THE EXCEPTIONAL 2002-2003 SEASON: WHY DID IT HAPPEN?

A SINGELS[1], S B DAVIS[2] and G R E LIONNET[3]

[1]*South African Sugar Association Experiment Station,*
P/Bag X02, Mount Edgecombe 4300, South Africa
[2]*Sugar Milling Research Institute, University of Natal, Durban, 4041, South Africa*
[3]*Tongaat-Hulett Sugar Ltd, Private Bag 3, Glenashley, 4022, South Africa.*
E-mail: singelsa@sugar.org.za

Abstract

The 2002/03 crushing season in South Africa was characterised by cane quality, and factory throughputs and performances well above recent averages, with a record tonnage of raw sugar produced. The low and well distributed rainfall was largely responsible for this, impacting on sucrose levels in cane, and steadiness of cane supply to the mills. A comparison of selected factory performance parameters over the past three seasons showed that the cane supply indeed impacted positively on factory performance.

Keywords: factory performance, raw sugar, cane quality, ash, pol

Introduction

Cane quality, factory performances and throughputs in South Africa have on average been good over the period 1998 to 2001; mixed juice purity was about 86, and cane and sugar tonnages around 22 and 2.6 million tons respectively, with cane to sugar ratios of 8.4 to 8.8. The 2002/03 season stands out not only because cane quality and sucrose content, factory performances and throughputs and sugar quality were better than for the period mentioned above, despite the high benchmarks set in 2000 and 2001, but also because these results were achieved over a shorter crushing time. Monthly values of sucrose in cane and mixed juice purity did not decline, as is usually the case, in the later part of the season.

The objectives of this paper are to review the past three seasons and determine the reasons for the 2002/03 season being exceptional. The following aspects will be considered in relation to climatic conditions: cane quality and delivery, factory performance and sugar quality. The full set of factory performance data is presented by Davis (2003), and only selected parameters will be considered in this paper.

Cane quality and delivery

Industry trends in cane quality, cane delivery and climate are shown in Table 1. It is clear that for the 2002/03 season, sucrose content was significantly higher than for the preceding two seasons, while no-cane stops, ash content, rainfall and soil water were significantly lower. No clear trends were apparent in temperature and radiation (data not shown).

These trends were also evident for most mill areas. The question arises as to how much of the improvements in cane quality and delivery can be attributed to climate and how much to field management. It has been shown that sucrose content for a given variety is determined primarily by crop age, recent crop water status and temperature (Singels and Bezuidenhout, 2002).

Similarly, experience shows that mill stoppages and ash content are primarily influenced by the amount of rain. An investigation was conducted to establish the extent to which climate controlled these parameters. The outcome could suggest whether it would be possible to repeat these achievements by field management.

Table 1. Industry average of selected cane quality, cane supply and climate parameters for three milling seasons.

Parameter	2000/01	2001/02	2002/03
Sucrose content (%)	12.81	12.87	13.67
No-cane stops (%)	10.05	10.86	6.75
Ash content (%)	1.85	2.03	1.62
Rainfall (mm)	895	843	666
Soil water (mm)	20.7	15.6	12.2
Temperature (^{o}C)	19.5	19.9	19.5
Climate index	0.90	0.91	0.96

Monthly means of rainfall, temperature and reference soil water content for homogenous climate zones (Bezuidenhout and Gers, 2002) were averaged per mill supply area. The period from March 2000 to December 2003 was considered. Soil water content was calculated from daily rainfall and evapotranspiration using the Canesim water balance method (Singels *et al*., 1998) for a reference soil (available water holding capacity of 80 mm) and reference crop (fully canopied sugarcane). A climate index (CI) was used to represent the combined effect of crop water status and temperature on the sucrose accumulation process as described by Singels and Bezuidenhout (2002). The calculation of CI is explained in the Appendix. CI accounts for enhanced partitioning of assimilated biomass to sucrose in favour of structural growth when temperature and/or water status is low. CI varies between zero and one, the latter indicating ideal conditions for rapid sucrose accumulation.

The association between selected cane quality and delivery parameters on one hand and climate on the other hand is quantified in Table 2. There exists a strong correlation between sucrose content of the current month and the climate index of the previous month for most mills, with the highest correlations for Pongola (r=0.85) and Amatikulu (r=0.82). Midlands mills had lower coefficients because older cane generally is more mature, with higher and less variable sucrose contents. Irrigated mill areas also showed surprisingly high correlations between sucrose content and climate.

Table 2. Correlation coefficients for the relationships between sucrose content and the climate index, ash content and rainfall, and no-cane stoppages and rainfall.

Relationship	Mill														
	ML	KM	PG	UF	EN	FX	AK	DL	MS	GH	NB	UC	ES	SZ	UK
Sucrose vs CI	0.66	0.63	0.85	0.83	0.80	0.68	0.82	0.72	0.73	0.66	0.48	0.35	0.48	0.59	0.56
Ash vs rain	0.87	0.39	0.69	0.44	0.48	0.67	0.69	0.53	0.54	0.25	0.48	0.69	0.47		0.60
Stops vs rain	0.88	0.85	0.62	0.65	0.67	0.65	0.47	0.57	0.56	0.60	0.58	0.39	0.54	0.62	0.42

ML=Malelane, KM=Komati, PG=Pongola, UF=Umfolozi, EN=Entumeni, FX=Felixton, K=Amatikulu, DL=Darnall, MS=Maidstone, GH=Gledhow, NB=Noodsberg, UC=Union Co-op, ES=Eston, SZ=Sezela, UK=Umzimkulu

Ash content for a given month was strongly correlated to the rainfall of that month at most mills. The highest correlation (r=0.82) was found for the Malelane mill area. Expectedly, mill stoppages due to lack of cane also correlated well with rainfall. This association was exceptionally strong in the Malelane and Komati mill areas where infield haulage is practised. Significant rainfall quickly waterlogs the irrigated fields and delays cane delivery to the mills. Hence, a dry season such as 2002/03 meant that the crop, which was not much diminished by low rainfall because of irrigation, could be delivered efficiently to the mills with minimal delays. For most other mills with zones and caneyards, rain has less of an effect on cane delivery and OTE, apart from exceptionally heavy falls, as was the case with the North Coast mills in July 2002.

The CI of a given month showed excellent agreement with the sucrose content of the next month (see Figure 1 for the example of Felixton). The flatter sucrose curve for the 2002/03 season was matched closely by the progression of CI. From the results presented here, it can be concluded that the CI fully captures the impact of climate on sucrose content and that the extraordinary quality trends for 2002 were primarily driven by climatic factors.

A closer inspection of the underlying components of climate revealed that rainfall, rather than temperature, was the dominant factor (see figure 2). Low summer rainfall caused early season soil water content to be lower in 2002 than for the other seasons. This compensated for the negative effects of high temperature on sucrose accumulation normally experienced during the summer period. Winter rainfall was above normal, resulting in high soil water contents. This did not impact severely on sucrose accumulation, as this was the period during which low temperature ensures good sucrose accumulation. Rainfall and soil water content was low towards the end of the season again, compared with the other two seasons. This enhanced accumulation of sucrose.

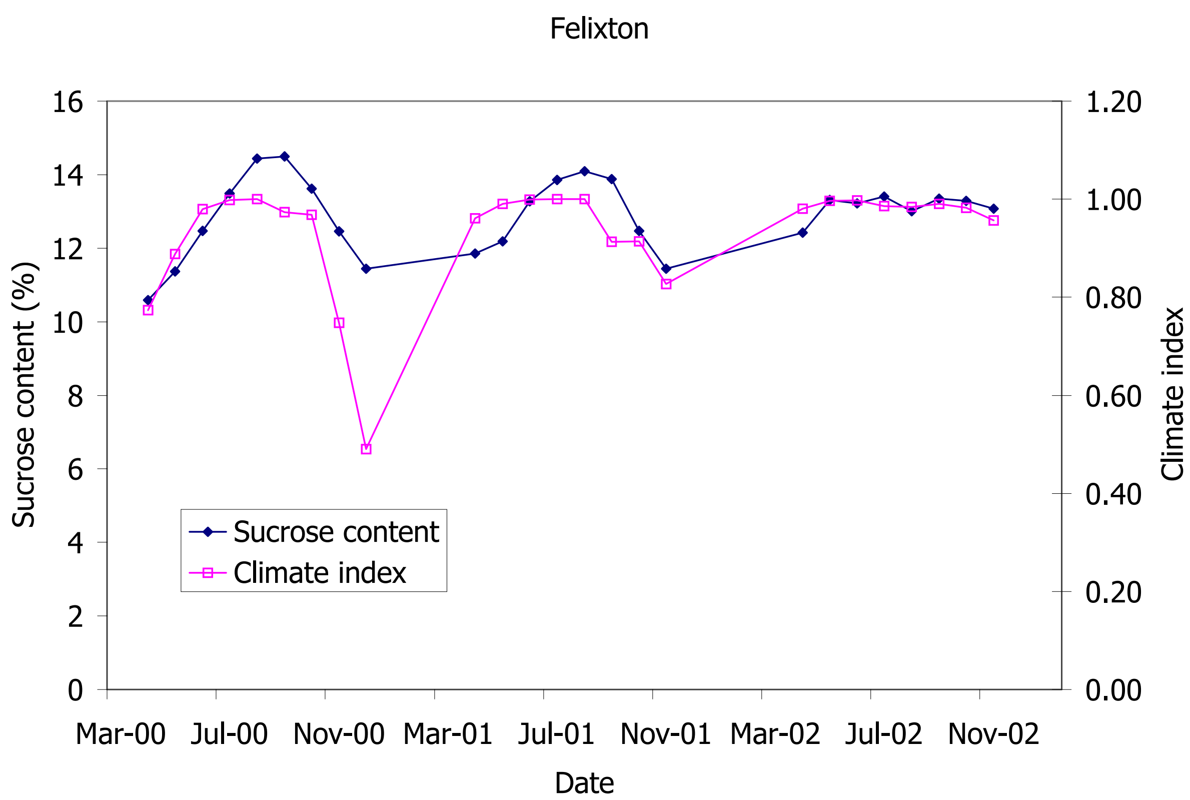

Figure 1. Monthly means of sucrose content of cane and the climate index for three milling seasons at the Felixton mill.

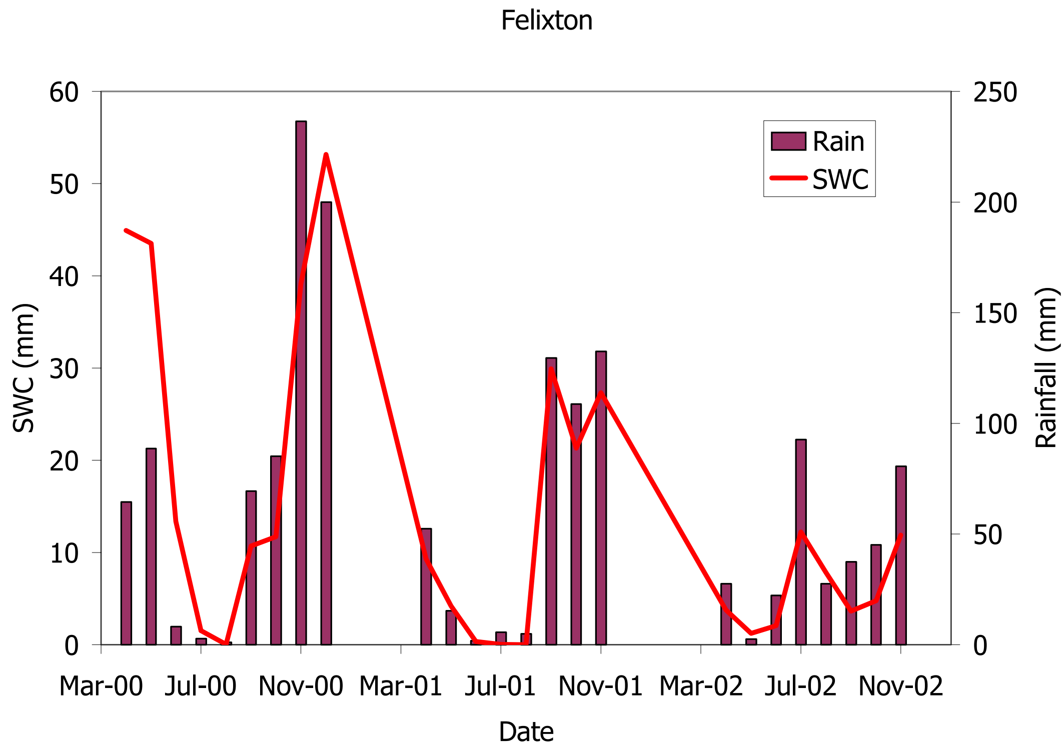

Figure 2. Monthly values of rainfall and reference soil water content (SWC) for the Felixton mill area.

In summary, it can be concluded that the major driving force for the excellent cane quality and supply of the 2002/03 season was climate, and specifically rainfall. The absence of excessive rainfall events promoted a steady cane supply and low ash contents. The low rainfall was distributed well (in winter) and led to the generally high sucrose content that was maintained throughout the season. It is unlikely that such as season will be repeated despite the best agronomic intentions by growers.

Steadiness of mill operation

The record sugar production from a relatively short season, at a very good cane-to-sugar ratio, was brought about by steady operation of the mills in conjunction with the good cane quality. A steady crush rate allows a mill to optimise its operations for maximum extraction and boiling house recovery, while good efficiencies should reduce sucrose losses to molasses and by chemical means (undetermined). To examine these factors for the past three seasons, the crush rates and time efficiencies should be considered.

Crush rate

The improved steadiness of supply can be gauged by plotting the frequency distribution of weekly throughput for the mills, that is, for how many weeks in the season the throughput was between 350 and 360 tons cane per hour (tch), for example, when steady throughputs will be shown by a narrow distribution. One such plot is given in Figure 3 for Umzimkulu (UK), showing that for most of the 2002/03 season, UK crushed at around 260-270 tch, whereas for the previous two seasons the crush rate varied between 220 and 260 tch.

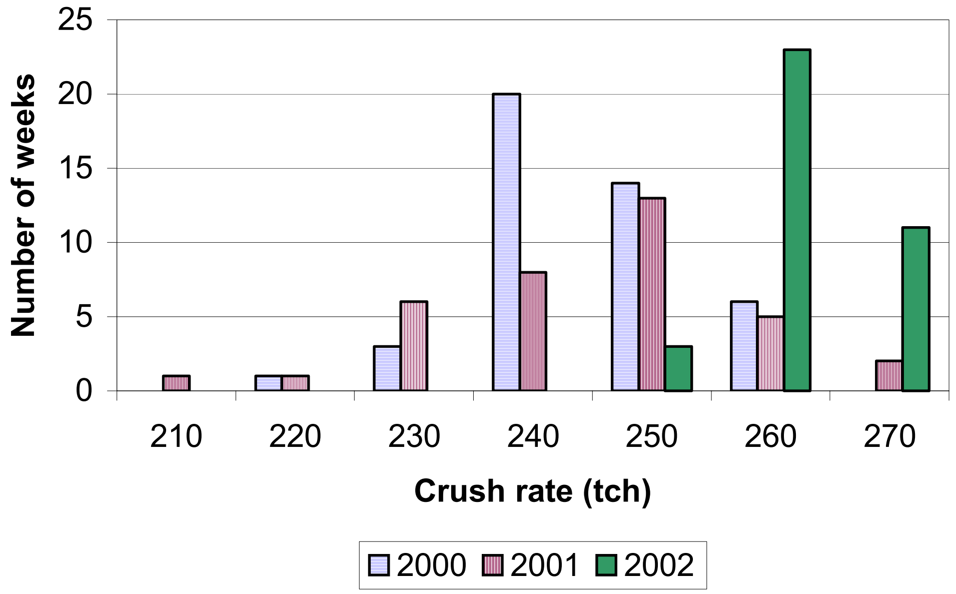

Figure 3. Frequency distribution of crushing rates at Umzimkulu.

It is also useful to plot the crush rates on a week-by-week basis, as this can reveal other reasons for the frequency distributions of the crush rates. For example, consider Figure 4, which shows the weekly crush rates for Union Co-op for the past three seasons. It is clear that the crush rate was very steady for the entire 2002/03 season, and that the crush rate was unusually high at both the beginning and the end of the season. The Midlands mills generally start slowly and run into problems towards the end of the season when the rains arrive, but the dry end of 2002 meant that these mills were able to crush consistently right until the end. A summary of the frequency distributions of crush rates is given in Table 3, with the mean rates and standard deviations given for each mill for the past three seasons.

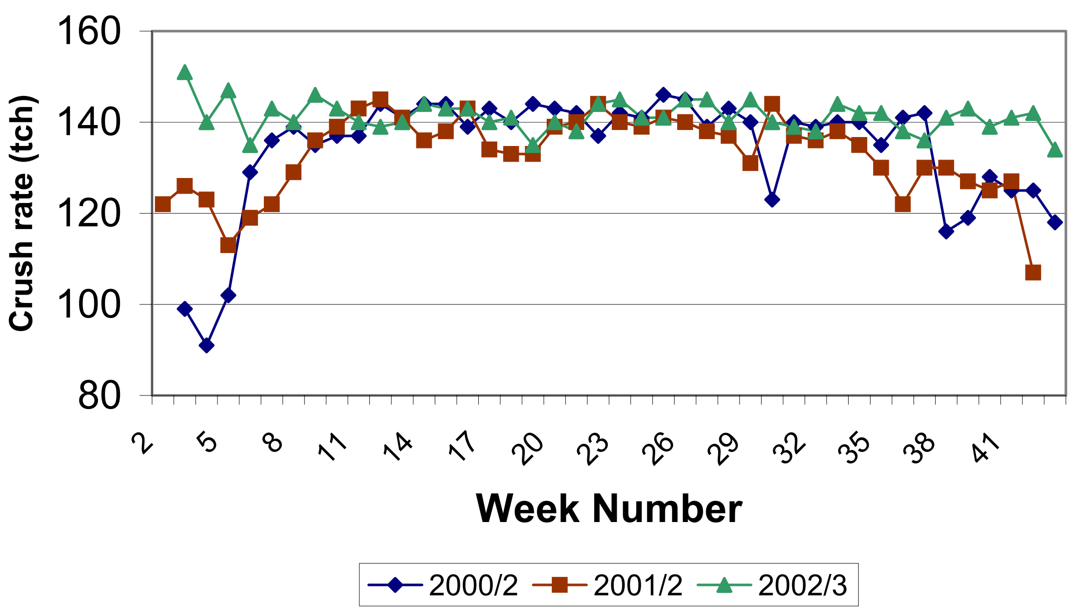

Figure 4. Weekly crush rates for Union Co-op.

Table 3. Average weekly crush rates (tch) for 2000/01, 2001/02 and 2002/03.

Mill	2000/01		2001/02		2002/03	
	Average	Std Dev	Average	Std Dev	Average	Std Dev
ML	317	46	317	50	342	26
KM	415	47	386	81	421	62
PG	246	16	249	14	254	18
UF	274	23	255	29	260	22
EN	88	7	89	8	89	4
FX	541	55	504	57	511	48
AK	361	25	364	27	346	40
DL	323	15	304	12	308	10
MS	422	28	384	28	377	27
GH	275	16	256	23	275	11
NB	285	25	301	24	295	19
UC	134	13	133	9	141	3
ES	241	20	232	18	252	13
SZ	415	33	406	72	425	29
UK	240	9	242	13	257	5

Time efficiency

Of equal importance is the steady operation during each week, as measured by the overall time efficiency (OTE). Figure 5 shows that the OTE was generally very high for Komati for 2002/03, whereas some much lower weekly efficiencies were recorded in the previous two seasons.

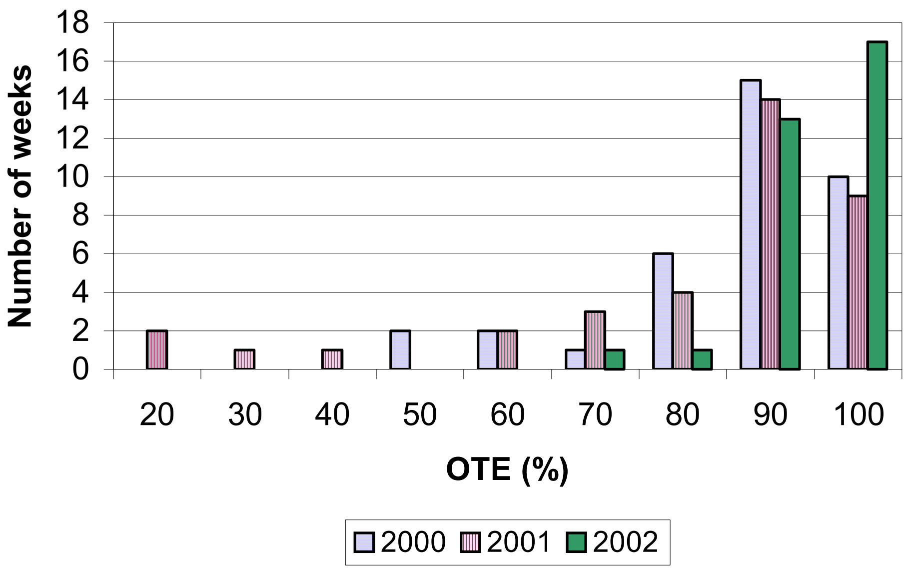

Figure 5. Frequency distribution of overall time efficiency at Komati.

Another method of quantifying this observation is by comparing the number of crushing hours per week at each factory, for the 2000/01, 2001/02 and 2002/03 seasons. The results from Malelane show clear trends and are presented in Figure 6.

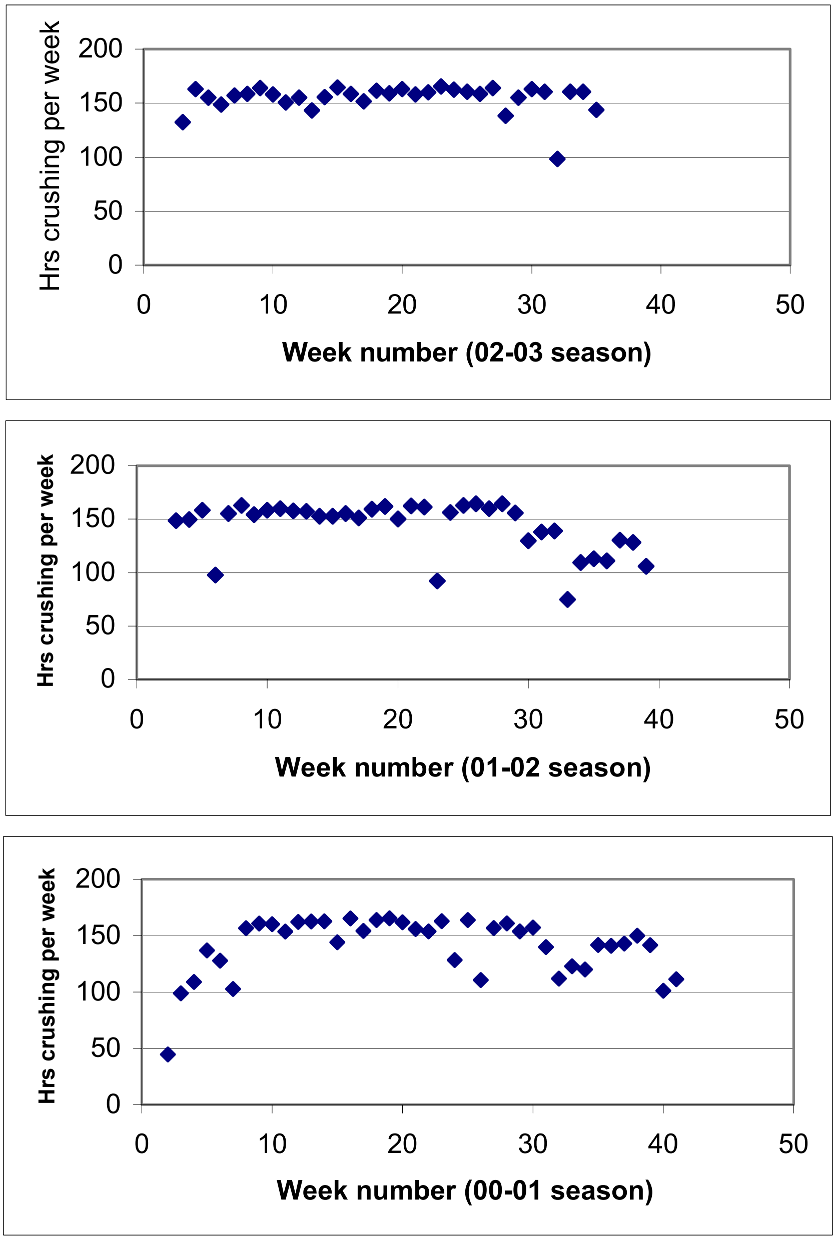

Figure 6. Number of crushing hours per week at Malelane over the past three seasons.

Two trends are apparent. Firstly, the average value for the 2002/03 season is higher than those of the previous seasons; in 2002/03 Malelane crushed for about 156 hours per week on average as opposed to 140 and 143 hours for the previous seasons. Secondly, there is less scatter in the data for the 2002/03 season. This can be quantified by calculating the standard deviation, which equals 13 in 2002/03, 23 in 2001/02 and 26 in 2000/01.

The plots in Figure 6 have been constructed to highlight the differences in the scatter. Most of the other factories present similar trends, as shown by the results in Table 4.

Table 4. Average hours crushing per week and standard deviations for the past three seasons.

Mill	2000/1		2001/2		2002/03	
	Average	Std dev	Average	Std dev	Average	Std dev
ML	140	26	143	23	156	13
KM	137	24	133	30	152	23
PG	124	33	138	15	139	12
UF	129	28	135	28	139	19
EN	130	24	129	22	132	24
FX	134	25	132	22	134	19
AK	137	24	139	21	136	19
DL	131	24	117	30	130	29
MS	138	25	135	21	145	21
GH	128	31	131	29	147	21
NB	128	33	137	24	141	19
UC	130	33	138	27	146	17
ES	137	26	140	24	142	18
SZ	138	25	137	27	149	12
UK	137	21	133	18	137	13

General comments on operation and performance

The above factors were considered for all South African mills for the past three seasons, and the following general comments can be made for the different regions. The northern irrigated mills had better OTEs during 2002, as discussed above, and generally higher crush rates, although Komati had a poor end to the season in terms of crush rates.

The Zululand and North Coast mills had an unexceptional 2002/03 season, which was very similar in terms of crush rates and OTEs to the previous two seasons. Maidstone crushed more slowly, but more steadily, while all these mills showed a performance dip in the middle of July 2002, when exceptional winter rains fell during one week.

The mills in the Midlands had a good season, with generally higher crush rates and steady operation, and a particular feature of the 2002/03 season was that good cane quality and adequate cane delivery were maintained to the end of the season, whereas they normally fall off significantly from October onwards, as can be seen in Figure 4. The South Coast mills showed more steady operation than previous seasons, with Umzimkulu also able to maintain a high crush rate until the end of the season.

In terms of factory performance, the industry average figures for extraction, boiling house recovery (BHR) and overall recovery were all better in 2002/03 than for the previous two seasons, as shown in Table 5. BHR in particular showed an improvement of nearly one per cent over the previous season, as might be expected from the high mixed juice purities. However, the corrected reduced figures for extraction (CRE) and BHR (CRB), which calculate the performances based on 'standard' qualities of cane, mixed juice, sugar and molasses, also increased slightly over 2001/02 figures. This shows that not all the improvements could be ascribed to the improved cane quality alone, but that the factories were able to improve performances, probably as a result of steadier operating conditions as discussed above.

Table 5. Values of Extraction, Corrected Reduced Extraction (CRE), Boiling House Recovery (BHR), Corrected Reduced BHR (CRB) and Overall Recovery for the South African industry for the past three seasons.

Season	Extraction (%)	CRE (%)	BHR (%)	CRB (%)	Overall Recovery (%)
2000/01	97.79	97.65	88.97	86.94	86.99
2001/02	97.74	97.59	88.18	86.69	86.19
2002/03	97.96	97.73	89.11	86.75	87.29

However, the steadier operation did not appear to have a significant effect on undetermined losses, with the industry average value for 2002/03 being 1.87%, only slightly improved over the value of 1.92% in 2001/2 and not as good as the value of 1.67% achieved in 2000/1. Hence, the significant improvement in boiling house and overall recoveries is due mostly to the decreased losses to molasses resulting from the high juice purities.

Sugar Quality

Very high pol raw sugar (VHP) is delivered at the South African Sugar Terminals (SAST) and at Huletts Refineries (HR). Monthly sugar quality data are available from these two institutions and have been used to prepare the following trends.

Sugar purity

Sugar purity [pol % sugar/(100 – moisture % sugar)] is more meaningful than the straight pol per cent as an indicator of the purity of the sugar. Monthly values for the SAST intake over the past three seasons, and monthly values for part of the HR intake during the 2002/03 season are shown in Figure 7.

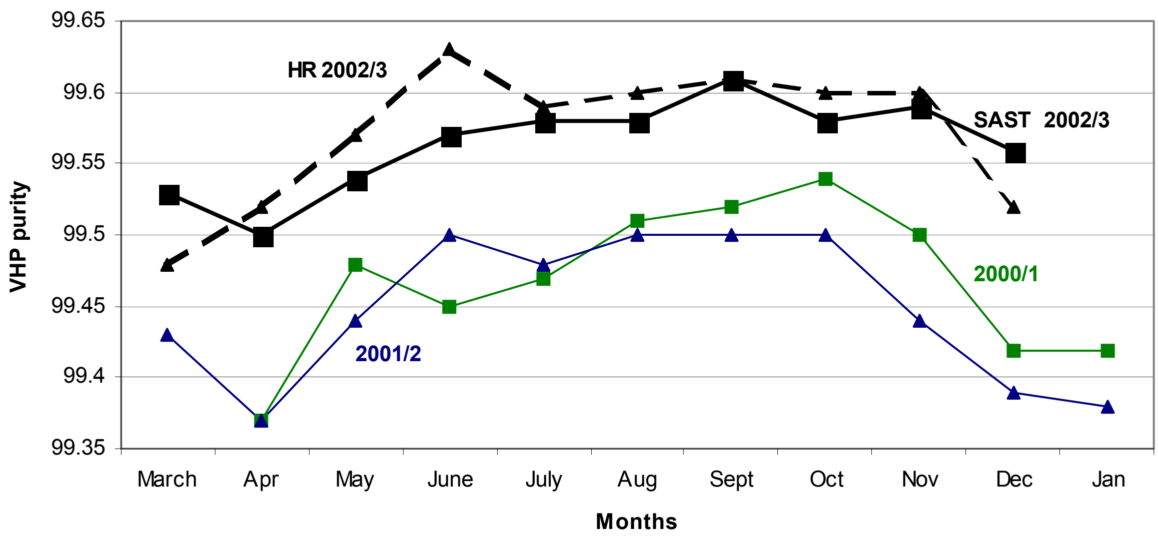

Figure 7. Monthly values of VHP purity over the past four seasons at the South African Sugar Terminals and over the 2002/03 season at Huletts Refinery.

Two points are apparent. Firstly, the VHP purities are clearly higher in 2002/03; and secondly, the trend is flatter than in the previous seasons. It is therefore apparent that the sugar purity trends have followed those found with cane sucrose content in 2002/03.

Sugar Colour

Trends in VHP colour are shown in Figure 8. There are no indications that the 2002/03 season was very different from the previous three seasons. No differences were found in starch levels in VHP sugar between the three seasons either, and so the exceptional properties of the 2002/03 season have therefore affected only purity as far as the main sugar quality aspects are concerned.

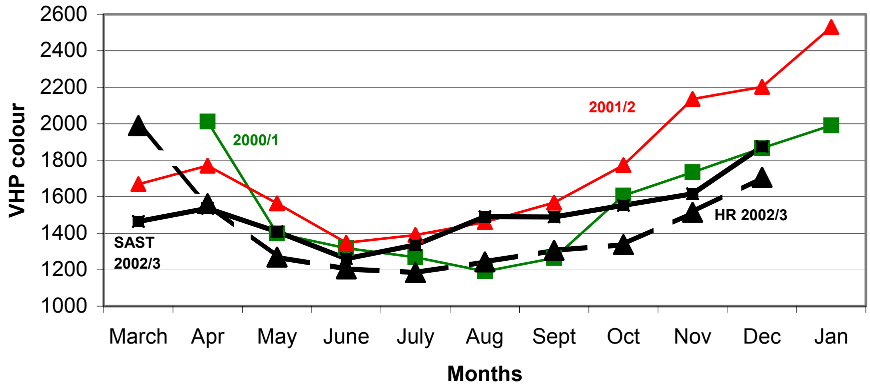

Figure 8. Monthly values of VHP colour over the past three seasons at the South African Sugar Terminals and over the 2002/03 season at Huletts Refinery.

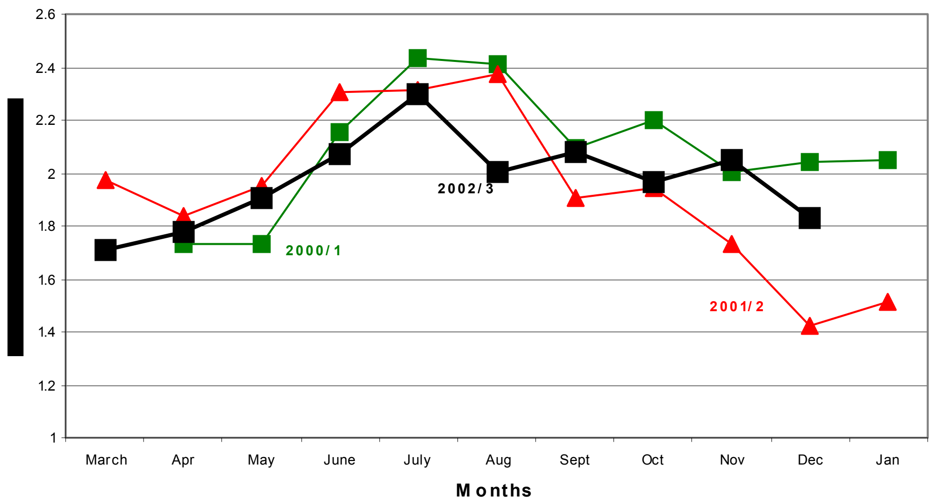

Figure 9. Monthly ratios of whole VHP colour to affinated VHP colour at the South African Sugar Terminals over the past three seasons.

It may be argued that consistent VHP colour can be maintained by increasing wash rates in the A-centrifugals, which would lead to an increase in VHP purities, and this may be the explanation for the trends shown here. However, colour values for affinated VHP sugars show the crystal colour, and the difference between this and the whole sugar colour gives an indication of how much washing took place, as washing removes the molasses coating of the crystal.

The ratios of whole sugar colour to affinated sugar colour for the past three seasons' input to the Terminals are shown in Figure 9, from which it can be seen that the colour ratios in the 2002/03 season were in the normal range. Hence it can be concluded that the higher sugar purities did indeed result from higher cane purities, and not from excessive washing.

Conclusions

The exceptional 2002/03 season in South Africa can be ascribed to the unusual rainfall distribution over much of the cane area, with relatively low rainfall outside the winter months. This led to high cane sucrose contents at the beginning and end of the season, while permitting the mills to crush steadily, as seen by the weekly crush rates and overall time efficiencies.

Although the season was shorter than usual, high throughputs were maintained with low losses generally. As a result, raw sugar purities were high and an excellent cane-to-sugar ratio of 8.32 was achieved. Although the exceptionally good results were caused by climatic factors and not by special efforts on the part of growers or millers, it has been useful to analyse the reasons for the results. Specifically, the Climate Index for a particular month has been shown to be a useful predictor of the sucrose content of the following month, and it will be interesting to see whether this correlation is maintained in other, wetter seasons.

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APPENDIX

The climate index (CI) was calculated using a water status (FW) and temperature factor (FT). The water status factor was calculated from the soil water deficit factor (SWDF), which is a function of the monthly mean soil water content (SWC) and the water holding capacity of the soil (TAM). The temperature factor was calculated using monthly mean temperature (T). The equations are as follows:

$$CI = (FW + FT - FW.FT) \quad (1)$$

$$FT = 1/(1 + e^{[0.32*(T-25)]}) \quad (2)$$

$$FW = (1 - SWDF)^{0.5} \quad (3)$$

$$SWDF = SWC/(1/2TAM)\ ,\ SWDF1 <= 1.0 \quad (4)$$

CI, FW, FT and SWDF all vary between zero and one. Equations 1, 2 and 3 are from Singels and Bezuidenhout (2002).