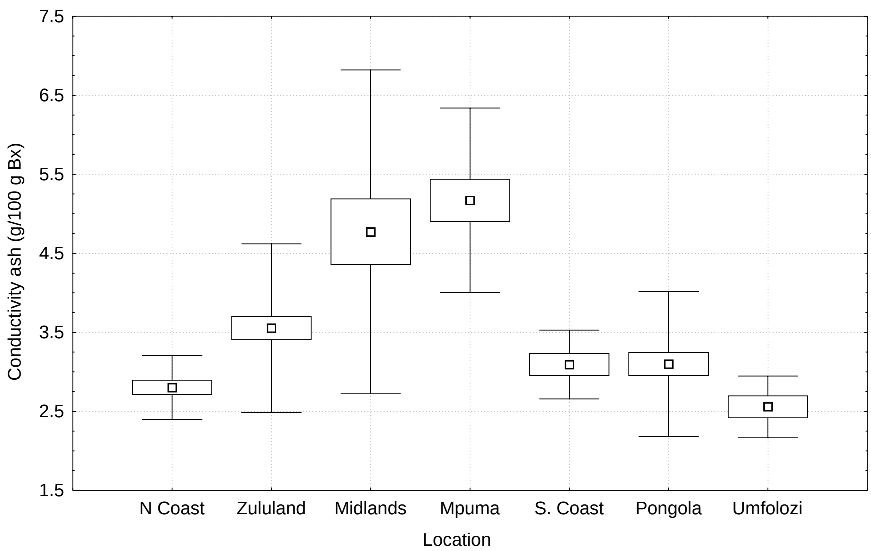

Figure 8. The effect of geographical location on conductivity ash.

Effect of harvest month and ratoon number

The effect of harvest month was highly significant, with higher conductivity ash levels during the early part of the season and lower levels at the end of the season. The number of ratoons was also highly significant, with plant cane having the highest conductivity ash levels.

Effect of burning versus trashing and of rainfed versus irrigated

Burning versus trashing was highly statistically significantly different, with burnt cane having higher conductivity ash levels. Statistically, rainfed or irrigated has a highly significant influence on conductivity ash levels, where cane from irrigated areas has higher conductivity ash than cane from rainfed areas (data not shown).

Cations

The levels of significance each of the different factors has on the cations (Na, K, Mg and Ca) are shown in Tables 4 and 5. The highest and lowest groups along with the actual values (as mg/kg Bx) are also shown.

Table 4. Effects of different factors on sodium and potassium.

Factors	**Sodium (mg/kg Bx)**			**Potassium (mg/kg Bx)**		
	Significance	**High**	**Low**	**Significance**	**High**	**Low**
Variety	-	-	-	*	N28 (13695)	N12 (5885)
Location	**	Pongola (466)	Mpuma (254)	**	Mlnds (16045)	N. Coast (4884)
Ratoon	**	Plant (436)	R2 (271)	**	Plant (13121)	R3 (6398)
Time of season	**	Early (471)	Late (296)	**	Early (10952)	Late (7080)
Burnt/trashed	-	-	-	**	Burnt (11992)	Trashed (8455)
Rainfed/irrig	-	-	-	**	Irrigated (12307)	Rainfed (6587)

** = Highly significant   * = Significant   - = Not significant

Table 5. Effects of different factors on magnesium and calcium.

Factors	**Magnesium (mg/kg Bx)**			**Calcium (mg/kg Bx)**		
	Significance	**High**	**Low**	**Significance**	**High**	**Low**
Variety	**	N39 (2166)	N26 (1212)	-	-	-
Location	**	N. Coast (1833)	Mlnds (1251)	**	Mpuma (1281)	Mlnds (652)
Ratoon	*	R3 (1675)	Plant (1403)	-	-	-
Time of season	-	-	-	**	Early (1120)	Late (952)
Burnt/trashed	**	Trashed (1619)	Burnt (1300)	**	Trashed (1077)	Burnt (738)
Rainfed/irrig	**	Rainfed (1694)	Irrigated (1361)	-	-	-

** = Highly significant   * = Significant   - = Not significant

Magnesium and potassium appear to be more influenced by agricultural factors than are sodium and calcium. As expected, geographical location has a highly significant effect on all four cations due to the different soils and climatic conditions experienced in the different locations. The effect of time of season shows that early harvested cane has higher cationic concentrations, while cane that is harvested later in the season has lower concentrations. This trend is also followed with conductivity ash.

Pith/fibre ratio

Varietal and geographical effects

Pith/fibre analyses of shredded cane were done only for the samples collected from SASRI in Mount Edgecombe, which excluded the far northern areas. This reduced the number of samples available for statistical analysis. Variety had a significant effect on the pith/fibre ratio, with the results illustrated in Figure 9. The maximum difference between varieties was 124%.

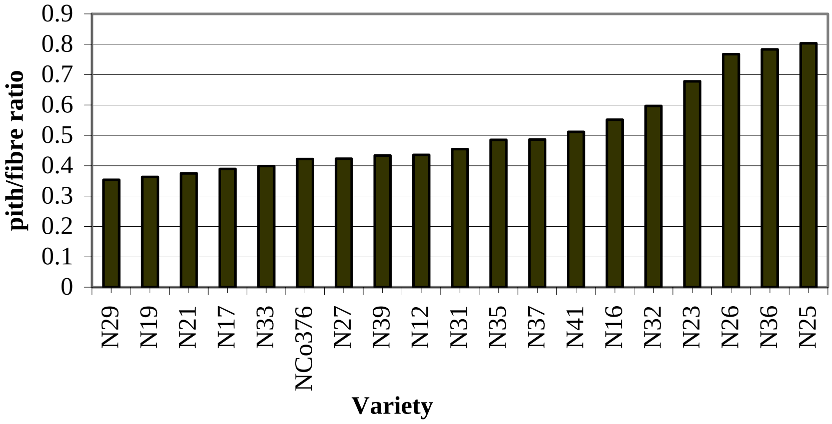

Figure 9. The effect of variety on pith/fibre ratios.

Location had a highly significant effect on pith/fibre ratios, with the Midlands having a higher pith/fibre ratio than any other location. The results are shown in Figure 10.

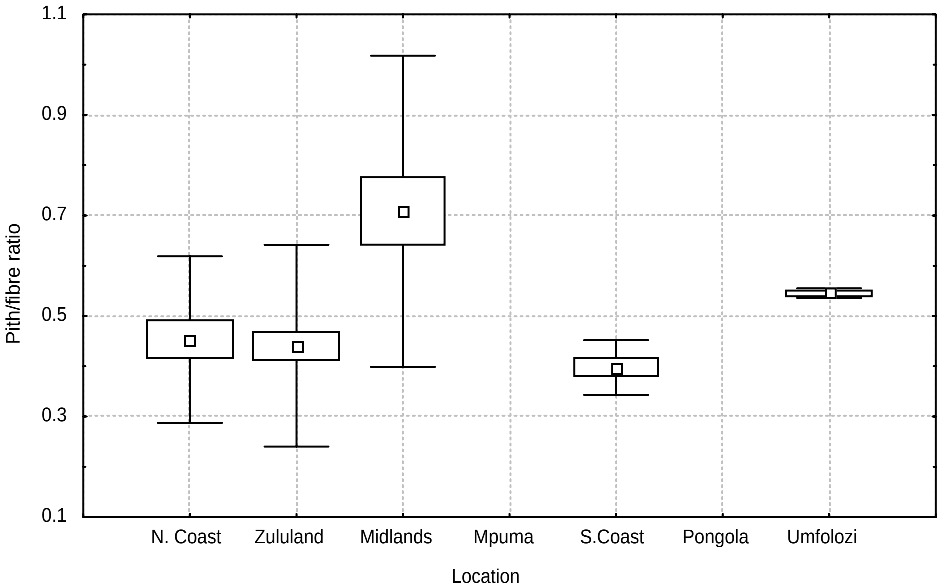

Figure 10. Effect of geographical location on pith/fibre ratios of shredded cane.

Effect of harvest month and ratoon number

The time of harvest was highly significant, with lower pith/fibre ratios being observed later in the season. Ratoon was also highly significant with plant cane having much higher pith/fibre ratios than ratoon cane (Figure 11).

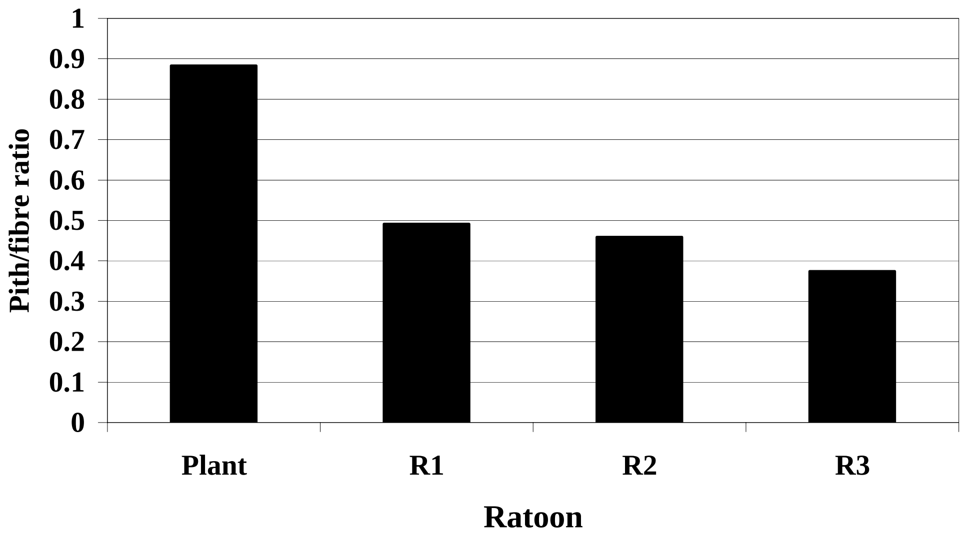

Figure 11. The effect of ratoon on pith/fibre ratio.

Effect of burning versus trashing and of rainfed versus irrigated

The effects of burning versus trashing and of rainfed versus irrigated were highly significant on the pith/fibre ratios. The results show that burnt cane had a higher pith/fibre ratio than trashed cane, and irrigated cane had ratios higher than rainfed cane (data not shown).

Interaction of factors

Multivariate analysis of variance has not yet been performed, but will be reported on later.

Comparisons with previous work

In most cases the results obtained from these trials compare well with previous work done by Naidoo and Lionnet (2000). Overall, more statistically significant effects were found on processing parameters than with the previous work. There were also a number of newer varieties that were not part of the previous investigation. The comparisons show that some varieties and locations followed similar trends. For example, both works highlighted N12 as a high colour variety, N19 as a low colour variety and N22 was shown to have high ash levels. Variety was also shown to be significant with respect to all factors except soluble silica. Results from both studies also highlighted the South Coast as having low silica levels and the North Coast having low phosphate levels. There were also large variations between the results of the two studies which may be due to the many interactive factors involved like different varieties, climatic conditions, soil types and age.

Ranking of varieties

A simple exercise to rank the varieties was undertaken to find the most suitable variety for process conditions. The ranking was then collated with the SASRI ranking of each variety, to investigate which variety in a specified area would be the most suitable for growing and processing. Since colour was seen as a very important aspect of processing, the varieties were ranked on colour and on annual ERC yield, with all other parameters such as disease resistance being excluded. The exercise was merely done to illustrate that the processing quality of the cane can be used as a selection tool if there are comparable varieties (in terms of agricultural properties) to choose from. It does not imply that colour and ERC have equal impacts on processing. Only variety and location have been considered, with all other effects being ignored. Table 6 highlights the results of the exercise where the two highest and lowest ranked varieties, based on annual ERC yield and colour, are shown.

Table 6. High and low ranked varieties in terms of annual ERC yield and colour.

Location	Best	Worst
Mpumalanga	N40, N24	N14, N36
Pongola	N40, N26	NCo376, N27
Umfolozi	NCo376, N19	N32, N30
Zululand	N14, N19	N33, N16
North Coast	N35, N39	N33, N16
Midlands	N40, N11	N31, N16
South Coast	N39, N21	N33, N41

The results show that N40, N39 and N19 are ranked highly in a number of different locations, while N33 and N16 are ranked lower. A number of different parameters other than colour can also be chosen, and this will be investigated in future work. It must also be noted that all varieties are not suitable for growing in all areas.

Conclusions

It must be stressed that the data from this investigation were analysed statistically using a one-way analysis of variance (ANOVA) method. The interactive effects of the other factors can influence the results, therefore the effects shown and their significance should be regarded with caution.

Table 7 summarises the statistically significant effects showing the maximum differences for all the factors and variables involved. In all cases except the effects on colour, the data from the Midlands were removed when the effects due to harvest time were investigated.

Table 7. Summary of statistically significant effects with maximum differences (expressed as %).

Parameter	Effects											
	Variety		Location		Harvest month		Ratoon		Burnt/ trashed		Rainfed/ irrigated	
Colour	318	**	-	-	21	*	-	-	-	-	-	-
Inorganic phosphate	197	**	123	**	-	-	57	**	-	-	21	**
Soluble silica	-	-	98	**	20	*	-	-	24	**	-	-
Conductivity ash	160	*	86	**	32	**	46	**	27	**	36	**

Magnesium	79	**	46	**	-	-	19	*	24	**	24	**
Potassium	133	*	229	**	55	**	105	**	42	**	87	**
Sodium	-	-	83	**	59	**	61	**	-	-	-	-
Calcium	-	-	96	**	18	**	-	-	46	**	-	-
Pith/fibre	124	*	78	**	35	**	138	**	58	**	53	**

** = Highly significant   * = Significant   - = Not significant

Although geographic location had no statistically significant effect on colour, individual areas where the trials took place had a highly significant effect on colour.

Ranking the varieties in the different geographical areas according to their annual ERC yields and colour content highlighted some suitable and unsuitable varieties. This preliminary study needs to be extended so that a reliable and useful tool for selecting varieties in terms of both agricultural and processability can be developed.

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