SUCROSE, YIELD AND DISEASE RESISTANCE CHARACTERISTICS OF SUGARCANE VARIETIES UNDER TEST IN THE SASEX SELECTION PROGRAMME

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Abstract

Varieties in test in the SASEX breeding programme during 1995 were compared, to illustrate trends in varietal development, and to assess the relative importance of diseases at different stages. It is apparent that there is a bias towards producing varieties with higher sucrose content and lower cane yield than control varieties. These varieties will contribute to achieving an 8:1 cane to sugar ratio, and also represent a gain in quality and profitability. Also obvious, is the large effect of disease on the selection programme, with 40% of the best varieties at each stage being rejected due to susceptibility to various diseases. This is a significant hidden cost to the industry, as many potentially high yielding varieties are not released because of disease problems. Possible solutions to this problem are discussed.

Introduction

The South African Sugar Association Experiment Station (SASEX) at Mount Edgecombe, is responsible for producing the commercial sugarcane varieties grown in South Africa. Every year, 180 000 candidate varieties, obtained from seed produced after cross pollination of selected parents, enter the selection programme. These potential new commercial varieties then undergo a six stage selection programme, which takes between 12 and 15 years to complete. During the selection process, clones are chosen for their sucrose content, sucrose yield per hectare, and resistance to the many diseases and pests that occur within the industry. This is done in conjunction with other SASEX departments, such as Pathology and Entomology, who provide valuable phenotypic assessments of varieties at various stages. By conducting a critical evaluation of the selection programme, and assessing the impact of the selection criteria on the types of varieties that are promoted through the programme, limiting factors can be identified. Knowledge of these bottle-necks allows strategies to be developed that make the selection process more efficient, and identifies the areas where new technologies can be used to help overcome these problems. The objective of this exercise was to see the effect that current selection criteria have on the characteristics of the new varieties coming out of the programme, and to see how these could be modified to make varietal development more efficient.

Methods

The layout of the selection programme is given in Table 1. For the first four stages, up to and including the primary variety trials, the selection is carried out independently at six farms. These are located at Mount Edgecombe, Umhlanga Rocks, Shakaskraal and Mtunzini on the North Coast, at Bruyns Hill in the Midlands, and at Pongola in the irrigated area. For the secondary variety trials at stage 5, testing is extended to an additional five sites, which includes two sites in Swaziland.

Table 1

Simplified layout of the SASEX selection programme. The varieties are divided between six selection farms, where evaluation is carried out independantly in stages 1 to 4. At stage 5 the best varieties from each site are combined, and planted across different sites.

Selection stage	Year	Trial type	No. varieties
	1	Potted seedlings	180 000
Stage 1	2	Single stools	130 000
Stage 2	3	Single lines	12 000
	4		
Stage 3	5	Observation trial	1 200
	6		
Stage 4	7	Primary variety trial	240
	8		
	9		
Stage 5	10	Secondary variety trial	48
	11		
	12		
	13		
Stage 6	14-15	Bulking for release	1-2

Trials in stages 3-5 that were measured during 1995 have been used for this study. To assess the effects of selection on sucrose content and yield, varietal means for ERS% (estimated recoverable sucrose), cane yield and sugar yield were calculated, and compared to the control variety NCo376 to eliminate site differences. Disease characteristics were evaluated by ranking the varieties in different trials on sugar yield, and determining how many of the top ranked individuals were discarded because of their susceptibility to different diseases.

Results

Sucrose content and yield characteristics

Trial means for ERS%, cane yield and sucrose yield, expressed as a percentage of NCo376 at the different selection stages, are shown in Table 2. In addition, the data has be broken down into the Southern and Northern areas, which represent rainfed and irrigated conditions. It must be emphasised that these figures are the means of all the varieties in test in the different stages, and that only the best 10-20% of individuals are promoted to the next stages.

From the results, three things are apparent. On average, the varieties at stages 3 to 5 of the selection programme have similar sugar yield to NCo376, but have a higher sugar content (ERS%), and a lower cane yield. Although their sugar yield per hectare is not appreciably greater, these varieties have a more favourable cane:sugar ratio.

As stressed earlier, the figures in Table 2 are means of all varieties in test for the respective selection stages. If individual varieties in the bulking plots at the end of the selection programme are compared, a similar trend is seen (Table 3). Although most have the high sugar content and lower cane yield displayed by the average of all varieties, there are some individuals that also have high cane yield.

Table 2

Means of the varieties in test in the southern and northern regions, expressed as a percentage of NCo376

	Region	No. trials	No. varieties	ERS%	Cane t/ha	Sugar t/ha
Stage 3	South	5	816	107	95	99
	North	4	374	112	83	92
Stage 4	South	13	311	104	95	100
	North	3	284	110	92	102
Stage 5	South	20	150	103	89	92
	North	18	81	110	91	100

Table 3

Sugar content and yield traits expressed as a percentage of NCo376, for some individual varieties at advanced stages in the selection programme. The values are the means of 18-22 different crops or trials.

Variety	Region	ERS%	Cane t/ha	Sugar t/ha
84E1334	South	123	83	103
86F3396	North	110	95	104
88F1730	North	111	97	107
88F2634	North	111	94	104
85H241	South	98	122	119
85L1769	South	111	108	120

It is important to note that some of the varieties shown here may be susceptible to disease, and so will not be released after the final assessment.

Resistance to disease and eldana

The effect of different diseases on the selection programme was measured by ranking the varieties at each stage on sugar yield, and determining how many of the top selectable individuals were discarded due to unacceptably high susceptibility to one or more diseases. These figures, broken down by stage and by southern or northern area, are shown in Table 4. In stage 5, the data has been combined across the two regions. Note that the numbers discarded for each disease may not add up to the total. This is because some varieties were susceptible to more than one disease.

The enormous impact of disease on the selection programme can be seen, with about 40% of the best varieties being discarded at stages 3 to 5 of the selection programme. It is important to realise that this is after many varieties have already been discarded at stage 2.

In the southern region, mosaic is the major problem, followed by smut and rust. Eldana only becomes a noticeable problem in the later stages of selection, but this is partly because reliable information on eldana resistance only becomes available at that time. In the northern area, rust is a major problem at stage 3, but is not a serious disease later on in the programme. This is because rust is a common disease with easily observed symptoms, which makes it very easy to select against. Smut, leaf scald, gumming and pokkah boeng are the other main diseases impacting on the selection programme in the northern area. Smut is heavily selected against at stage 2 in the northern programme.

Table 4

Number of varieties ranked top for sugar yield, that were discarded because of their susceptibility to disease

	South		North	
	Disease	No. discarded	Disease	No. discarded
Stage 3	Mosaic	17	Rust	20
	Smut	15	Smut	14
	Rust	13	Gumming	11
	Other	7	Leaf scald	1
	Total	52/130 (40%)	Total	39/100 (39%)
Stage 4	Mosaic	14	Rust	1
	Smut	8	Smut	3
	Rust	5	Gumming	5
	Eldana	6	Leaf scald	2
			Pokkah Boeng	3
	Total	18/44 (41%)	Total	11/20 (55%)
Stage 5	Smut		3	
	Eldana		3	
South & North combined	Mosaic		2	
	Rust		1	
	Total		9/26 (35%)	

An example of an outstanding variety discarded because of disease, is 75E247. This variety has a sucrose content of 123%, and a sugar yield of 114% of Nco376, but is highly susceptible to mosaic and so has not been released for commercial use. Examples of recent varieties rejected due to disease are given in Table 5, illustrating the enormous hidden cost that diseases have on the sugar industry by preventing the release of high sugar yielding varieties. Note that these results are from primary variety trials, so the figures are likely to be inflated.

Table 5

Some recent varieties discarded at stage 4 due to disease susceptibility. The figures are expressed as a percentage of NCo376

Variety	No. crops	ERS %	Cane t/ha	Sugar t/ha	Disease susceptibility
84L0889	3	113	127	146	Mosaic, smut
86M0564	3	116	118	144	Mosaic, smut
87E1293	3	114	123	139	Mosaic
88H0016	2	107	143	153	Mosaic

Rust would not normally be considered an important disease in the industry, but during 1995, forty of the best varieties for sugar yield were discarded because of rust. Likewise, 33 top varieties were discarded because of susceptibility to mosaic. From this it is clear that diseases have a major effect on the selection programme, and are the main hindrance to the release of high sugar yielding varieties to the industry.

Discussion

An assessment of varietal performance at different selection stages has illustrated that many recent varieties show increased sugar content, reduced cane yield, and similar sugar yield, compared to the common control. Varieties with these characteristics should be more profitable to grow, as the same amount of sugar is produced from a smaller quantity of cane, reducing harvesting, transport and milling costs. These characteristics should be taken into account when deciding which variety to plant, and the decision should not be based on sugar yield alone. Varieties like these will assist growers in achieving the desired 8:1 cane to sugar ratio, and help the South African industry remain a cost-effective competitor in the global sugar market. The observed trend in reduced cane yield also serves as a warning to the breeding programme. If selection for low cane yield continues over several generations, the possibility exists that useful genetic variation for this trait may be lost from the breeding population. This can be avoided by selecting high cane yielding individuals within each selection series, and using these as parents in the breeding programme.

Although it is generally recognised that diseases influence the selection of varieties, the illustration that 40% of the best varieties were discarded at each of the later selection stages has highlighted the high cost of disease on the selection programme. This is the major limiting factor in the release of high sugar yielding varieties to the industry, and more attention needs to be focused on this problem to increase the efficiency of the breeding programme. One way of tackling this problem is to create specialised breeding populations of disease resistant parents, and to use these more extensively in the crossing programme. However Nuss (1975) has pointed out that for smut disease, crossing resistant parents does not necessarily result in a high proportion of resistant progeny. An additional difficulty in using conventional methods to select for disease resistance, is that symptom expression can vary with time, and it may take several years before reliable information on resistance and susceptibility can be obtained. Breeding for disease resistance would thus be slow, unless assay techniques could be developed that would predict resistance or susceptibility at an early stage.

Novel biotechnological methods may help overcome some of the problems associated with developing disease resistant varieties. Gene constructs that may impart mosaic resistance to transformed plants have been developed in several laboratories (Mirkov *et al.*, 1996; Smith *et al.*, 1992). Genetic transformation of high yielding but mosaic susceptible varieties with these constructs, would allow the use of varieties such as 75E247, and would result in substantial benefits to the sugar industry. SASEX has the technology to do this if the genetic constructs already available could be aquired, although extensive field testing would need to be done on transgenic plants. In addition, the development of molecular markers linked to disease resistance would allow the identification of resistant individuals at the earliest stage of the programme. This would enable a greater proportion of disease resistant candidates to enter the programme, and greatly enhance the efficiency of breeding and selection.

Conclusions

The problem of disease susceptability is a major bottleneck in the process of developing high sugar yielding varieties for use in the South African sugar industry. Although varieties combining high sucrose content and high sugar yield can be identified, they are often not released as they may lack resistance to one or more diseases or pests. By combining conventional breeding strategies with new technologies, progress may be made in overcoming this problem. This is likely to be a long-term process, but one in which the use of genetic transformation could have a very valuable role to play.

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