PROGRESS IN SELECTING FOR ELDANA RESISTANCE

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Abstract

The South African Sugar Association Experiment Station variety selection programme is carried out at six different sites, which were chosen to represent the major climatic regions where sugarcane is grown in South Africa. The Experiment Station farm at Mtunzini was originally chosen because it represented the areas on the main coastal belt with poor soils and a relatively high annual rainfall. However, in 1974, eldana was found in the cane on the farm and the damage caused by this pest in selection trials resulted in resistance to eldana becoming a major criterion in the selection of varieties at this site. The results of a series of secondary variety trials, in which varieties emanating from Mtunzini selection programme were compared with those from other selection sites, are presented. Comparisons of cane yield, cane quality, parentage, and eldana resistance are made. The results indicate that the varieties selected at Mtunzini have better resistance to eldana than those selected at other sites. Estimates of the degree of genetic determination contributing to eldana resistance are made, and possible strategies for selecting for such resistance are considered.

Introduction

The selection programme followed at Mount Edgecombe has been described previously (Bond;[2] Brett;[4] Nuss[6]). The first 4 stages in the programme are concerned with selecting a few promising clones from a large number of original seedlings. This work is carried out at 6 different sites, which have been chosen to represent the major climatic regions where sugarcane is grown. In the fifth and sixth stages of selection, the most promising clones from the different sites are entered into a series of variety trials to evaluate them under different environmental conditions. The codes used to identify the individual clones include a letter that identifies the original selection site: F = Pongola, M = Mtunzini, W = Shakaskraal, E = Experiment Station, L = Central Field Station (CFS), H = Windy Hill.

In addition to the sites listed above, varieties in the southern rainfed areas are also evaluated in trials at La Mercy (code C) and Umhlatuzi Valley Sugar Company (code A). The trials at the La Mercy site are frequently subject to high levels of eldana. These two sites are used only for evaluation trials and not for the early stages of selection.

Pongola is representative of the irrigated northern areas, while Shakaskraal and the Experiment Station typify the conditions of the main coastal belt where sugarcane is harvested at a young age. CFS is situated on sandy soils, and Windy Hill is in the Natal Midlands where sugarcane is traditionally harvested at more than 20 months of age. The Mtunzini farm was originally chosen to represent the main coastal belt areas with poor soils and a relatively high annual rainfall.

However in 1974, eldana was discovered in fields on the farm and within a few years the damage caused by this pest in selection trials was sufficient to mask the normal differences in yield between varieties in the selection programme. Due to the extent of the damage in trials at all stages in the selection programme, variety resistance to eldana became a major criterion in the selection of varieties at Mtunzini, because of both the direct effect of the pest on the sucrose yield and deliberate attempts to find varieties exhibiting resistance to eldana.

Nearly 10 years have elapsed since selection for resistance to eldana began being practised in the Mtunzini programme. In this paper the results from the fifth and sixth stage variety evaluation trials are examined for responses to these selection pressures.

Methods

The results from variety trials planted at Mtunzini, CFS, La Mercy, and Windy Hill in two different years were considered. The variety trials used in the selection programme generally have 3 replications, each plot consisting of 5 cane rows 8 m long. The first series, identified as the 'Q' series of varieties, was planted in the spring of 1982, and contained 31 varieties, excluding standard varieties. The 'S' series was planted in 1984 and contained 24 varieties. The variety lists for each series, showing the appropriate selection site codes are shown in Appendix I.

The trials were harvested at approximately 18-month intervals, and in the trials planted in 1982, data from a plant crop and two ratoon crops have been obtained. In the trial planted in 1984, plant cane and one ratoon crop have been harvested so far. Table 1 shows the planting and harvesting dates of the individual trials.

Table 1

Planting and harvesting dates of trials

Trial code	Date planted	Date harvested		
		Plant	1R	2R
M(V)(Q)/82	24.11.82	22.06.84	28.11.85	13.05.87
C(V)(Q)/82	24.11.82	24.05.84	14.11.85	10.06.87
L(V)(Q)/82	02.12.82	21.06.84	29.11.85	18.05.87
H(V)(Q)/82	28.10.82	19.06.84	22.05.86	09.12.87
M(V)(S)/84	02.11.84	18.06.86	19.11.87	–
C(V)(S)/84	20.11.84	04.06.86	05.11.87	–
L(V)(S)/84	29.11.84	29.05.86	26.11.87	–
H(V)(S)/84	25.10.84	18.11.86	–	–

Data on agronomic ratings and cane quality components as well as yield were obtained for each crop. The trials at Mtunzini and La Mercy were also sampled to assess eldana damage. At CFS, damage caused by eldana was negligible in the years considered, and eldana has not been recorded at the midlands site at Windy Hill.

Sampling for eldana damage

For those crops harvested in 1984, the number of eldana larvae per 100 stalks (e 100^{-1}) was estimated from samples comprising 50 stalks per plot. In 1985 and 1986, both the number of e 100^{-1} stalks and the percent internodes damaged, were estimated from a sample comprising 50 stalks taken at harvest. In 1987 the number of damaged internodes was measured in a sample comprising 20 stalks per plot. An internode was counted as damaged if more than half the internode had red discolouration when the stalk was split longitudinally.

Results and discussion

Association between eldana damage and cane quality

The results for brix % dry matter, estimated recoverable sugar, and purity from the trials at Mtunzini and La Mercy were combined and the averages were taken to represent cane damaged by eldana. Similarly, the results from the trials at CFS and Windy Hill were taken to represent crops not damaged by eldana. The average proportion of internodes damaged by eldana for the respective varieties was calculated from the trials at Mtunzini and La Mercy. Then the cane quality values obtained at Mtunzini/La Mercy and CFS/Windy Hill, respectively, were correlated with the estimated proportion of internodes damaged (from Mtunzini/La Mercy). These figures are presented in Table 2, together with the differences between the cane quality values obtained from damaged and undamaged crops.

Table 2

Correlation coefficients for damaged and undamaged cane, and differences between quality component values

Cane category	'Q' series			'S' series		
	Brix % dm	Ers	Purity	Brix % dm	Ers	Purity
Damaged	0,10	-0,56	-0,59	0,22	-0,63	-0,63
Undamaged	0,76	0,00	0,14	0,57	0,26	0,20
Difference	0,80	0,66	0,72	0,59	0,80	0,70

Correlation coefficient (r)

Nuss *et al.*[7] presented data to show that the degree of susceptibility of a variety to eldana was correlated to various components of cane quality in the undamaged cane and, in particular, to brix % dry matter which was the most strongly correlated component. The results obtained from the analyses confirm the relatively strong correlation between eldana damage and the brix % dry matter. However, in these data there is no correlation between internode damage and estimated recoverable sugar or juice purity in the undamaged cane. This suggests that varieties with high sucrose contents are not necessarily eldana-susceptible and that high juice purity does not necessarily predispose the cane to attack.

Loss of estimated recoverable sucrose

Eldana damage may result in yield losses and lower sucrose contents. Poorly grown cane has been observed to have a higher incidence of eldana than well-grown cane. Estimates from these data of yield losses due to eldana, are likely to be biased, since low yields may be due to the poor growth of cane in the plot or due to eldana damage. However, the effect of poor growth on sucrose content is usually less marked than it is on cane yield. In fact, poorly grown cane often has a higher sucrose content than well-grown cane.

Results from two separate trials (Bond, unpublished report), where stalk samples were divided into damaged (reddened internodes) and undamaged portions and analysed separately, showed that the sucrose content of the damaged cane is very low. These results are shown in Table 3.

Table 3

Results of analyses of damaged and undamaged cane

Trial and date	Cane category	dm % cane	Brix % cane	Brix % dm	Juice purity (%)	Ers % cane
1 June 1985	Undamaged Damaged	30,3 25,5	15,1 7,9	49,8 32,3	93,9 72,9	12,9 3,6
2 June 1987	Undamaged Damaged	27,8 24,1	13,8 6,4	49,7 26,4	87,9 64,0	10,5 2,0

Murdoch (unpublished data) has subsequently collated data from many trials and concludes that estimates of losses in cane yield are very difficult to obtain without bias, and that the major losses in total sucrose yield seem to be reflected most clearly in a reduced sucrose content. It was decided that in view of these findings, only the components of cane quality would be considered in this study.

Variety differences in number of internodes bored

The results recorded from all the crops in the Mtunzini and La Mercy trials were used to obtain an average for percent internodes damaged in each variety of the 'Q' and 'S' series respectively. For each series these data were arranged from the lowest to the highest percent damaged internodes and plotted on separate bar graphs. The original selection site for each variety is shown at the base of the appropriate bar (Figure 1).

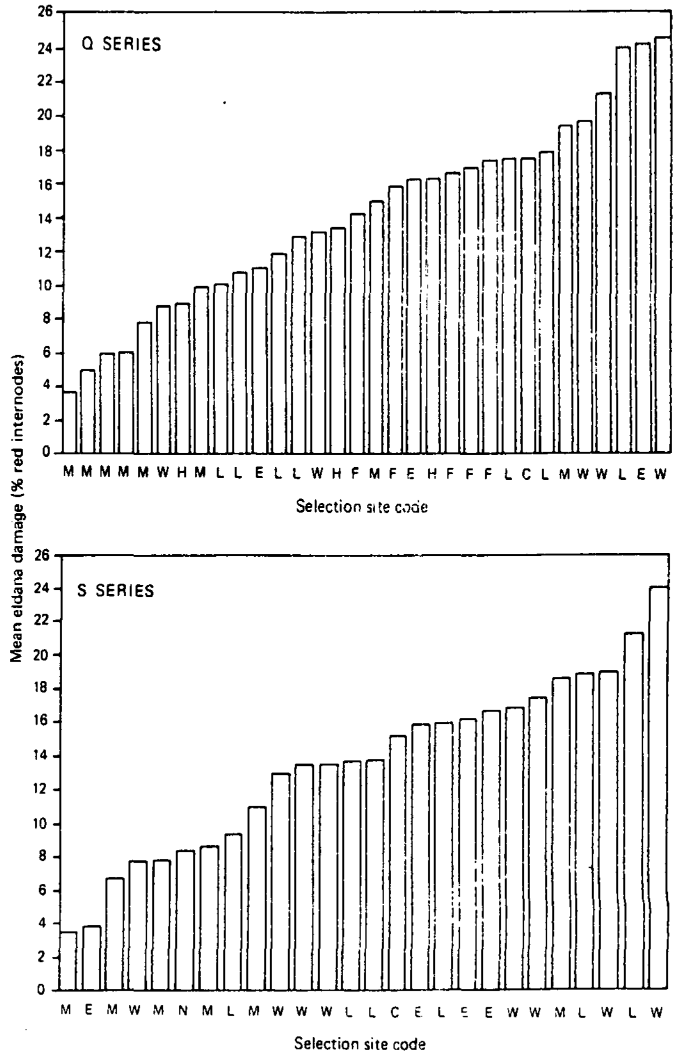

FIGURE 1 Bar graph showing eldana damage according to variety origin.

This shows that the Mtunzini-derived varieties are generally superior in respect of relative resistance to damage. In the 'Q' series there are two Mtunzini-derived varieties that appear to be anomalous, namely 76M205 and 76M226. However, the selection records show that in 1982, when these varieties were planted into the 'Q' series trials, the apparent susceptibility of these two varieties to eldana was noted, but they were promoted in spite of this limitation.

The 'S' series is perhaps the most encouraging to date. Of the 10 most resistant varieties, 5 were from the Mtunzini programme. Variety N12, code N, is also in this group. The resistant variety, code E, is the clone 71E280. This variety is currently being tested at an advanced stage, with a view to possible bulking-up in 1988. The occurrence of a resistant variety amongst those from a site that did not have a high incidence of eldana, illustrates the necessity to test all varieties for their susceptibility to eldana and not only those varieties that have been selected in the Mtunzini programme. However, it is apparent that the frequency of resistant varieties will be higher in the Mtunzini-derived material.

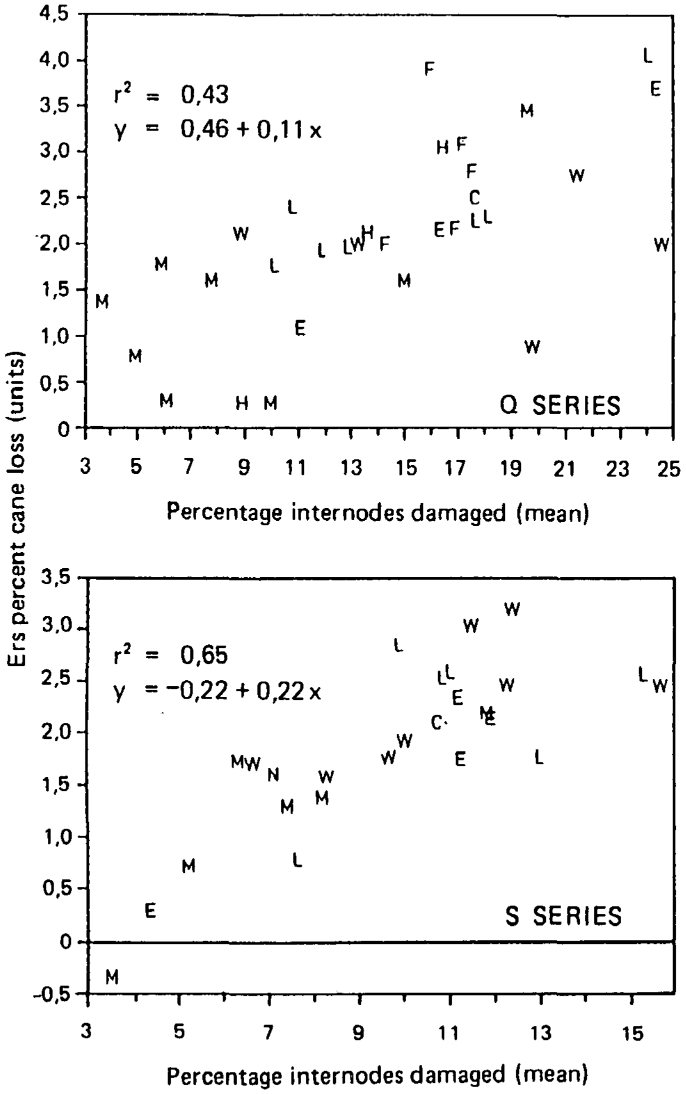

FIGURE 2 Loss of estimated recoverable sugar plotted against eldana damage, using site code as plotting point.

Effect of eldana on sucrose content

The results from 'Q' and 'S' series trials were used to determine the estimated recoverable sugar content of damaged and undamaged cane, according to the method described. These differences were plotted against the mean value for the percent internode damage, and the selection code for the original selection site used for the plotting point. This was done for the 'Q' and 'S' series separately and these graphs are shown in Figure 2.

The graphs show that the Mtunzini selections, denoted by code M show a lower percent internode damage and smaller losses of estimated recoverable sugar than the selections from the other selection sites. Selections from Pongola, code F, on the other hand show a high percent internodes damaged, and rather large losses of estimated recoverable sugar.

The regression equations calculated for these data are shown in Figure 2. These indicate that, for the two trials under consideration, there were 0,11 and 0,22 units of sucrose lost for every 1% of the internodes bored. Murdoch (unpublished data), using data from 20 plant breeding trials, has plotted the relationship between number of e 100^{-1} stalks and the percent internodes bored. Although there is considerable variation in this relationship, 1% internodes bored approximates to 2 e 100^{-1} stalks.

Selection for eldana resistance

The results reviewed refer to Mtunzini varieties in the 75M, 76M, and 78M series. This means that the first selection stage, the single stools, were planted in the years 1973, 1974, and 1975 respectively, the single line stage following 2 years later in each case. The early stages in the selection process of these varieties were either free from eldana or the pest was only present at a very low level. Improvement in the eldana resistance of these varieties can be ascribed to the later selection stages, which were planted when the outbreak was already serious. It is therefore of interest to predict whether future series emanating from Mtunzini are likely to show even better resistance and whether any undesirable characteristics are likely to be prevalent.

Degree of genetic determination

The degree of genetic determination (g^2) measures the extent to which characteristics are influenced by heredity and environment (Skinner[9]), and can be derived from the analyses of variance of replicated trials.

$$g^2 = \frac{Vg}{Vp} = \frac{Vg}{Vg + Ve}$$

where Vg = total genetic variance

Ve = environmental variance

Vp = phenotypic variance = Vg + Ve

The degree of genetic determination was calculated for cane yield, sucrose content, sucrose yield, and the percent internode damage by eldana from the analyses of variance of the variety trials in this study. In addition, estimates were also made from 3 observation trials, each containing approximately 150 different varieties, where sampling for eldana damage had been carried out. Observation trials in the Mount Edgecombe programme consist of 2 replications of each variety, each plot consisting of 2 cane rows, 8 m in length. The determinations for these trials are shown in Table 4.

Table 4

Estimates of the degree of genetic determination from replicated trials

Trial	Crop	tc	Ers	t ers	Eldana damage (%)	Av no eldana in trial
C(V)(Q)/82	P	0,80	0,86	0,70	0,70	1,0
	1R	0,60	0,60	0,56	0,40	2,0
	2R	0,70	0,74	0,69	0,89	4,1
M(V)(Q)/82	P	0,68	0,66	0,70	0,80	4,9
	1R	0,73	0,86	0,77	0,50	1,6
	2R	0,61	0,90	0,84	0,75	4,8
M(V)(S)/84	P/PHS*				0,71	3,7
	P	0,47	0,66	0,55	0,87	4,9
	1R	0,69	0,41	0,67	0,58	2,9
C(V)(S)/84	P	0,33	0,52	0,50	0,86	1,8
	1R	0,61	0,75	0,64	—	—
Average		0,62	0,70	0,66	0,70	—
M(O)80/82	Plot 1	0,47	0,47	0,47	0,29	3,1
	Plot 2	0,60	0,64	0,60	0,29	2,2
M(O)81/83		0,29	0,41	0,29	0,69	2,6
M(O)82/84		0,37	0,71	0,47	0,70	3,9
Average		0,45	0,51	0,45	0,42	—
		tc	Brix % dm	Mass brix	Single stool value	
Single stools**		0,42	0,48	0,42	0,46†	

Note: Variety trials (V) have 3 replications, each plot consisting 5 rows x 8 m length.
Observation trials (O) have 2 replications, each plot consisting 2 rows × 8 m length.
* PHS = pre-harvest sample
** = degree of genetic determination asessed from successive selection stages
† = probable value for single stools (see text)

The degree of genetic determination may also be determined from regression or correlation measurements of characteristics of the same varieties in successive stages of selection. This estimate of degree of genetic determination includes environmental variations in two different seasons as well as the season by variety interaction, and is usually a smaller, but more realistic figure to use in evaluating selection concepts. Estimates of the degree of genetic determination, using this method, have been made from several trials for cane yield and brix content (Anon[1]). However, due to the destructive sampling methods required to establish the amount of eldana damage and the limited amount of seedcane available at the early stages of selection, values for the degree of genetic determination for eldana damage could not be established by this method. However, an indication of the probable value may be obtained from a comparison with cane yield and quality values.

The response to selection may be determined from the formula (Simmonds;[8] Skinner[10]): $\Delta G = i\,g^2\sigma$, where g^2 is the degree of genetic determination, σ is the phenotypic variation of the varieties being selected, and i is the 'intensity of selection'; i is a statistical term and depends on the proportion of the population promoted to the next selection stage. Values of i may be determined from the empirical formula (Simmonds[8]): $i = 1{,}13 + 0{,}73 \log \frac{1}{k}$, where k is the fraction of the total population that is advanced to the next stage. Alternatively, values of i may be obtained from tables (Falconer[5]). The phenotypic variation has been calculated for the trials in this study for % internodes damaged, as well as for cane yield and sucrose content. These are compared in Table 5.

Table 5

Genotypic and phenotypic parameters obtained from replicted trials

Trial	Crop	% internodes bored			Yield (t ha⁻¹)			Suc (ers)		
		Mean	Sp*	Sg**	Mean	Sp	Sg	Mean	Sp	Sg
M(V)(Q)/82	P	48,5	45,4	40,9	142,7	12,5	10,4	9,6	13,5	10,9
M(V)(Q)/82	1R	8,0	45,9	31,1	117,1	14,7	12,6	12,0	13,5	12,5
M(V)(Q)/82	2R	19,1	38,3	33,3	88,1	15,8	12,9	6,3	25,1	23,8
C(V)(Q)/82	P	9,8	61,6	52,9	161,7	12,5	10,6	10,0	11,3	10,2
C(V)(Q)/82	1R	12,9	61,5	34,6	96,4	16,0	11,6	13,4	7,5	5,9
C(V)(Q)/82	2R	16,6	48,1	45,3	133,3	18,0	14,6	9,3	10,8	9,3
L(V)(Q)/82	P	—	—	—	183,0	10,3	8,3	11,6	9,1	7,8
L(V)(Q)/82	1R	—	—	—	73,5	35,9	33,6	12,9	7,7	6,1
L(V)(Q)/82	2R	—	—	—	110,2	29,1	24,0	9,4	13,5	11,9
H(V)(Q)/82	P	—	—	—	178,1	13,7	12,4	10,2	15,8	14,3
H(V)(Q)/82	1R	—	—	—	154,4	13,3	10,9	12,0	7,3	5,6
H(V)(Q)/82	2R	—	—	—	105,2	16,9	15,1	11,4	8,8	7,3
M(O)80/82		12,6	28,9	15,7	124,6	22,1	17,5	10,5	11,9	9,3
M(O)81/83		12,2	50,9	42,3	104,8	22,1	11,8	8,9	19,1	12,8
M(O)82/84		17,7	42,6	35,6	76,7	28,1	17,5	9,6	16,1	13,6
Average		14,2	40,8	31,2	123,3	18,7	14,9	10,5	12,7	10,7
					kg			Brix		
Single stools					25,0	40,1	22,7	17,8	7,0	5,4

* Sp = phenotypic variation expressed as % of mean
** Sg = genotypic variation expressed as % of mean

Estimates of phenotypic variation (expressed as % of mean) in single stools have been obtained for cane yield and brix content from several selection trials of the type reported by Bond,[3] and these are also shown at the bottom of Table 5. No experiments have been done to establish phenotypic variance for eldana damage in single stools, but an indication of the probable magnitude can be obtained by comparison with the yield and sucrose figures in Table 5. From the above formula and the parameters established for the variety trials, percent gains from selection have been calculated. These are shown in Table 6 for a range of selection rates, in comparison with responses that have been determined for cane yield and sucrose content.

Table 6

Predicted response to selection (% gain on trial mean)

Selection rate (%)	Cane component selected		
	Cane yield (%)	Sucrose content (%)	Internodes bored (%)
5	15,00 (31,9)	11,58	29,63
10	13,42 (25,6)	10,36	26,51
15	12,24 (26,0)	9,45	24,17
20	11,05 (23,5)	8,53	21,83
30	9,32 (19,8)	7,19	18,40

The estimates of phenotypic variation for yield obtained from variety trials are considerably lower than those obtained for the single stool stage. Clones entering the later selection stages are selected primarily for yield and this may be a reflection of the reduced variability of these clones. However, in the case of eldana damage, it must be remembered that the selections for the variety trials have been derived from sites both with and without eldana, and the variability in this characteristic is probably little changed from original single stools. A more realistic prediction of selection response for cane yield and sucrose content would be obtained by using the variability figures established for single stools. These figures are shown in brackets in Table 6.

Conclusions

Soon after the initial outbreak of eldana at Mtunzini, evidence from replicated trials indicated that there were inherent differences between varieties in their susceptibility to eldana attack. It was also apparent that the presence of eldana could markedly reduce the sucrose yields of affected varieties. Correlations between sucrose yields and percent internodes damaged by eldana were relatively strong and the calculated correlation coefficients ranged from -0,50 to -0,65. This means that by selecting clones with high yields of sucrose, some progress towards resistance to eldana damage would automatically be achieved. More resistant varieties would result if the selection at early stages were to be based solely on eldana resistance, but the selections would be lower yielding than those selected with sucrose yield as the main criterion.

These results contradict earlier findings that eldana-resistant varieties will have lower cane quality than varieties that have not been selected with resistance to eldana as a criterion. Further investigations are required to clarify this aspect as there may be important consequences to the selection programme.

The clones being tested in the 'Q' and 'S' series secondary variety trials were single stools and single lines before the eldana outbreak developed to a serious level at the Mtunzini farm. It may therefore be expected that future series obtained from the Mtunzini programme will have greater numbers of resistant varieties and varieties with higher levels of resistance than previously obtained. Selection amongst late stage material to date has identified varieties with improved resistance, such as N20, from the CFS programme. However, in N20, eldana resistance is combined with undesirable quality characteristics and barely satisfactory disease resistance. Variety 71E280 appears to be another eldana-resistant variety that is better than N20 in both sucrose content and disease resistance. Subject to further trial results, 71E280 may be sent out for large-scale propagation in 1989.

Analysis of these trial results has revealed that the degree of genetic determination measured in variety trials is relatively high and this encourages the screening of clones at as early a stage as possible in the programme. Selection against eldana is already being practised in the single lines through inspection and sampling. It appears that investigations into sampling for eldana damage at the single stool stages would be justified. The number of clones tested at the single stool stage each year is very high and any sampling technique used at this stage should be simple and quick. Due to the small amounts of seedcane available from single stools, samples would need to be very small and it is necessary to determine whether such small samples could provide useful information.

REFERENCES

1. Anon (1979). Ann Rpt S Afr Sug Ass Exp Stn, p 64.
2. Bond, RS (1982). Maturing differences between varieties in the selection programme. *Proc S Afr Sug Technol Ass* 56: 136–139.
3. Bond, RS (1973). Some observations on the selection of single stools at Mount Edgecombe. *Proc S Afr Sug Technol Ass* 47: 201–208.
4. Brett, PCG (1954). The first ten years of sugarcane breeding in Natal. *Proc S Afr Sug Technol Ass* 28: 141–145.
5. Falconer, DS (1960). *Introduction to quantitative genetics.* Longmans, New York.
6. Nuss, KJ (1977). Synchronization of flowering to implement a proven cross breeding system in sugarcane. *Proc int Soc Sug Cane Technol* 16: 111–119.
7. Nuss, KJ, Bond, RS and Atkinson, PR (1986). Susceptibility of sugarcane to the borer *Eldana saccharina* Walker and selection for resistance. *Proc S Afr Sug Technol Ass* 60: 153–155.
8. Simmonds, NW (1979). *Principles of crop improvement.* Longmans, New York.
9. Skinner, JC (1966). ISSCT Sugarcane Breeders Newsletter XVI: 2–9.
10. Skinner JC (1971). Selection in sugarcane: A review *Proc int Soc Sug Cane Technol* 13: 159–162.

APPENDIX I

'Q' series	'S' series
75M25	78M786
75M6M49	78M1073
75M205	78M1080
75M467	78M1522
76M547	78M1632
76M1101	78L109
76M1566	78L651
76L309	78L960
76L496	78L1181
76L1242	78L2091
76L1291	78L3014
72L959	77E46
73L932	77E809
73L1362	77E1359
75E247	71E280
74E1246	77W128
75E1293	77W635
75W312	77W746
75W703	77W906
75W781	77W1241
75W1422	72W1249
75W1719	72W1273
75F2515	72W1585
75F2674	
75F2753	
75F2795	
75F2825	
74H29	
75H2	
75H131	

Note: Variety identification, eg 75M25
75 = year selected to single line stage
M = selection site code
25 = variety identification number