

**BUREAU OF SUGAR EXPERIMENT STATIONS
QUEENSLAND, AUSTRALIA**

**FINAL REPORT – SRDC PROJECT
BS96S - OPTIMISATION OF THE INITIAL STAGES
OF THE NEW SOUTH WALES SELECTION PROGRAM**

by

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SUMMARY

The main aim of this project was to obtain the basic information required to implement an efficient and effective breeding and selection program in NSW. However, the project suffered major difficulties that affected the delivery of the proposed objectives. In spite of this, useful information that will have impact on the NSW selection program was obtained from the available data. In areas where two-year crops predominate, selection from Stage 1 and Stage 2 trials should be applied based on the data from two-year old crops. In addition, there was a strong correlation between the estimated net merit grade (NMGVol) and calculated net merit grade (NMG) in both the one-year and two-year Stage 2 crops at Broadwater. The correlation between the one-year NMGVol and the two-year NMG, however, was not significant. The results also show that family selection combined with visual selection in Stage 2 was generally more effective to identify elite clones in Stage 3 than family selection alone. Additionally, when the Brix of clones was taken into account the efficiency of identifying elite clones was increased even further.

1.0 BACKGROUND

In 1992, BSES was contracted to conduct a selection program for the NSW sugar industry. However, with limited experience in NSW and with two-year crops (see BS5S and BS15S Final Reports), BSES had little information on which to construct a selection program. Consequently, the current selection theory based on one-year cropping experience in Queensland had previously been used to formulate the existing NSW program. As a result, a lengthy selection program was in place, and less clonal information has been obtained compared with the Queensland-based selection programs. The basic information necessary to alter the NSW program was unavailable.

The focus of this project was to design a rapid and effective selection program for the three NSW mill areas, with particular reference to problems associated with mixed one- and two-year cropping. By determining the intensity of family selection that gives the greatest genetic gain from selection, an opportunity may arise either to expedite the selection program or to evaluate more families in NSW. Similarly, by finding the best level of clonal selection, it should be possible to identify elite clones more rapidly and efficiently.

2.0 PROJECT OBJECTIVES

The objectives of this project were to:

- determine the optimum intensity of family selection and of clonal selection within families;
- determine the best characters on which to base clonal selection in Stage 1 and Stage 2 trials;
- assess the merit of evaluating families as original seedlings versus 4-sett plots.

The objectives were not fully met due to difficulties described in detail in section 8.0. Total funding received for the project: \$63,763.

3.0 METHODOLOGY

Trials were planted in the three NSW mill areas (Condong, Broadwater, Harwood) to assess the performance of a range of families and clones in the first three BSES selection stages. All families and clones were to be common among the three stages so that the merit of the wide range of selection scenarios could be established. Potential selection strategies were assessed by computer simulation. The overall concept of the trials proposed for this project can be more easily understood by reference to Appendix 1, a flow diagram of the major trial events.

Seed from 41 families was germinated at Broadwater in 1993. Twenty original seedlings from 40 of these families were planted in the selection and evaluation trials. An additional 80 original seedlings from each of the 41 families were planted at Broadwater. The purpose

of these additional clones (Stage 1 trial) was to allow for an assessment to be made of the performance of original seedling families as one-year and two-year crops.

The 800 clones (20 seedlings from 40 families) were propagated in 1994 so that the selection and evaluation trials could be run concurrently. In the first ratoon crop of the original 800 seedlings, clonal measurements were taken on Brix, stalk number, 2-stalk ccs (commercial cane sugar), 2-stalk weight, stalk height, stalk diameter, and visual estimate of yield.

Stage 1 trial

Two replicates of the additional original seedlings (Stage 1 trial) were harvested as family plots after one year. The family yields of this harvest were compared with the other two replicates, which were harvested after two years' growth. Family plots were mechanically harvested and weighed to obtain cane yield (tonnes of cane per hectare, TCH). Sugar content (ccs) was estimated from the juice of eight randomly chosen stalks using standard BSES procedures (BSES, 1984). TCH and ccs were then used to calculate sugar yield (tonnes of sugar per hectare, TSH) and net merit grade (NMG) (Skinner, 1965) for each family.

Stage 2 trial

In 1995, the 800 clones were planted as 4-sett plots in families (family plot was 10 clones /family plot), in selection trials at Condong (two reps), Broadwater (four reps) and Harwood (two reps). Both replicates from the Condong trial and two replicates from the Broadwater trial were to be harvested as one-year crops, while the other two replicates from Broadwater and both replicates from the Harwood trial were to be harvested as two-year crops. This selection trial was planted to simulate a Stage 2 trial. Unfortunately, the trial planted at Condong germinated poorly, and there was insufficient planting material to replant it the following season. Therefore, comparison between the Condong and Broadwater Stage 2 trials could not be made.

Clonal measurements were taken in the first ratoon crop of the one-year and two-year selection trials (Stage 2). These measurements were the same as described above for the Stage 1 trial, and were used to assess the merit of using these measurements to make selection decisions in Stage 3.

Stage 3 trial

The evaluation trial containing the 800 clones was planted at the same three sites as the Stage 2 trials. The clones were planted in single row 10 m plots, simulating a Stage 3 trial. Harvest weights were collected, and ccs was determined for each clone using a 2-stalk sample. The Stage 3 trial at Condong was harvested after one year, while the plant crop trials at Broadwater and Harwood were harvested after two years. To minimise costs and time, first ratoon crops were harvested as one-year crops for all stages of this project at all sites.

Data analysis

Stage 1. Spearman's rank correlation test (Conover, 1980) was used to test for significant correlations between the two crop ages of the Stage 1 trial. This correlation test was chosen because it is a non-parametric test and therefore no assumptions are made as to the underlying distribution of the data.

Stage 2. An estimate of the volume of cane per hectare (VCH) was obtained from the clonal measurements described above. In addition, field Brix was recorded for each clone using a hand-held refractometer. This allowed for the calculation of visual grade Brix (VGB), which is an adjusted measure of Brix taking into account the difference in Brix between the clone and the standards (Skinner, 1965). Volume of sugar per hectare (VSH) and a net merit grade value based on the volumetric estimates (NMGVol) were also calculated. These estimated values were correlated to the yield data obtained during harvest of the Stage 2 trials.

Stage 3. An evaluation was made of the different selection strategies for advancing clones to Stage 3 and for identifying superior clones from Stage 2 using computer simulation.

4.0 RESULTS AND DISCUSSION

Stage 1

The aim of family selection is to identify families with a high frequency of superior clones (Cox *et al.*, 1996). In NSW areas where two-year crops predominate, superior families are normally selected after two years' growth. However, provided there is a good relationship between the performance of families for the two crop ages, selecting superior families after one year's growth would expedite the selection process and the identification of superior families.

The mean values for the four traits measured over the 41 families are shown in Table 1. The coefficient of variation estimates in this series of trials ranged from 6% for ccs up to 26% for NMG, which is typical for such trials in NSW. The performance of original seedling families as one-year and two-year crops was compared by calculating the correlation coefficient (r) using Spearman's rank correlation test (Table 1). There was a significant correlation between the two crop ages for TCH ($P < 0.01$) and TSH ($P < 0.05$), but not for ccs and NMG. This suggests that family selection based on TCH or TSH could be applied after one year to identify families that perform well after two years' growth. However, the current practice at BSES is to select superior seedling families based on NMG. NMG is a selection index incorporating TCH, ccs, and other important agronomic characteristics. It is calculated relative to standard cultivars that are adjusted to a mean NMG of 10 (Skinner, 1965). Therefore, these data indicate that in NSW areas where two-year crops predominate, family selection in Stage 1 should be applied based on the data from two-year old crops.

Table 1. Population mean values for cane yield (TCH), sugar content (ccs), sugar yield (TSH), and selection index (NMG) and the correlation coefficient (r) between one-year and two-year original seedling families.

	TCH		ccs		TSH		NMG	
	1 yr	2 yr	1 yr	2 yr	1 yr	2 yr	1 yr	2 yr
Mean	41.2	150.5	13.2	13.1	5.4	19.6	8.1	7.1
St dev	5.6	34.9	1.0	0.8	0.9	4.8	1.5	1.8
CV%	14	23	7	6	17	25	19	26
r	0.606**		0.106 ns		0.371*		0.298 ns	

* $P < 0.05$, ** $P < 0.01$, ns not significant

Visual selection as a predictor of Stage 2 performance

Clonal measurements were taken in the first ratoon crop of the one-year and two-year selection trials at Broadwater (Stage 2). The measurements taken on each clone were: stalk number, 2-stalk ccs, 2-stalk weight, stalk height, stalk diameter, and visual estimate of yield (Visual yield grade, VYG). From these measurements, an estimate of the volume of cane per hectare (VCH), volume of sugar per hectare (VSH), and a net merit grade value based on the volumetric estimates (NMGVol), were calculated for each clone planted in the Stage 2 trial. These estimated values were correlated to the yield data obtained during harvest of the Stage 2 trials (Table 2).

There was a strong correlation between VCH and TCH for the one-year and two-year crops. Similarly, VSH and NMGVol were strongly correlated with TSH and NMG, respectively. However, the correlation between VGB and ccs was not significant for both the one-year and two-year crops. Therefore, the estimated values of VCH, VSH and NMGVol could be used to select for high performing clones in Stage 2. However, for two-year crops grown in Broadwater, visual estimates must be made on a two-year crop, because the correlations between the visual estimates from the one-year crop and the data from the two-year crop were not significant for all traits measured (Table 2).

Table 2. Correlation between estimates based on volume and actual performance of clones in Stage 2 trials for Broadwater (BW) one-year and two-year crops.

BW Visual	BW Stage 2	Correlation coefficients			
		VCH:TCH	VGB:ccs	VSH:TSH	NMGVol:NMG
1 year	1 year	0.85**	0.14ns	0.87**	0.89**
2 year	2 year	0.86**	0.23ns	0.87**	0.88**
1 year	2 year	0.25ns	0.12ns	0.23ns	0.23ns

* $P < 0.05$, ** $P < 0.01$, ns not significant

One of the aims of this project was to evaluate different selection strategies for advancing clones and identifying superior clones from Stage 2. The different selection strategies of (1) family selection (Family), (2) family plus visual selection (Visual), and (3) family plus visual plus Brix (Visual + Brix) were tested. These three strategies were applied to the two-year Stage 2 trial information obtained from Broadwater. This crop was chosen after an examination of the genetic gains made after selecting from the different crops (one-year P

Family selection in Stage 2 was effective in identifying a high proportion of elite clones in Stage 3 (Fig. 1). In addition, the percentage of elite clones in Stage 3 identified from family selection in Stage 2 was consistent up to about the top 40% of families. These results indicate that the top 40% of families should be chosen for visual selection in the breeding program, and is consistent with results from the Burdekin (Kimbeng *et al.*, 2000), Mackay (Kimbeng *et al.*, 2001), and Bundaberg (Cox *et al.*, 1997) regions. The results also show that family selection combined with visual selection was generally more effective in identifying elite clones than family selection alone. Additionally, when the Brix of clones was taken into account, the efficiency of identifying elite clones was increased even further.

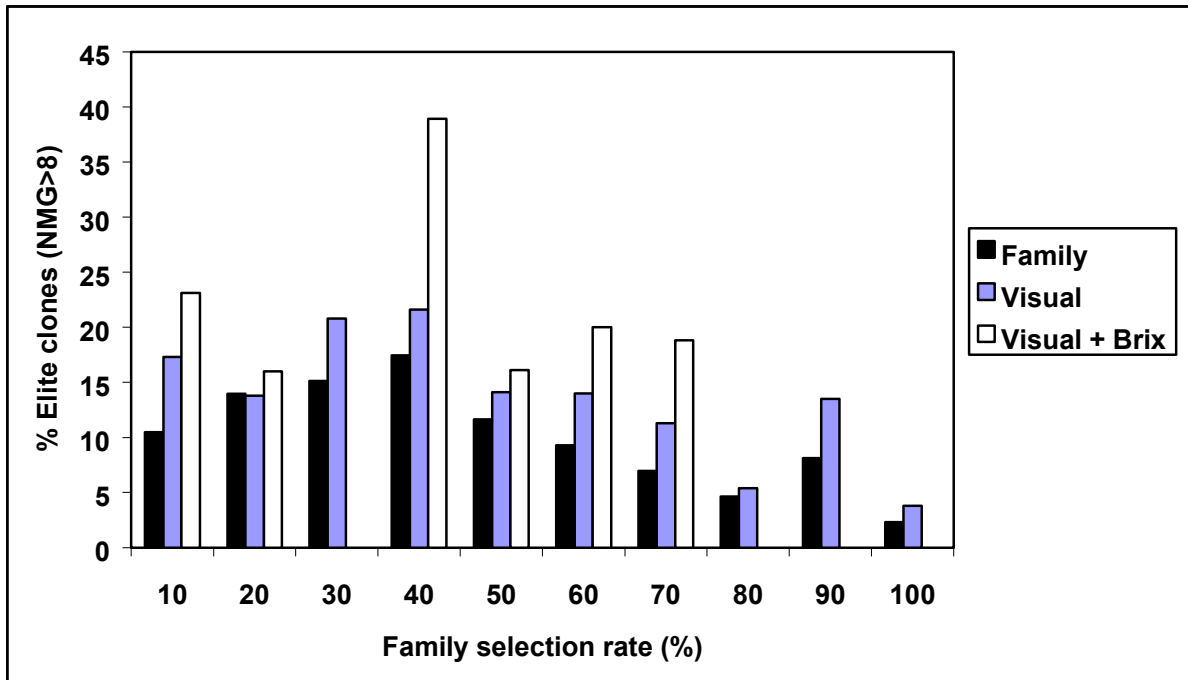


Figure 1. Percentage of elite clones that would have been obtained following family selection and family selection combined with visual yield grade and Brix.

5.0 IMPACT

The selection program in NSW has undergone considerable changes in recent years as a result of previous research (BS5 and BS15), which showed that families could be selected for the NSW region based on their performance in either NSW or in Bundaberg. There was no real advantage in terms of genetic gain in having two separate programs. By combining the NSW early selection stages with the Bundaberg program, a much more effective and efficient means of identifying elite clones is now possible. Family selection and Stage 2 testing (Clonal Assessment Trials) are now conducted in Bundaberg. Previously, about 20,000 seedlings were planted at Bundaberg and 4,000 clones (4-sett plots) at Broadwater in family selection trials. Now, about 32,000 seedlings are planted in Bundaberg each year. This larger number of seedlings (populations of families) increases the probability of identifying elite varieties. The advantages of this combined program are now becoming apparent, with selections from the southern program currently performing well in advanced trials in NSW.

6.0 RECOMMENDATIONS AND CONCLUSIONS

It is difficult to draw any major recommendations or conclusions from this project due to the difficulties experienced (see Section 8.0). However, the integration of the NSW and Bundaberg selection programs has produced substantial benefits for the NSW industry and economies of scale for both BSES and NSW. BSES is now well positioned to continue providing improved varieties for the NSW industry.

7.0 PUBLICATIONS

There are no publications arising directly from this work.

8.0 DIFFICULTIES

Dr Jason Bull was the supervisor for this project until he resigned from BSES in 1998. At the time of his departure, most of the trial work had been completed and the data collected; only one trial remained in the ground.

Dr George Piperidis was given the responsibility for analysing and interpreting the data generated from this project and for submitting the final report. It was soon realised that there were some major difficulties with the project right from its inception in 1993. Initially, the same families and same clones were to be planted in common in the three selection stages in the three NSW mill areas. However, only eight families were in common between the Stage 1 trials and the Stage 2 and 3 trials (Appendix 2). Apparently, families planted to the Stage 1 trials were taken from the nearby core seedling populations and not from the propagation plot dedicated to this project. The families planted to the Stage 2 and 3 trials were taken from the propagation plot intended for this project. This major error has had a serious effect on delivery of the proposed objectives for this project. For example, it was not possible to make an assessment on the merit of evaluating original seedlings versus four-sett plots based on data from only eight families. In addition, there were a couple of important staff changes at critical stages of the project, which led to the loss of some important trial information.

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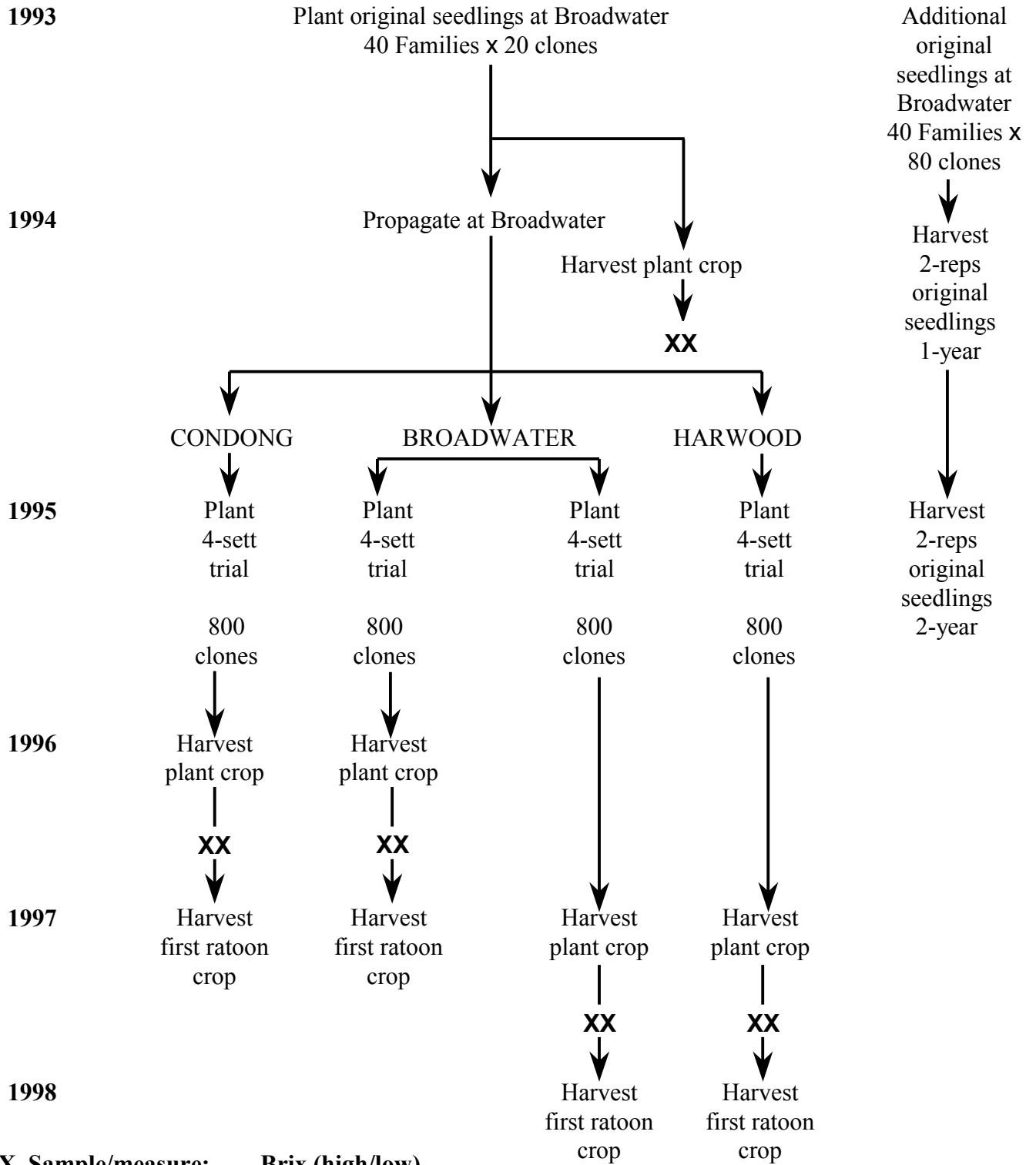
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10.0 ACKNOWLEDGMENTS

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Appendix 1: Flow diagram of major trial events

SELECTION TRIAL



XX Sample/measure: **Brix (high/low)**
Stalk number
Visual yield estimate
2-stalk weight
2-stalk ccs
Select or reject group

Appendix 1 continued

EVALUATION TRIAL

1993

1994

CONDONG

BROADWATER

HARWOOD

1995

Plant 10 m trial
800 clones

Plant 10 m trial
800 clones

Plant 10 m trial
800 clones

1996

Harvest
plant crop

Harvest first
ratoon crop

Harvest
plant crop

Harvest first
ratoon crop

Harvest
plant crop

Harvest first
ratoon crop

1998

Appendix 2: Clones and families planted in the trials

Stage 1	Female	Male	Stage 2 & 3	Female	Male
85-332	BN71-1370	Q142	85-312	59S55	Q142
86-408	CO740	72S1058	86-408	CO740	72S1058
86-849	CO740	59S55	86-554	CO740	CP53-19
87-52	76S1643	Q96	86-849	CO740	59S55
88-1118	77S1104	Q142	87-52	76S1643	Q96
88-1165	Q153	BN75-5026	88-221	67N3150	CP51-21
88-146	KRUOS	MQ63-436	88-827	59S55	Q121
88-198	CP51-21	MQ63-436	89-685	H60-3802	Q153
88-221	67N3150	CP51-21	90-22	74S875	CP73-341
88-827	59S55	Q121	90-35	MQ65-698	BN79-9301
89-1107	H60-3802	66N2008	90-61	CP44-101	BN79-9301
89-309	CP65-357	BN72-2503	90-81	TS66-440	BN81-1031
89-685	H60-3802	Q153	90-99	CP65-357	BN80-0332H
90-292	CP72-356	Q142	91-09	BN80-0315	BN79-9652
91-1045	Q117	BN78-8031	91-1042	79N238	80S7031
91-1131	CP51-21	79S7152	91-1097	H52-663	82N49
91-1155	77N330	73C947	91-114	74S875	CL69-451
91-1331	77N557	80S7031	91-1224	77S1104	H52-663
91-1454	83S1825	Q142	91-1336	Q117	80S7031
91-1458	84S2134	77S425	91-1546	80S7138	77S1423
91-1459	84S2134	79S2954	91-485	77N330	CO954
91-1460	84S2134	80S7417	91-490	Q146	76S323
91-1546	80S7138	77S1423	91-492	Q146	72S730
91-1788	77N557	59S55	91-500	77N330	NA56-79
91-310	80N3425	78S1181	91-51	Q96	KRUOS
91-448	80S7212	Q146	91-52	Q96	MQ68-79521
91-482	77N330	82N450	91-781	74C826	79A362
91-487	77N330	MQ74-675	91-837	Q125	CP71-1240
92-11	CONCORD	CP78-1247	92-103	BN80-0332H	Q115
92-137	BN80-0332H	Q146	92-144	CP70-1547	BN79-9343H
92-15	CP65-357	MQ79-1123	92-16	CP72-355	CP78-1247
92-23	BN77-7175	Q146	92-238	Q117	BN79-9343H
92-238	Q117	BN79-9343H	92-256	BN75-5003	MQ72-5089
92-243	81C580	83S2159	92-274	CP75-1322	75S2497
92-244	BN78-8031	Q142	92-280	84S2447	SP71-3501
92-246	BN79-9301	MQ77-340	92-32	CP65-357	Q146
92-50	78C540	BN74-4422	92-39	CP65-357	MQ63-425
92-51	BN80-0332H	BN79-9113	92-705	BN77-7214	CL73-239
92-620	80C173	MQ78-740	92-76	BN79-9442H	BN73-3388
92-77	75C87	SP71-3501	92-79	IAC51-205	79A362
92-81	74S875	SP71-3501			

Note: The eight families in common between the Stage 1 trials and the Stage 2 and 3 trials, are in bold print.