

OBSERVATIONS ON FAMILY SELECTION IN THE MOUNT EDGECOMBE SUGARCANE BREEDING PROGRAMME

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Abstract

Four hundred sugarcane crosses were grown in a series of replicated yield (cross assessment) trials in which plots were planted with randomly selected progeny of a cross. They were planted as spaced seedlings 0,5 m apart. The selection history of over 150 000 seedlings derived from these crosses or from crosses with identical parentage, was compared with the mean yields of the cross progeny determined from these trials.

There was a greater proportion of clones promoted to the late selection trials from cross combinations with a high yield in the cross assessment trials, than from those with a low mean yield. In several instances the cross assessment trials failed to identify crosses containing clones which reached the late stages of selection. Poor prediction did not appear to be associated with variability in the cross assessment trials.

In a separate trial, nineteen crosses were evaluated in a cross assessment trial and 8000 single stools were planted from them. These single stools were subjected to the routine selection procedures and eventually five clones were promoted to the 5th selection stage (secondary variety trial). All five of these were from the top 50% of the crosses as assessed in the cross assessment trial.

Introduction

In a sugarcane selection programme, promising clones are normally selected on their individual value. With family selection, however, whole families are selected or rejected as units according to the mean phenotypic value of the family (Falconer³). Environmental effects are usually large in original seedling populations of sugarcane, and in such circumstances both individual and family selection are appropriate strategies (Skinner *et al*⁵). In sugarcane, determination of the mean value for yield, with an estimate of variance, would be a time consuming and costly procedure, involving the weighing of many thousands of individual stools. In view of this, Skinner *et al*⁵ considered that a selection programme, with family selection based on selection rates instead of mean values was likely to be the most efficient strategy. They emphasized that a family is valuable only if it includes superior individuals.

At Mount Edgewcombe interest in using a modified form of family selection began in 1975. Considering the time required to measure the yield of individual seedlings, an investigation was begun to determine whether the mean yield of a family, estimated from replicated plots of spaced original seedlings, would give an indication of the potential occurrence of superior individuals in that family (Cross assessment trial). A trial carried out with 19 families gave positive correlation ($r = 0,69$) between the number of seedlings selected from a cross at the single stool stage and the mean value of mass recoverable sugar for the family (Bond²). During the period 1975 to 1977 many crosses were evaluated in cross assessment trials. In this paper, the results in these trials are compared to the actual performance of these families in the routine selection programme.

Experimental Procedures

Cross Assessment Trials

In the cross assessment trials each family was represented by 64 original seedlings. These were planted into a trial with two replicates, each replicate consisting of two 8 metre rows, each containing 16 seedlings spaced at 0,5 m. Control plots of NCo376 were planted using plants grown in pots from single budded setts. Immediately before harvest, a 16 stalk sample for sucrose determination was taken from each plot. This was done by collecting one stalk from every alternate stool in each of the two rows. The cane was then cut, topped and the cane from all stools within a plot combined for weighing. The mass of cane per hectare, estimated recoverable sugar percent cane and the mass of recoverable sugar per hectare were calculated for each family. This was expressed as a percentage of the results for the control variety, NCo376.

Analyses of variance were carried out for each trial and an estimate of the degree of genetic determination (DGD) was obtained from the F ratio, according to a method devised by Murdoch.⁴

$$DGD = \frac{F - 1}{F}$$

Cross assessment trials were carried out at various selection sites, and assessments of some families were done at more than one site. After the requirements of the cross assessment trials had been met, any surplus seedlings were planted into one of the regional selection programmes as single stools.

Over a period of three years, some 152 716 seedlings from families that had been evaluated in cross assessment trials were planted into the routine selection programme. For each family, the number of seedlings, at each selection stage, was recorded. The crosses were ranked in terms of mass of recoverable sucrose, as determined by the cross assessment trials. In addition they were classified according to the site where the single stools were planted. Comparisons were then made between the rates of selection for the top ranked crosses and those for the bottom ranked crosses.

Trial Series B

First trial

In 1976 at the Experiment Station, 19 crosses were evaluated in a trial in three replicates. From each of these crosses, 400 seedlings (making a total of nearly 8 000) were planted into the single stool selection stage at the Experiment Station. To avoid possible bias due to soil variation, the seedlings were planted in two replications of 200 single stools each. The subsequent selection of these single stools were done in accordance with normal practice. The numbers of seedlings promoted at each stage were recorded. The crosses were again grouped according to their ranking in the original cross assessment trial and the rates of selection of the top ranked families were compared with the bottom ranked families.

Second trial

Progeny from the two best and the two worst crosses, according to the cross assessment trial, were chosen for a further trial. Thirty randomly chosen seedlings from each of the crosses, were planted as single stools, making a total of 120 seedlings in the trial. At the time of selection these stools were weighed individually and all the seedlings were advanced to the second (single line) stage. At harvest each single line was sampled for sucrose content and weighed.

Results

Cross assessment trials

The planting and harvesting of the cross assessment trials proved to be no more time consuming than that of conventional replicated plot trials. The trials indicated that there were significant differences between the mean yields of the crosses, and generally cross yields averaged about 65% of the NCo376 control plot. Because of variation in site uniformity, there were differences between trials in the precision with which these differences were determined. The F ratio, coefficient of variation, standard error, and degree of genetic determination for these trials are shown in Table 1.

The numbers of families evaluated in cross assessment trials and the numbers of seedlings selected from these crosses are shown in Table 2. The ratio between the number of seedlings at stage 1 (single stools) and the number at stage 3 (observation trial) is also given in the table.

Over the three year period 400 crosses were evaluated and 152 716 seedlings from these crosses entered the selection programme at one or more of the plant breeding selection sites. In spite of the relatively large number of seedlings in this study, the number of individuals retained until the secondary variety trial stage was only 48 and no commercial varieties were released from this group.

1975 Results

Where a cross was evaluated in more than one cross assessment trial, the results were averaged. The results were expressed as a percentage of the NCo376 control, and those families with an average sucrose yield above 65% of the control were grouped together, those below 65% forming the second group. This grouping was arbitrary and the figure of 65% was chosen to obtain a similar number of single stools in each group. In this case there were approximately 22 000 seedlings per group. Table 3 shows the numbers of seedlings and selection rates at each stage for the two groups.

Table 2

The number of crosses and the distribution of seedlings in the selection programme. (Percentages in brackets)

Year	Number crosses	Number of seedlings at:					
		S. Stools	S. Lines	Obs Tr	VT1	VT2	OP/SS
1975	130	44 637	3 913 (8,8)	391 (10,0)	61 (15,6)	13 (21,3)	0,00876
1976	116	45 387	3 385 (7,5)	336 (9,9)	71 (21,1)	15 (21,1)	0,00740
1977	154	62 692	4 944 (7,9)	459 (9,3)	85 (24,7)	20 (24,7)	0,00730
Total	400	152 716	12 242	1 185	217	48	-

Table 3

1975 TRIAL. Comparison between families yielding more than and less than 65% of control in Cross Assessment Trial

Mean sucrose yield in C.A. trial	Number of seedlings at:					
	S. Stools	S. Lines	Obs Tr	VT1	VT2	OP/SS
> 65%	22 007	1 944 (8,8)	208 (10,7)	36 (17,3)	7 (19,4)	0,00945
< 65%	22 630	1 969 (8,7)	183 (9,3)	25 (13,6)	5 (20,0)	0,00808

Differences in selection rate between the top and bottom ranked crosses was small. Seven seedlings were recovered at the secondary variety trial stage from the top group, compared with five from the bottom group of crosses, but seedling numbers at the earlier selection stages were similar for both groups. The ratio between observation trial numbers and single stool numbers was 0,0083 and 0,0082 respectively.

There were differences in experimental precision in the cross assessment trials (Table 1). To ascertain whether lack of precision in the cross assessment trials was responsible for the relatively small differences in the subsequent selection programme, between the best and the worst crosses in this series, the data were re-examined using only the results from the trial at Pongola. The Pongola trial appeared to be the least affected by soil variability, judging from the F ratio, coefficient of variation, and the degree of genetic determination. However, although this series contained over 12 000 single stools, there was little difference between the top and bottom groups of crosses, as determined by the ratio between observation trial and single stool numbers.

1976 Results

In the 1976 series of cross assessment trials there were 116 crosses, from which 45 387 seedlings were planted into

Table 1
Summary of statistics of cross assessment trials

Year	Component	Experiment Station				CFS				Shakaskraal				Pongola							
		Treat F	C.V. %	Mean	SE	DGD	Treat F	C.V. %	Mean	SE	DGD	Treat F	C.V. %	Mean	SE	DGD	Treat F	C.V. %	Mean	SE	DGD
1975	t cane/ha	1,38	19,6	55,4	7,7	0,28	1,98	26,9	82,2	15,6	0,49	3,21	13,2	77,2	7,2	0,69	2,80	12,4	142	12,5	0,64
	ers % cane	4,31	4,4	12,9	0,4	0,77	2,04	6,1	12,6	0,5	0,51	3,51	6,6	10,4	0,5	0,72	2,51	10,3	12,0	0,9	0,60
	ters/ha	1,28	20,6	7,1	1,0	0,22	1,98	27,2	10,3	2,0	0,49	3,50	15,2	8,1	1,0	0,71	3,29	14,8	17,1	1,8	0,70
1976	t cane/ha	1,25	22,9	84,6	13,7	0,20					4,81	10,0	65,8	4,6	0,79	8,36	9,6	100	6,8	0,88	
	ers % cane	1,15	13,3	9,0	0,8	0,13					4,17	6,3	12,1	0,5	0,76	1,10	11,6	12,1	1,0	0,09	
	ters/ha	2,25	22,2	7,6	1,2	0,56					4,70	12,0	8,0	0,7	0,79	2,77	17,4	12,2	1,5	0,64	
1977	t cane/ha	2,40	10,2	103	7,2	0,58	4,00	11,2	100	7,9	0,75					5,50	9,5	132	8,8	0,82	
	ers % cane	2,10	8,8	12,4	0,8	0,52	3,80	6,4	11,0	0,5	0,74				1,70	8,71	11,5	0,7	0,41		
	ters/ha	3,10	11,1	12,8	1,0	0,68	4,00	13,1	11,0	1,0	0,75				6,90	10,2	15,2	1,1	0,86		

selection programmes at three sites: Experiment Station, Shakaskraal and Pongola. The results for the three sites were averaged and the crosses were divided into approximately equal groups by taking those above and below 69% of the mass recoverable sucrose of the standard variety. The results are shown in Table 4.

Selection rates during the early stages of selection were lower in the bottom group of crosses. The ratio between the number of selections in observation trials and the initial number of single stools was 0,00868 in the best crosses and 0,00577 in the poorer group. In the top group, 11 varieties were retained until the secondary variety trial stage, and only 4 in the other group.

Table 4

1976 TRIAL. Comparison between families yielding more than and less than 71% of control in Cross Assessment Trial

Mean sucrose yield in C.A. trial	Number of seedlings at:					
	S. Stools	S. Lines	Obs Tr	VT1	VT2	OP/SS
> 71%	21 856	2 003 (9,2)	208 (10,4)	47 (22,6)	9 (19,2)	0,00952
< 71%	23 531	1 382 (5,8)	128 (9,3)	24 (18,7)	6 (25)	0,00544

Association of Cross Assessment Results with single lines

Twenty-four of the crosses that were evaluated in the cross assessment trial at Pongola in 1976, were planted into the Pongola selection programme. At stage 2 (single lines), all lines were routinely sampled for sucrose content and the harvested cane was weighed. Mean values for cane yield, sucrose content and sucrose yield at Stage 2 were calculated for each cross, and these were compared with the results obtained in the cross assessment trials. There was a positive correlation between the cross mean values obtained in the cross assessment trial and those from the single lines. As expected, the sucrose content was more highly correlated than cane yield; $r = 0,55$ and $r = 0,34$ respectively.

1977 Results

In the 1977 series of trials there were 154 crosses, and 60 132 seedlings from these crosses were planted into the selection programme. Cross assessment trials were carried out at the Experiment Station, Central Field Station and Pongola. As with the 1976 series of trials there was a tendency for the selection rates to be higher in the group of crosses performing better in cross assessment trials, the observation trial to single stool ratio being 0,0080 and 0,0061 for the top and bottom groupings, respectively. The percentages of single stools selected for planting into single lines were 8,2% and 7,3% for the top and bottom groups, and from single lines into observation trials they were 9,7% and 8,4% respectively.

Table 5

1977 TRIAL. Comparison between families yielding more than and less than 66% of control in Cross Assessment Trial

Mean sucrose yield in C.A. trial	Number of seedlings at:					
	S. Stools	S. Lines	Obs Tr	VT1	VT2	OP/SS
> 66%	32 307	2 657 (8,2)	257 (9,7)	44 (17,1)	9 (20,5)	0,00800
< 66%	27 002	1 979 (7,3)	166 (8,4)	26 (15,7)	6 (23,1)	0,00610

There was a total of 15 seedlings that remained in the selection programme until the secondary variety trial stage; 9 of these were from the top group of crosses and 6 from the bottom group. Of these six varieties, two belonged to a different series of single stools and were not directly comparable. Three were selections at the Pongola site which were among the lowest yielding selections in the 78F series of secondary varieties. One variety had been selected on mid-land site because of its mosaic resistance rather than its yielding ability (90% of the standard). There were no selections to secondary variety trial from crosses that had yielded below 60% of the standard in cross assessment trials.

Table 6

Ranking in Cross Assessment Trial and subsequent selection details of the Series B trials

Rank	Parent 1	Parent 2	Cross assessment trial			Single lines			Selection Programme Details						
			Yield t/cane	Suc cont ers % cane	Suc yield t/ers/ha	Numbers			Numbers			Percentage			
						Rep 1	Rep 2	Mean	Obs Tr	VT1	VT2	SL	OP	VT1	VT2
1	NCo339	N7	87	11,8	10,3	18	19	37	6	3	0	9,2	16,2	50,00	0,0
2	NCo376	N55/805	85	12,1	10,3	10	17	27	8	2	1	6,8	29,6	25,0	50,0
3	NCo376	N8	80	12,8	10,2	15	21	36	2	2	1	9,0	5,6	100,0	50,0
4	N66-328	N52/214	78	11,3	8,8	12	11	23	4	0	0	5,8	17,4	0,0	0,0
5	NCo310	69E1493	71	12,4	8,8	12	10	22	4	0	0	5,5	18,2	0,0	0,0
6	NCo339	Co301	84	10,4	8,7	12	8	20	1	0	0	5,0	5,0	0,0	0,0
7	NCo376	CB40-35	79	10,9	8,6	12	8	20	3	1	1	5,0	15,0	33,3	100,0
8	NCo292	Co301	72	11,7	8,4	13	14	27	7	1	1	6,8	25,9	14,3	100,0
9	CB40-35	N7	77	10,7	8,2	12	23	35	5	2	1	8,8	14,3	40,0	50,0
Average			79,2	11,6	9,2	2,9	14,6	27,4	4,4	1,2	0,6	6,9	16,4	29,2	58,3
10	NCo293	CB40-35	74	10,9	8,1	9	11	20	4	0	0	5,0	20,0	0,0	0,0
11	NCo293	CB40-35	74	10,9	8,1	9	11	20	4	0	0	5,0	20,0	0,0	0,0
12	NCo293	Co331	74	10,8	8,0	2	4	6	0	0	0	1,5	0,0	0,0	0,0
13	PR1000	N7	73	11	8,0	10	13	23	0	0	0	5,8	0,0	0,0	0,0
14	CP41-106	N8	69	11,4	7,9	12	9	21	3	0	0	5,3	14,3	0,0	0,0
15	57NG155	Co285	74	10,6	7,8	14	9	23	0	0	0	5,8	0,0	0,0	0,0
16	Co421	Co312	69	11,1	7,7	7	5	12	1	0	0	3,0	8,3	0,0	0,0
17	POJ2725	Co285	68	11	7,5	13	8	21	5	2	0	5,3	23,8	40,0	0,0
18	N51-539	CP44-101	60	12,1	7,3	10	8	18	1	0	0	4,5	5,6	0,0	0,0
19	J59-5	Co421	69	9,9	6,8	5	9	14	1	0	0	3,5	7,1	0,0	0,0
	Co462	CP44-101	52	11	5,7	4	7	11	0	0	0	2,8	0,0	0,0	0,0
Average			68,2	11,0	7,5	8,6	8,3	16,9	1,5	0,2	0,0	4,2	7,9	40,0	0,0

Results of Series B trials

First trial

The results of the cross assessment trial together with the numbers of seedlings selected in the subsequent selection programme are shown in Table 6.

Five varieties from the original 8 000 seedlings reached the secondary variety trial stage, and all these were from crosses that had been placed in the top half of crosses in the cross assessment trial. The rate of selection from stage to stage was noticeably greater in the higher ranked crosses than in the lower ranked crosses.

Second trial

Cane yield in the single stools was positively correlated with cane yield of the same clones in single lines; the value of $r(0,33)$ was consistent with previous estimates of this association obtained from the South African programme (Anon¹). The relationship between yield in the single stools and in the single lines is plotted in Fig 1.

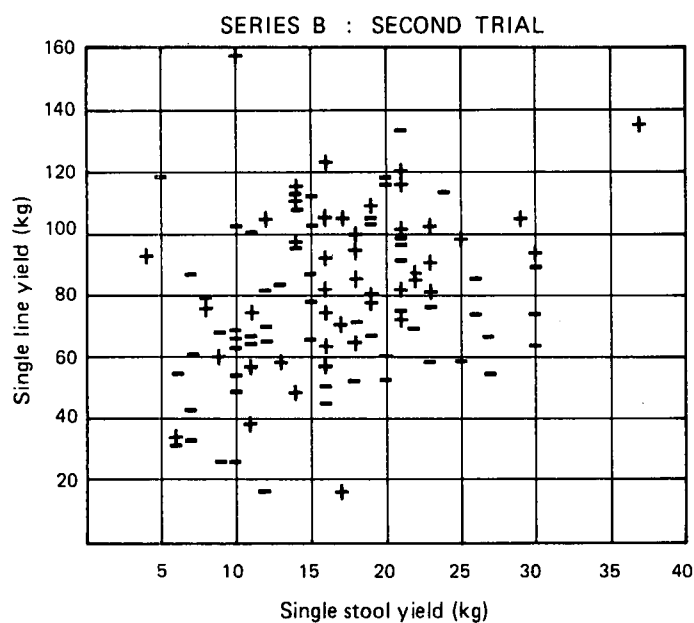


FIGURE 1 A comparison between cane yield measured at the single stool stage compared with cane yield measured at the single line stage.

The “+” points represent the two best crosses as assessed in the cross assessment trial, while the “-” points indicate the two worst crosses. There were 12 stools (10%) that had a yield of 25 kg or better, but only one of these was in the top 10% in the single line trial (> 115 kg). However, 8 out of the 12 top single lines were from the two best crosses. It may be seen from the graph that these crosses tended to have comparatively poor yields at the single stool stage, perhaps because they happened to be situated in a poor part of the field.

Discussion

It is difficult to define a satisfactory criterion by which the worth of the families can be judged. No variety was released

from among the 150 000 seedlings that were examined in this study. Thus the ultimate test of a good family, namely that it contains seedlings of a commercial standard, has not been met. The numbers of clones reaching the variety trial stage were relatively small. A difference of two or three individuals at this stage could have a marked effect on the interpretation of the results. The numbers of clones reaching the variety trial stage were relatively small. A difference of two or three individuals at this stage could have a marked effect on the interpretation of the results. The numbers of seedlings selected from single stools to single lines is large, but selection at this stage is based on a visual assessment and may be inaccurate. The ratio between the numbers of seedlings at observation trial stage and single stool stage could be the best assessment. The number of individuals at the observation trial stage is relatively high, and selection to this stage is based on measured yields at the single line stage.

Taking this ratio as a criterion, those families that were more highly ranked in the cross assessment trials, tended in general to show a larger ratio of numbers of clones at the observation trial stage to numbers of single stools, and therefore relatively more seedlings in the later selection stages. However, there was wide variation amongst trials. There appeared to be little difference in subsequent performance between high and low yielding crosses in the 1975 series of trials. In later series, and in the series B trials differences in cross yield appeared to be more meaningful. In all cases, however, late stage selections occurred in low ranked families, although there was some indication in the data to suggest that these were inferior, on average, to equivalent selections from the more highly ranked families.

With the system under which seedlings are raised for transplanting to the field at Mount Edgecombe, Thomas⁶ has demonstrated that single stools can be established in the field using the pencil-thin stalks produced from untrimmed, potted seedlings. Thomas⁷ has also shown that there is a positive correlation between the mass of individual seedlings in pots and the subsequent yield in field trials. It is therefore likely that the mass of these stalks, harvested and bulked together as families, would indicate the cross mean value for yield. Family selection might be carried out at the time that the seedlings are planted from the pots to the field; those families with a mean mass below a certain value would not be planted. This method of planting would prove easy in practice, and the only additional operation would be the weighing of the planting material, amounting to about 0,5 ton per 25 000 seedlings. Further trials are planned to examine the implications of such a system.

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