FINAL REPORT

CTA043

Provision of improved varieties and pathology services for the Ord Sugar Industry

CSIRO Plant Industry, Agriculture Western Australia, CSR Ltd.

Principal investigator: Phillip Jackson,
CSIRO Plant Industry
Davies Laboratory PMB PO Aitkenvale, Qld. 4814.
SPRN:
Phone 07 47538592
Email Phillip.Jackson@csiro.au

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Summary

This project was established to introduce and evaluate new sugarcane varieties into the Ord River Irrigation Area (ORIA), and to provide advice on pathology issues relating to the ORIA. Cultivars in the ORIA currently are old (introduced in 1980 or before) and it is believed that newer varieties bred since then could provide improved productivity and profitability for the ORIA industry. Varieties were initially chosen for introduction to the ORIA based mostly on commercial performance in north Queensland. They were transferred to the ORIA via a three to four year process that aimed to reduce the risk of inadvertently introducing important diseases present in Queensland but which are not present in the ORIA. Professional pathology advice was provided in supervising this process and ensuring plant material was apparently disease free at various points in the process. Pathology related advice was also provided to Agriculture Western Australia staff and growers on specific crop management matters in the ORIA throughout the project.

The directions taken in this project were greatly impacted on by the discovery of smut disease in the ORIA in 1998. This was the first time this disease had been found in Australia. It has a potentially devastating effect on productivity of susceptible varieties. The environmental conditions in the ORIA are highly favourable to smut infection, and a high level of resistance is required in cultivars for sustainable production. It was very fortunate that three cultivars in the ORIA at the time of the outbreak were resistant, and this enabled the industry to maintain productivity levels much better than it otherwise would have. However, in 1998 little was known about the relative smut resistance of most Australian varieties. As testing for smut resistance proceeded in the next few years in Indonesia by BSES (through BSS214) and by the CTA043 project team in the ORIA, it became apparent that around 80% of varieties from Australian breeding programs were too susceptible to smut to be grown commercially in the ORIA.

All varieties were therefore screened for resistance to smut following introduction to the ORIA, before subsequently considering their suitability for other agronomically important characters in the ORIA. Varieties showing sufficient smut resistance were then evaluated in a yield trial (design: plot size 4 rows x 10 m long, 3 replicates, at one site - Frank Wise Institute) where CCS and cane yields were measured in plant and ratoon crops. Despite only a relatively small number of varieties being evaluated in these yield trials (95 varieties to date), a number were identified with possible commercial potential. These varieties include: MQ88-2022, 89-680-6, MQ80-805, Q171$^{\Phi}$, 95H4021, 95H4039, Q176$^{\Phi}$ and KQ88-8151. These varieties will need to be monitored in ratoon crops in current trials, and evaluated further in commercial fields before any decisions are made regarding commercial release. The variety Mida$^{\Phi}$ performed well in the first two yield trials and was being considered for release during the course of the project, but it was later discarded based on observations in commercial fields showing it was too susceptible to red stripe/top rot disease.

The fact that some varieties were found exhibiting commercial value, even though only a relatively small number of (smut resistant) varieties were effectively evaluated, suggests that it will not be difficult to identify varieties with greater profitability than the current few cultivars dominating production in the Ord. An ongoing program to introduce clones already known to be smut resistant (based on results obtained in Indonesia) should be a high priority for R&D investment in the immediate future. However, results soon to be obtained from project CTA028 and results from screening a range of overseas varieties in the next few years should influence decisions about the best sources of varieties for the ORIA in future. A number of suggestions are made regarding the process of variety evaluation in the Ord, considering the experiences and results obtained through CTA043. In particular it is suggested that a multi-stage selection system for evaluation of CCS and cane yield rather than the one used in this project could be more efficient and effective. Possible specifications of such a program are given in this report, but details should be also guided by results from simple experiments to investigate an optimal system.

Apart from smut, surveys done in the ORIA during the project indicated the region is free of some other important diseases affecting sugarcane growing regions, including RSD, leaf scald and Fiji disease. This emphasises the continued importance of retaining strict quarantine for the ORIA. Red stripe/top rot disease is the most significant disease after smut, with many varieties being found too susceptible to this disease for commercial production.

1. Background

Sugarcane has been considered as a possible commercial crop for the Ord River Irrigation area (ORIA) since the 1960's but repeated attempts to establish a commercial industry failed until a re-examination in the early 1990's. The latter study led to the construction of a sugar mill by CSR Ltd. with the first cane being processed in 1995 and the first full commercial crushing season in 1996. The mill has a crushing capacity of about 120 tonnes of cane per hour, and is capable of crushing around 550,000 tonnes of cane per year and producing about 73,000 tonnes of sugar. This represents around 2% of the total Australian crop. Average commercial cane yields in each year have ranged from 94 to 171 tonnes of cane per hectare, with an average of 128 tonnes cane per hectare. Average percent pol is about 13.25%.

The Ord industry relies on sugarcane varieties that were introduced for trial work in 1980. The major varieties grown commercially initially were Q96, NCo310, Q99 and Q95. At the commencement of this project Q117 had been recently resurrected from old variety plots for testing and was showing considerable promise in commercial fields, but was yet to reach significant levels of cultivation.

It is known from experience in many sugarcane industries that the correct choice of varieties can make a large difference to profitability of growing and milling enterprises. Variety choice can often make the difference between profit and loss positions through impact on cane yield, sugar content and ratooning performance. Genetic resistance is also the main means by which important diseases are managed in most industries, as opposed to possible alternative, possibly prohibitively expensive, or environmentally damaging methods. For this reason, along with the assurance, speed, and low cost in obtaining widespread adoption of good new varieties by growers, sugar industries in Australia and around the world consistently target variety improvement as being the highest priority area of investment of research and development funds. It was hypothesised that since 1980 some varieties bred for environments on the east coast of Australia could be more profitable than the old varieties currently growing commercially in the ORIA. Therefore, introduction and evaluation of a range of high performing varieties from east coast regions was considered a high priority by the industry in the ORIA.

Low pol and low purity have been and still are significant problems in the Ord affecting the future viability of the industry. This is the case particularly during the first 2 months of the season. New higher CCS varieties are urgently needed by the industry. Q117 (pre smut) had a higher CCS and was far easier to process than existing varieties and this suggested that high CCS varieties could have a significant impact on factory processing and mill profitability.

The ORIA is also presently free from a number of potentially devastating diseases that occur in other sugarcane growing regions. These diseases include ratoon stunting disease (RSD), leaf scald, and Fiji disease. These diseases are currently kept under control in Queensland and NSW by farm hygiene (particularly in the case of RSD), or by restricting

the use of susceptible varieties. These strategies both come at considerable cost, and it would clearly be advantageous if the disease free status of the Ord for these diseases was maintained. For this reason, strict quarantine protocols were established for introduction of varieties into the ORIA. The adherence to these protocols, involving a process spanning at least 3 years, represented a major cost, and a major timeframe constraint, in this project, but was a necessary component.

At the commencement of this project there was also little known about what other diseases or pests were present in the ORIA and their potential for having an impact on the region. However, being an isolated and new region with many new growers, it was considered that the need for disease prevention and early detection and control could be even more important than in established regions. Also, because the ORIA is close to Indonesia, there was a possibility that important pests and diseases in that region could spread to the ORIA. For these reasons the Ord industry considered it vital that an experienced sugarcane pathologist be involved in routine inspections and advice in relation to potential or actual problems.

Near the commencement of this project (July 1998) smut disease was located in the ORIA, and this greatly impacted on the industry and this project. This was the first time smut had been found in Australia. Smut has been present in nearly every other sugarcane growing country, but its impact has been managed in other countries through resistant varieties. Its effect on susceptible varieties is potentially devastating, with complete losses in productivity in severe cases. Out of the varieties being grown commercially in the Ord at the time of the outbreak, NCo310 and Q117 are susceptible, Q99, Q95 highly resistant, and Q96 intermediate in reaction. The industry was very lucky to be in a position where a significant portion of the area was planted to highly resistant varieties. This is particularly the case considering about 80% of commercial varieties released on the east coast are susceptible to smut. However, it had a major impact on both NCo310 and Q117 and both these varieties were completely removed from commercial production over a short period at considerable cost.

In 1998 the smut resistance of most Australian varieties was unknown. A large proportion of effort in this project was therefore diverted toward testing varieties introduced into the Ord for smut resistance. This occurred in parallel with smut testing of commercial cultivars and promising experimental varieties from the east coast regions in project BSS214 by BSES. It became apparent through this testing that on average around 80% of varieties coming through Australian breeding programs were probably too susceptible to smut to be grown commercially in the ORIA. This meant that a large proportion of varieties introduced for evaluation in the Ord were subsequently discarded because of smut susceptibility, prior to any evaluation for CCS or cane yield. The occurrence of smut has been the biggest factor that has limited the success of this project in finding high yielding varieties for the Ord. Thus, the continuing cost of smut to the ORIA has been not so much its direct impact on yields of varieties growing commercially, but rather its impact on eliminating from consideration many varieties which could probably otherwise offer substantial productivity gains. The problems faced in this project during this transitory phase following introduction of smut, associated with the

discard of many varieties after going through an expensive quarantine process, should reduce in the future since we now have a solid database of smut resistance ratings of many Australian varieties. Therefore, it is likely that mainly varieties known to be smut resistant will be introduced for evaluation to the Ord in the future.

Throughout this project, it was not yet clear to what extent relative variety performance in selection trials on the east coast or in other countries could be used to predict relative performance in the Ord. This issue will be investigated in the project CTA028. However the fact that only a proportion (20 out of 48) varieties evaluated as part of CTA028 exhibited at least moderate smut resistance, and were therefore included in the one trial in the Ord, might limit the confidence in the interpretation of results obtained. However, in the absence of other information, it was assumed that performance of varieties in other Australian regions would provide some guidance for CCS and cane yield in the ORIA. Therefore, the top performing clones from breeding programs, and particularly released cultivars, were generally selected for evaluation in the ORIA, as opposed to unselected or random seedling clones.

3. Objectives

The objectives of this project, as stated in the original proposal, were:

1. To introduce high yielding commercial and elite experimental sugarcane varieties from Queensland into the Ord.

2. To ensure introduced varieties are free from disease (particularly ratoon stunting disease and yellow leaf syndrome) through frequent inspections by an experienced pathologist.

3. To assess their performance alongside the current leading varieties in replicated trials under Ord growing conditions.

4. To keep the Ord sugarcane crop as disease free as possible by examining crops on farms at two critical growth periods each year.

5. To provide specialist advice on control measures should a major pest or disease problem be identified in the Ord.

6. To pass on knowledge of cane pest and disease identification to local research, extension and technical staff.

4. Methodology.

4.1 Variety introduction

This project continued work initiated in SRDC funded projects ORD1S and ORD2S that ended in December 1997. In brief, the procedure involved with variety introduction included:

(i) Selecting varieties that are either cultivars in east coast regions, or were exhibiting promising performance in variety trials in Queensland.

In the first and second batches of varieties sent, some unselected seedling clones were also sent. These had been extensively evaluated across environments in the Herbert region in project CSR11S. The aim was to evaluate these clones in both the Ord and the Burdekin (and possibly other regions) with a view to determining if a correlation existed between variety performance in the Ord and other regions. This would be important information for determining appropriate strategies for sourcing varieties for the Ord into the future. However, this objective of examining GE interactions between the Ord and other regions was subsequently subsumed with the initiation of the SRDC funded project CTA028 ("The mega GxE project"), which aimed to address the same issue but on a wider scale across all sugarcane growing regions in Australia. Most of the clones sent to the Ord in batches 1 and 2 were also chosen for use by the CTA028 project team, but an additional group of clones was also selected. This additional group (prefixed with "95H") was transferred to the Ord within this project as part of the third batch of clones sent in 1999.

In the latter half of the project information was becoming available about the smut resistance of some Australian cultivars and advanced stage selections, and this influenced some choices about which clones to continue through quarantine. The last two batches of clones sent to the Ord included mostly overseas clones introduced by BSES through the quarantine glasshouse in Brisbane. It was thought that a larger proportion of these clones may be resistant to smut compared to Australian varieties, and it was also of interest to assess (i) if clones from any particular country as a group showed promise in the Ord, and (ii) how smut ratings obtained from overseas countries compared with smut susceptibility observed in the Ord.

In a few cases, varieties originally chosen and entered into the quarantine pipeline for introduction were later discarded at some stage before sending to the Ord because they showed disease like symptoms in quarantine (eg. YLS symptoms in early batches). Batch 4 only included a small number of varieties because leaf scald was found in the intitial targeted source (at Macknade experiment station) of most varieties selected for transfer to the Ord in that batch. A summary of the source of varieties introduced to the Ord in this project is shown in Table 1, and the full list of varieties is given in Appendix 1.

Table 1. Sources of varieties introduced to the Ord.

Batch	Year of introduction	CSR exp.[1]	CSR cultivars	BSES exp.[2]	BSES cultivars	Overseas varieties	Total
1	1997	24	5	4	13	2	48
2	1998	14	0	0	6	3	23
3	1999	2	0	31	4	0	37
4	2000	3	0	0	5	0	8
5	2000	4	0	7	9	11	31
6	2001	0	1	0	2	93	96
7	2002	0	0	0	2	84	86
Total		47	6	42	41	193	329

[1, 2] Refers to experimental varieties sourced from the CSR and BSES breeding programs, respectively.

(ii) Propagating varieties through a quarantine protocol. This protocol ("Protocol for growth in quarantine and disease screening of sugarcane propagation material to be imported into Western Australia above 26 degrees south from other states and territories", approved by the Director General of Agriculture Western Australia), was developed initially by the AgWA Quarantine Pathologist, but was later modified in 1997 with input from the project team, particularly Mr Brian Egan. The protocol included growth of clones in a quarantine glasshouse for two years. In 2000, on further advice from Mr Egan, AgWA developed a modified protocol based on revised conditions for sourcing plant material, to ensure higher health status of this material but reducing the period in the quarantine glasshouse to only 1 year. This protocol followed in this project from batch 5 onwards in the project is given in Appendix 2. In brief, the procedure followed involved:
- Obtaining source cane from apparently disease free cane (which included testing for RSD).
- Growing this cane in a special plot in the field in an area with no history of key diseases. The cane was cold-soaked (CS), and long hot water treated (LHWT) before planting into this plot.
- Inspection of these source plots by a qualified pathologist (Mr Brian Egan) and testing for RSD to ensure freedom of disease.
- CSLHWT cane from these plots and growing setts in a quarantine glasshouse for one year, with regular inspections by Mr Egan.
- Conducting an RSD test, before sending to Frank Wise Institute, in the Ord region.
- Planting the cane into open quarantine at Frank Wise Institute, followed by inspections and culminating in a recommendation by Mr Egan to the AgWA Quarantine Pathologist for their release for further planting.

(iii) Planting the clones into evaluation trials in the ORIA. Following the discovery of smut in the ORIA it was necessary to test all clones in a smut resistance trial before planting resistant clones into a yield evaluation trial. This was the procedure followed for batches 2 onwards. The progression of each of the batches of cane through the trials in the Ord is shown in Table 2.

Table 2. Progression of varieties in project.

Batch	1997	1998	1999	2000	2001	2002	2003
1	Intro to Ord	Propagation	Plant to ST1 and YT1	Plant crop results	1st ratoon crop results		
1.1		Intro to Ord	Plant to ST1 and YT1	Plant crop results	1st ratoon crop results		
2		Intro to Ord	Plant in ST1	Plant to YT2	Plant crop results	1st ratoon crop results	
3			Intro to Ord	Plant to ST2 and YT2	Plant crop results	1st ratoon crop results	
GE clones[1]					Planted in GE trial	Plant crop results	1st ratoon crop results
4				Intro to Ord	Plant to ST3	Plant to YT3	Plant crop results
5				Intro to Ord	Plant to ST3	Plant to YT3	Plant crop results
6					Intro to Ord	Plant to ST4	Plant to YT4
7						Intro to Ord	Plant to ST5

[1] These clones were introduced successively in batches 1, 2 and 3.
ST and YT refer to smut trial and yield trial, respectively.

4.2 Trial methodology

4.2.1 Smut trials

The dates of planting and final inspection of these in each crop are indicated in Table 3. The smut trials were all planted on Frank Wise Institute, using a standard technique previously reported (Ferreira and Comstock, 1989). In brief, smut spores were collected from whips in the field and air-dried. Testing of these showed about 70% viability. Setts to be planted in the trials were dipped for 10 minutes in a solution of approximately 5 x 10^6 viable spores/mL, and then planted the next day into moist soil and irrigated. In all cases a randomised complete block design was used, with five standard clones. In smut trial 1, four replicates were used. Analysis of data from this trial indicated a very high broad-sense heritability (0.91 in plant crop, 0.96 in ratoon crop; Engelke *et al*, 2001), and it was decided that three replicates would be sufficient to achieve objectives of identifying resistant, susceptible and intermediate clones in subsequent trials.

Each plot was rated and data primarily analysed on the basis of the percentage of diseased stools, as identified from careful visual inspection. Stools which showed a smut whip of any form were regarded as diseased. Secondary subjective ratings were made on the number and severity of the symptoms, which was related to the tolerance of the clone to smut. In general there was a high correlation between the primary and secondary ratings. However, the tolerance rating was not used significantly in deciding which varieties to truncate in selection, with the percentage infected stools being the main basis for this.

4.2.2 Yield trials

All yield trials were planted on Frank Wise Institute. The dates of planting and harvest of the yield trials (to date) are given in Table 3. The trial designs were randomised complete block designs with three replicates. The plot size was 4 rows (@1.5 m spacing) x 10m, with 1 m gap between plot ends. The cane was grown similarly to commercial cane in the Ord, including application of approximately 200 kg/ha N and 50 kg/ha P each crop cycle. The trials were furrow irrigated approximately after every 120mm of evaporation before canopy closure, and after every 80mm after canopy closure.

Table 3. Dates of planting and harvest of each of the yield evaluation trials.

Trial	Planting date	Harvesting dates
Yield trial 1	5 May 1999	30 May 2000 (Plant) 18 Sept. 2001 (1 Ratoon)
Yield trial 2	24 May 2000	5 July 2001 (Plant) 15 Aug 2002 (1 Ratoon)
GE trial	31 May 2001	10 July 2002 (Plant)
Yield trial 3	8 May 2002	16 July 2003 (Plant)
Yield trial 4	17 April 2003	

The cane was burnt immediately before harvest. The middle two rows of each plot were mechanically harvested and weighed to determine cane yield. A six-stalk sample was taken from the two middle rows (3 stalks from each row) for CCS and fibre determination immediately before harvest. Three stalks were crushed in a small mill and brix and pol determined, while the other three were fibrated in a Jeffco cutter grinder, with the fibrated material pressed in a Carver press for fibre determination using the press method (Tanimoto, 1964). Data was analysed using standard analysis of variance methodology, using SAS software (SAS Institute Inc. version 8.00).

4.3. Pathology services

Pathology services were provided by Mr Brian Egan, an experienced sugarcane pathologist. Two main types of input were made, namely inspection of cane during each phase of the quarantine process, to satisfy the requirements of the protocols for importing cane into the ORIA, and inspection of trials and commercial fields of cane in the ORIA to identify existing or potential problems and recommend responses to these. During the quarantine process, source cane was inspected by Mr Egan in the field prior to being sent for propagation in closed quarantine at a CSIRO glasshouse at Samford, Brisbane, then at least four times during closed quarantine, and then again in the open quarantine plots at Frank Wise Institute. Mr Egan made two visits per year to the ORIA during the project, with one visit generally around April and the other around November. The timing of these visits allowed a range of crop sizes to be observed in the field, and also generally coincided with final inspections of the smut trials.

5. Results and outputs

5.1 Smut resistance trials

Results from analyses of variance of % stools infected by smut (not shown) indicated highly satisfactory (>0.8) levels of clonal repeatability (or broad sense heritability) in all trials. Results for each clone are shown in Appendix 1: these results represent the % infections observed when the mean infection level for the trial was greatest. In all cases, a high (>0.9) correlation existed between % infection recorded between the plant and first ratoon crops. LSD ($P<0.05$) values were generally around 25 to 30%. While these levels appear high, because of the large range in % infection (from 0% to 100%), it was easy to distinguish between clones that were resistant, susceptible and intermediate in their response to smut under the trial conditions.

A summary of the number of susceptible, intermediate and resistant varieties in each of the smut trials is given in Table 4. Results from smut trial 4 are tentative only because observations in the ratoon crop have not been made, and an increase in infection levels are likely to be observed in quite a few clones in the ratoon crop. It should also be noted that the great majority of clones in trial 4 are foreign and hence likely to be less susceptible to smut than the Australian clones which predominated in trials 1-3.

Overall, only 20-25% of clones in smut trials 1-3 were regarded as being resistant, and therefore able to be considered for cultivation in the ORIA without fear of being adversely affected by smut.

Table 4. Total number of varieties tested in each smut trial, along with the number which were classed as susceptible, intermediate and resistant to smut.

Trial	Planting time	Number of varieties	Number susceptible	Number intermediate	Number resistant
ST1	Sept. 1999	80	54(68%)	9(11%)	17(21%)
ST2	July, 2000	37	28(76%)	3(8%)	6(16%)
ST3	May, 2001	39	23(60%)	6(15%)	10(25%)
Total		156	105(67%)	18(11%)	33(22%)
ST4	August 2002	95	42(44%)?	15(16%)?	38(40%)?

Infection levels observed in the Ord were compared with those obtained in BSES smut trials in Indonesia where clones were observed in both places. 63 clones had ratings obtained in both places (Figure 1). Overall, a reasonably good correlation existed, suggesting that results obtained from screening in Indonesia would be a reasonable predictor of response to smut in the ORIA.

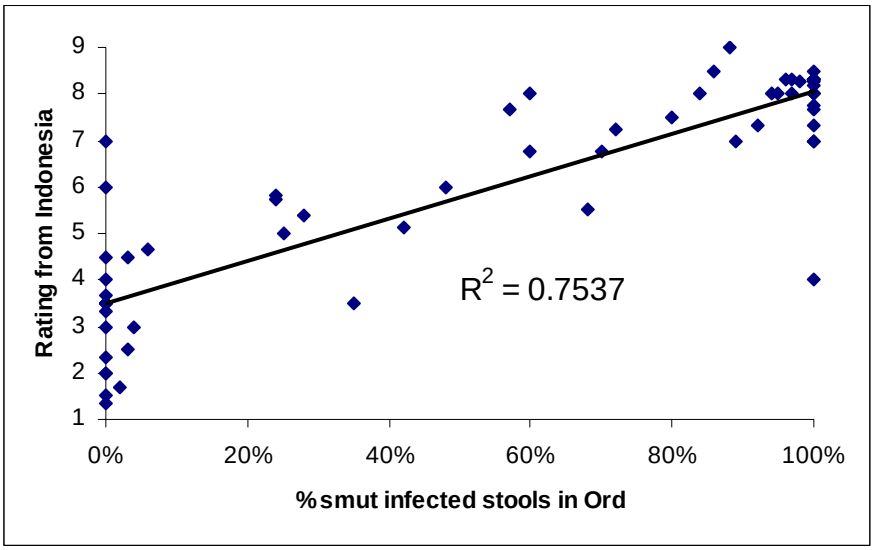

Figure 1. Relationship between smut ratings obtained in BSES smut trials in Indonesia (Barry Croft, personal communication) and infection rates of the same clones in smut trials in the Ord.

49 varieties sourced from various overseas breeding programs have been rated from both their source country (overseas ratings obtained via Barry Croft, BSES), and from trials in the Ord. The relationship between the overseas ratings and the % infection in the Ord is poor (Figure 2). This suggests that ratings obtained from overseas programs in general may be unreliable for predicting response to smut infection in the Ord. The reasons for this are not clear, but conceivably could be due to (i) different reactions to smut associated with environmental differences, (ii) poor or different screening techniques in the source countries, (iii) mis-labelling of clones somewhere in the process of importation and screening in the Ord, (iv) different strains of smut existing in some other countries. However, this result also raises the question of reliability of ratings obtained from at least some overseas countries in general, and has implications for targeting smut resistant parental material for breeding in Australia. Whatever the cause of the difference, it does suggest that overseas introductions would need to be screened for smut resistance in the Ord, before undergoing yield evaluation trials, even if these varieties are reported as being resistant from the source country.

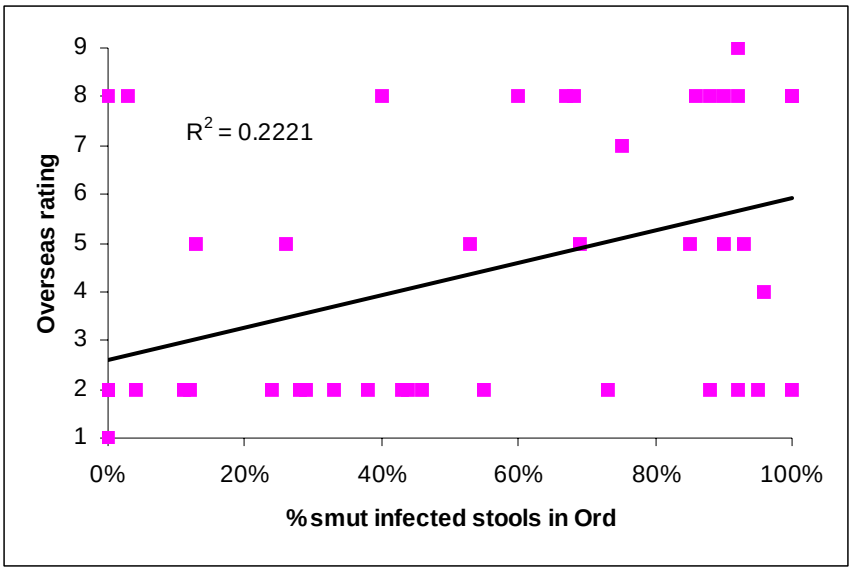

Figure 2. Relationship between smut ratings obtained from overseas programs (ratings obtained via BSES; Barry Croft, personal communication) and infection rates of the same clones in the Ord.

5.2 Yield evaluation trials

Results from analyses of variance of each of the four trials established in the ORIA (including the GE trial) are summarised in Table 3. Yield trials 1 and 2 were harvested in plant and first ratoon crops, so estimates of variety x crop-year interactions can be estimated. In all cases, the interaction components were smaller than the variety main effect or not significant. This indicates that, on average, in both trials, relative variety performance in the plant crop was a reasonable predictor of ratoon crop performance, although some individual exceptions to this were observed in the data.

One problem apparent in these data is the relative lack of precision in estimating CCS in the trials. Least significant difference (LSD) values are shown in Table 5 which represent the difference between an experimental clone and a standard clone that would need to be observed before one could say there was less than a 5% chance of that difference being due to random experimental error effects. In all trials, the LSD values are 2 units or greater when dealing with data from an individual crop. This value is over twice that commonly observed in trials on the east coast, including in lodged cane in the Burdekin. The reason for this was first hypothesised as being due to sampling error, which could be associated with stalk-to-stalk variability in the lodged conditions in the trials. To investigate this hypothesis, in the 2000 planted trial, two subsamples per plot were taken in each plot of one replicate to determine if error variance (ie. block x variety interaction) was associated with sampling variation or interplot variation. An analysis of variance indicated that the major source of variation was interplot variation rather than sample-within-plot variation (block x variety variance component = 2.07; within plot sampling variance component = 0.77).

These results suggested that little improvement would occur by taking more or larger samples of stalks from individual plots. In the two most recently planted trials (the GE trial and YT3), error variation for CCS appeared to increase even further. It is clearly apparent that precise estimation of CCS in trials represents a serious issue in the Ord for evaluating varieties in small plot trials. Some suggestions for exploring this issue and obtaining a satisfactory solution to the problem are given in the discussion and recommendations.

Table 5. Summary results from analyses of variance of four trials in the Ord (abbreviations given in Table 3). Data given for varieties, variety x crop-year (V x crop), and error are variance components. Heritabilities are broad-sense heritabilities on the basis of clone means, and determined from genetic variance divided by phenotypic variance. LSD values are for P<0.05 and represent the difference between means for individual standard clones (where there were 2 plots per replicate in most cases) and an individual experimental clone.

Trial	Source of variation	Fibre (%)	CCS (%)	Cane yield (t/ha)	Sugar yield (t/ha)
YT1	Varieties (V)	1.28**	1.11**	117.6**	2.97**
	V x crop	0.61**	0.49(NS)	29.0(NS)	1.95(NS)
	Error	1.26	3.06	229.0	13.8
	Heritability	0.71	0.68	0.75	0.56
	Mean	14.1	11.13	160.6	17.61
	LSD	1.12	1.74	15.1	3.71
YT2	Varieties (V)	0.186(NS)	0.32**	326.5**	6.52**
	V x crop	0.24 (NS)	0.20(NS)	31.9[x]	1.73*
	Error	1.67	1.98	169.7	6.63
	Heritability	0.40	0.49	0.53	0.61
	Mean	14.1	12.01	145.8	17.5
	LSD	1.29	1.41	13.0	2.57
GE	Varieties	1.93**	1.24*	471.0**	7.64**
	Error	1.76	4.05	231.1	11.51
	Heritability	0.76	0.47	0.86	0.67
	Mean	14.5	9.64	146.3	14.1
	LSD	1.87	2.83	21.4	4.78
YT3	Varieties	1.13**	1.10**	187.9**	4.76**
	Error	1.36	2.58	137.9	7.96
	Heritability	0.71	0.56	0.80	0.64
	Mean	15.7	10.84	163.2	17.7
	LSD	1.64	2.26	16.5	3.97

Results for individual varieties in each of the four trials are shown in Tables 6 to 9 below. The GE trial is shown here even though it was conducted mainly for project CTA028 because a couple of clones included in this trial exhibit potential commercial value based on the plant crop data. In all trials, experimental varieties were compared with the commercial varieties Q95, Q96 and Q99 .

Varieties with potential commercial value were considered to need to show smut resistance similar to,and preferably much better than, Q96, with at least equivalent profitability compared with the best standard varieties in the trial. The CSR variety Mida$^{\phi}$ exhibited potential in this regard based on yield trials 1 and 2. This variety was propagated for inclusion into commercial strip trials, but during this time it exhibited susceptibility to top rot, and for this reason was considered unsuitable for commercial production. Interestingly this variety also showed very low mean CCS in the yield trial 3, despite it having the highest CCS of all varieties based on the averages across yield trials 1 and 2. The reasons for the high variability in yield trial 3 is not known, although this trial did have the highest error variation for CCS out of all trials and this may have been at least a contributing factor. Mida$^{\phi}$ also showed heavy smut infection on one planting on a commercial farm, despite it exhibiting complete resistance across all smut resistance trials it was in. Again, the reasons are not clear.

Several other varieties have exhibited commercial potential based on these results, in particular, varieties MQ88-2022, 89-680-6, MQ80-805, Q171$^{\phi}$, 95H4021, 95H4039, Q176$^{\phi}$ and KQ88-8151. However, at this stage it is not possible to make firm predictions on the commercial value of any of these clones. These clones should be propagated for further observations and measurement in commercial strip trials, and further observations made in small plot trials, especially in subsequent ratoon crops. It is likely that at least one or two of these clones would be suitable as commercial varieties for the ORIA.

Table 6. Performance of varieties in yield trial 1 in plant and first ratoon for cane yield (t/ha; TCH), CCS, sugar yield (t/ha; TSH) and fibre content (%). Also indicated is the highest stool infection rate for smut in the smut trials.

	PLANT CROP			1ST RATOON CROP			Average Fibre	Average CCS	Average TSH	
VARIETY	TCH	CCS	TSH	TCH	CCS	TSH				SMUT%
PELORUS	189	12.8	24.22	163	14.2	23.1	14.4	13.5	23.7	44
Q96	187	12.4	23.2	155	14.6	22.6	17.7	13.5	22.9	32
Mida$^{\phi}$	188	13.2	24.66	137	15.2	20.7	14.1	14.2	22.7	8
MQ74-110	187	11.8	21.98	158	13.7	21.4	13.4	12.8	21.7	100
Q161	181	9.6	17.48	179	14.1	25.2	13.6	11.9	21.3	70
Q99	192	11.6	22.28	145	13.7	19.9	14.2	12.7	21.1	0
Q127	190	12.7	24.11	146	12	17.6	14.7	12.4	20.9	100
TELLUS	166	13.6	22.59	153	11.1	17.1	17.8	12.4	19.8	97
KQ88-8075	163	13.7	22.32	118	13.4	16	14.1	13.6	19.2	75
KQ91-31405	178	10.6	18.82	167	11.6	19.6	15.5	11.1	19.2	48
KQ91-31506	178	9.9	17.58	146	14.3	20.9	14.8	12.1	19.2	42
BMQ89-15	193	10.2	19.79	150	12	18	14.2	11.1	18.9	95
Q138	179	10.9	19.57	142	12.8	18.2	14.8	11.9	18.9	100
Q155	171	12.6	21.57	140	11.6	16.2	14.4	12.1	18.9	0
Q142	188	9.8	18.47	143	12.9	18.7	14	11.4	18.6	3
BMQ89-77	152	12.3	18.75	140	12.8	18.3	17.5	12.6	18.5	100
ORPHEUS	164	12.4	20.25	127	13.1	16.6	14.5	12.8	18.4	15
MQ87-155	201	9	18.01	178	10.4	18.4	14.4	9.7	18.2	38
89-503-10	176	10.1	17.71	152	12.2	18.5	14.1	11.2	18.1	42
Q125*	173	11.9	20.54	124	11.6	14.2	14.2	11.8	17.4	0
MQ79-141	164	9.4	15.43	149	12.5	18.6	16.1	11	17	67
BMQ89-14	185	8.7	16.17	150	11.6	17.3	14	10.2	16.7	80
89-680-3	175	9.8	17.03	142	11.2	15.9	16.5	10.5	16.5	3
89-518-6	181	10	18.1	121	11.7	14.2	13.8	10.9	16.2	0
Q122	154	12	18.38	106	12.8	13.6	17.2	12.4	16	100
Q124	165	8.7	14.28	125	12.8	15.9	12.9	10.8	15.1	42
AVERAGE	178	11.1	19.7	144	12.7	18.3	14.9	11.9	19	50
LSD (p<0.05)	24	3.2	6.7	26	2.3	4.9	1.1	1.7	3.7	

* This clone, labelled as Q125, was subsequently revealed to not be Q125 using DNA marker testing. It was tested following a contrasting smut reaction being observed with Q125 in Indonesia.

Table 7. Performance of varieties in yield trial 2 in plant and first ratoon for cane yield (t/ha; TCH), CCS, sugar yield (t/ha; TSH) and fibre content (%). Also indicated is the highest stool infection rate for smut in the smut trials.

VARIETY	Plant crop			1st ratoon crop			MEAN FIBRE	MEAN CCS	MEAN TSH	SMUT%
	TCH	CCS	TSH	TCH	CCS	TSH				
MIDA$^{\phi}$	168.2	13.2	22.2	148.9	13.9	20.7	13.2	13.5	21.4	0%
Q96	173.9	13.4	23.3	138.6	14	19.4	14.8	13.7	21.4	35%
Q101	181.7	12	21.8	136.5	13.7	18.7	13.8	12.9	20.3	40%
MQ88-2022	201.1	9.1	18.3	162.3	12.2	19.8	13.8	10.6	19	0%
89-680-6	161.5	9.1	14.7	152	15.2	23.1	13.4	12.1	18.9	0%
Q155	156.8	11.8	18.5	146.2	13.2	19.3	14.3	12.5	18.9	0%
MQ80-805	154.5	12.3	19	146	12.6	18.4	14.3	12.5	18.7	3%
Q171$^{\phi}$	154.9	11.3	17.5	141.1	14.1	19.9	13.6	12.7	18.7	0%
Q124	159.3	10.8	17.2	138.6	14.5	20.1	14.2	12.7	18.7	42%
89-393-1	160.9	11.5	18.5	148	12.3	18.2	13.9	11.9	18.3	0%
Q135	170.9	11	18.8	145.5	12.1	17.6	15.1	11.6	18.2	24%
84-608-10	160.4	10.6	17	143.9	13.2	19	14.9	11.9	18	21%
Q99	172.6	11.7	20.2	126.6	12.4	15.7	13.3	12.1	17.9	3%
Q142	182.4	10.2	18.6	150.9	11.4	17.2	14.3	10.8	17.9	3%
Q130	166.7	11.1	18.5	137.7	12.2	16.8	13.8	11.7	17.7	4%
Q95	151.3	11.3	17.1	138.1	12.6	17.4	14.2	11.9	17.3	2%
KQ88-8151	154.5	12.1	18.7	122.8	12.3	15.1	13.5	12.2	16.9	0%
KQ91-2616	171.4	9.8	16.8	130.1	12.3	16	13.9	11	16.4	100%
89-518-6	159	10.5	16.7	129	12.4	16	13.5	11.5	16.3	6%
90-77-5	137.9	11.6	16	122.1	13.6	16.6	13.3	12.6	16.3	17%
ORPHEUS	148.3	11.8	17.5	124.4	11.9	14.8	14.7	11.9	16.2	15%
90-83-5	139.4	10.9	15.2	120.3	13.3	16	14.6	12.1	15.6	4%
Q125	137.9	11.6	16	94.2	12	11.3	14.3	11.8	13.7	0%
89-393-3	134.2	11.7	15.7	106.7	10.5	11.2	14.6	11.1	13.4	0%
95H4035	131.3	9.9	13	113.4	11.9	13.5	15.3	10.9	13.2	28%
89-247-5	93.7	9.5	8.9	78.4	11.6	9.1	13.9	10.6	9	4%
AVERAGE	157	11.1	17.5	132	12.7	17.0	14.1	12.7	17.2	10%
LSD		2.3	4.7		2.6	4.1		1.6	2.9	

Table 8. Performance of varieties in the GE in plant crop for cane yield (t/ha; TCH), CCS, sugar yield (t/ha; TSH) and fibre content (%). Also indicated is the highest stool infection rate for smut in the smut trials.

Variety	TCH	Fibre	CCS	TSH	Smut
95H4021	204.4	14.7	10.9	22.3	0%
95H4039	152.8	13.1	13.8	21.1	4%
Q99	169.5	13.2	12.3	20.8	3%
Q96	163.3	17	11.6	18.9	35%
95H4022	166.7	12.6	10.8	18	96%
Q135	167.1	15	10.6	17.8	24%
95H4032	163	15.4	10.0	16.4	100%
95H4010	168.2	15.2	9.7	16.3	97%
Q124	158	14.3	9.9	15.7	42%
95H4005	150.6	15.5	10.4	15.7	89%
89-518-6	158.1	12.7	9.3	14.7	6%
95H4007	134.5	14	10.9	14.6	46%
95H4027	161.5	13.4	9.0	14.5	100%
95H4023	182.8	15.1	7.8	14.3	100%
95H4003	130.4	13.2	10.6	13.8	100%
89-503-10	151.9	13.5	9.1	13.8	42%
95H4004	135.2	16.5	10.0	13.5	4%
95H4030	125.4	15.2	10.6	13.3	100%
89-680-6	125.4	13.5	10.5	13.2	0%
87-105-10	136.7	13.6	9.6	13.2	83%
89-393-3	146.1	12.8	9.0	13.1	0%
90-83-5	110.6	14.4	11.4	12.6	4%
95H4024	119.3	14.9	10.5	12.6	0%
95H4029	133	11.8	9.4	12.5	69%
90-110-9	190.4	12.3	6.5	12.3	64%
95H4048	124.8	16.1	9.8	12.2	36%
95H4047	139.5	16.9	8.7	12.2	73%
95H4035	124.1	16.5	9.0	11.1	28%
95H4033	138.9	14.6	7.3	10.1	100%
Q138	151.5	14.3	6.7	10.1	100%
95H4044	128.7	16.1	7.7	9.9	100%
90-77-2	109.1	18.3	7.9	8.6	100%
95H4001	108.7	12	7.4	8	20%
AVERAGE	146.4	14.5	9.7	14.2	53%
LSD (P<0.05)	24.8	2.2	3.28	5.53	

Table 9. Performance of varieties in Yield trial 3 in the plant crop for cane yield (t/ha; TCH), CCS, sugar yield (t/ha; TSH) and fibre content (%). Also indicated is the highest stool infection rate for smut in the smut trials.

VARIETY	TCH	FIBRE	CCS	TSH	SMUT%
Q176$^{\phi}$	185.1	15	12.0	22.1	0%
Q95	179.4	16.3	12.0	21.6	2%
KQ88-8151	152.6	17.1	13.3	20.2	0%
MQ89-673	179.3	13.7	11.0	19.7	0%
Q99	172.3	15.9	11.2	19.3	3%
Q208$^{\phi}$	184.8	16	10.3	19	40%
KQ91-71304	151.7	15.7	12.5	18.9	0%
Q146	166.7	15.5	11.3	18.9	0%
Q173$^{\phi}$	166.3	16	11.3	18.8	0%
Q151	181.7	14.4	9.8	17.8	0%
Q156	148.7	16.2	11.8	17.6	25%
Q177$^{\phi}$	172.6	14.7	10.2	17.5	0%
Q96	147.1	16.6	11.6	17.1	35%
Q171$^{\phi}$	154.1	15.6	10.9	16.9	0%
Q172$^{\phi}$	153.5	17.2	10.9	16.9	6%
Orpheus	144.8	15.5	11.4	16.4	15%
F172	146.1	16.7	10.9	15.9	21%
Q149	161.5	15.4	9.9	15.9	0%
PS79-82	175.5	15.2	8.7	15.2	28%
Q133	151.3	15.4	8.7	13.1	0%
Q175$^{\phi}$	141.1	19	9.1	13.1	0%
Mida$^{\phi}$	166.1	13.1	7.6	12.6	0%
AVERAGE	162.8	15.7	10.7	17.5	8%
LSD (P<0.05)	16.5	1.6	2.3	4.0	

5.3 Pathology services

This section provides a summary of the findings by Mr Brian Egan during the project.

All pest problems seen, plus red stripe & pokkah boeng diseases, are endemic to the Kimberley region. Pineapple disease & YLS probably have been present since the 1980s, but could also have some local component. Smut disease is the only introduction since the current Ord Sugar Industry started in the early-mid 1990s.

5.3.1 Diseases

A description of the discovery of smut and its successful management in the ORIA was reported by the project team (Engelke *et al,* 2001). **Smut disease** was located by a farmer in July 1998, but had been present for a few years prior to that. There was a large input from the project in advice on control measures up to the present time; involvement in the Federal Government Consultative Committee on Sugarcane Smut: including discussions on control in the ORIA and risk assessment for Queensland cane; development of the protocols for control; development of smut trial and variety testing procedures; inspections and ratings of all plantings of introduced varieties; inspections of commercial varieties, particularly in following smut disease incidence in Q96; investigating the situation with smut in Mida(ɸ).

Smut will always remain a threat to canegrowing in the Ord, where environmental conditions are particularly favourable for the disease. Although minor amounts of less resistant varieties could be grown if only certified smut-free planting material was used, in reality only resistant to moderately resistant varieties should be grown.

Red stripe/top rot disease continues to cause yield problems of varying intensity in commercial crops, depending on variety and environmental conditions. Q117 was the most susceptible commercial, but Mida(ɸ) is at least as bad and probably worse. We routinely see red stripe in new introduction batches, and some canes appear quite susceptible. As red stripe occurs widely in cane grass, it will always be necessary to have resistance or tolerance in commercial canes.

Pokkah boeng disease is also endemic on cane grass and other grasses in the Ord. While commonly found in some canes during periods of rapid growth, it is unlikely to cause serious problems.

Pineapple disease has caused only a few problems with germination over the years, but is easily controlled with fungicide dip or spray.

YLS (yellow leaf syndrome) was found to be fairly widespread in Ord commercial canes during surveys in 1998 – 99 in conjunction with Northern Territory University (NTU) staff on a separate SRDC project. It was also present in a number of proposed Ord introductions during quarantine in Queensland. These were rejected initially, but were

subsequently introduced after the 1998 Ord surveys confirmed YLS as present in the Ord. Pathologists in several countries are trying to establish the relevant importance of the disease. The Final Report on SRDC Project NTU001 contains further information on YLS findings in the Ord and the results of tests for phytoplasmas in the cane.

RSD (ratoon stunting disease) is the most widespread and economically important sugarcane disease in the world, but the Ord is considered to be RSDfree. A major thrust of the Protocol to Introduce Cane into the Ord is to ensure that cane imports are free of RSD – all our imports were checked for pathogen presence twice and given 2 heat treatments. Sporadic checks on commercial fields in the 1995-97 period did not find RSD. A planned survey over all varieties in half the Ord cane area in 1999 was negative. Considerable testing was also negative on a farm with an illegal introduction of Q117.

White leaf/grassy shoot diseases of grasses were found by the NTU team in the Northern Territory and the Kimberleys, including the Ord. These were related to, but distinct from, the pathogens causing WL/GSD in cane in Asia. We cooperated with NTU in this investigation, but there is no evidence that cane is in any danger of contracting either of these diseases. The Final Report on SRDC Project NTU001 contains further information on these investigations.

Fungal leaf spots of cane, so common in Queensland, PNG and Asian sugarcane, have never been seen in the Ord, probably because of the long periods of very hot, very dry weather.

5.3.2. Pests

Rats (*R.villosissimus*) caused considerable damage in several blocks in a few locations during late 1996/early 1997, with minor problems in 1997 summer also. An experienced Cane Productivity Board supervisor from Ingham surveyed the scene and provided control recommendations. Rat populations in the bush have not built up to plague proportions since, but will do so at some time.

Froghopper blight, produced by the froghopper *Eoscarta carnifex*, caused severe streaking and browning of leaves in several locations in early 1997. Q99 and Q96 were worst affected but yield losses were small. Minor effects were noted in 1998, and we can expect a recurrence of the problem at some future date.

Perkinsiella leafhopper populations built up sufficiently on a few occasions to cause considerable reddening of the leaf midrib following egglaying, as well as heavy honeydew excretions. The consequent sooty mould deposits on the leaf surfaces were very noticeable in some blocks. This insect is closely related to other *Perkinsiella* species which transmit Fiji disease and probably would be a vector, but is no real problem as long as the virus disease is kept out of the Ord

Termites have caused a few minor losses at times, mainly on the edge of blocks.

Cane killing weed (*Buchnera asperata*) caused death and stunting of cane in several small patches in one field near the aerodrome in 1996, with minor recurrence in that block at times. It has been found recently in a nearby canefield developed from bush/grassland It is endemic in Kimberley grassland & could be found in any land newly developed for cane (eg Stage 2), but is easily controlled by weedicide.

5.3.3 Other problems

An **illegal introduction of Q117** from Queensland by an Ord canegrower was discovered in 1996. A lot of time was spent with AgWA quarantine people, but legal action did not eventuate. Fortunately, intensive RSD testing of Q117 and other cane on the farm proved to be negative.

Germination and early root growth problems were checked in several blocks in April 2002. There do seem to be some problems associated with factors such as high soil temperature, wet soil, poorer quality setts, & less than adequate planting methods. Sett root production was often sparse and the roots did not look healthy, while shoot root production was slow and the few roots showed some reddening. Further investigation is warranted.

5.3.4 Passing on knowledge of cane diseases and pests to Agriculture Western Australia staff.

This has largely been a failure at the level of professional pathologists for reasons beyond our control. Both AgWA plant pathologists involved with Mr Egan in the smut campaign, other diseases and quarantine matters left W.A during the project. The cane agronomist (Mr Jim Engelke) resigned from AgWA in January 2003 and returned to Perth.

AgWA Technical Officer Tim Triglone has good knowledge of smut disease, its control and the running of resistance trials. He also was involved in all the items noted above. Cane farmers generally have a reasonable appreciation of smut & red stripe/top rot diseases & their effects, while a few have taken a deeper interest in the various problems.

6. Expected outcomes

It would seem likely (although not certain at this stage) that at least one of the varieties currently exhibiting promising performance in the trials reported here will be released to growers in the ORIA in the future and make a contribution to improving productivity. Varieties introduced in batches 6 and 7 may also make such contributions.

The methodologies developed in this project, and the experiences gained, will also help with conducting future variety introduction work for the ORIA in an efficient and effective manner. This will help facilitate provision of more productive varieties, and therefore improved profitability, for the sugar industry in the ORIA.

Advice provided by project staff, and information obtained on variety resistance to smut following the outbreak of smut in the ORIA, also helped minimize the adverse impact of smut.

Procedures developed and refined for quarantine protocols for introducing varieties into the ORIA will help maintain the region's disease free status for several important diseases (eg. RSD, leaf scald), while keeping costs and time for variety introduction to a reasonable level.

7. Discussion and recommendations

Below is a discussion of some of the previous and/or current key constraints in conducting an effective variety improvement program for the ORIA, as well as suggestions on addressing these constraints.

(i) Smut resistance

The main constraint to the delivery of profitable varieties to the Ord during the timeframe of this project was the outbreak of smut to the region at the commencement of the project. For the first few years in the project the smut resistance of most Australian varieties was unknown. It was subsequently found, from both trials in Indonesia as part of project BSS214, and in the Ord as part of this project, that about 80% of current cultivars on the east coast in Australia, and about 70% of clones coming from advanced stage selection trials in Australian breeding programs, were too susceptible to smut to be grown in the Ord. This high proportion exists because there has been no selection pressure for smut resistance in Australian breeding programs in the past because the disease has not been present in Australia. Consequently, the chances of identifying highly productive varieties suited to commercial production in the ORIA from simply evaluating Australian varieties in this project was greatly diminished.

However, this situation has changed in recent years for two reasons: (i) smut resistance ratings of all cultivars being released from Australian breeding programs, and of many

advanced stage experimental varieties, is now being obtained through an ongoing screening program in Indonesia conducted by BSES (with funding contribution from SRDC), (ii) Australian breeding programs are putting a greater emphasis on breeding for smut resistance by selective use of parents, which should result in a greater proportion of clones coming through selection systems being resistant. For both reasons, a greater proportion of varieties introduced into the ORIA in the future from Australian breeding programs should be smut resistant. This should greatly improve the cost-effectiveness ratio of future variety introduction programs.

Despite the fact that only a small proportion of varieties were smut resistant, a number of varieties were identified in the four yield evaluation trials conducted during the project with possible commercial potential. These varieties include: MQ88-2022, 89-680-6, MQ80-805, Q171$^{\phi}$, 95H4021, 95H4039, Q176$^{\phi}$ and KQ88-8151. These varieties will need to be monitored in subsequent ratoon crops, and evaluated in commercial fields before commercial release.

The fact that varieties were found exhibiting commercial value, even though only a relatively small number of varieties were effectively evaluated, suggests that it will not be difficult to identify varieties with greater profitability than the current few cultivars dominating production in the Ord. An ongoing program to introduce and evaluate smut resistant clones in the ORIA should be a high priority for R&D investment. This is also important from a risk management point of view, given the dependence of the industry currently on two main smut resistant varieties (Q95 and Q99).

(ii) Getting accurate measurements of CCS is a problem

It is recommended that consideration be given to alternative methods for estimating relative CCS of varieties being evaluated in the ORIA in the future, rather than the methods used in this project. As indicated in the results section, current methods are giving a situation where differences between varieties of over 2 units CCS are often not possible to detect. This is unacceptable given an aim of determining commercial potential of varieties. As indicated in the results section, sampling variation within plots was considered during the project as a possible cause of this problem, but the variation appeared to be more associated with between-plot variation rather than within-plot variation. One response to this would be to increase replicate number in trials, but other options are also possible.

One possible reason for such large variation may be the impacts of lodging and differential stalk deterioration following resulting stalk damage under the conditions of both heavy lodging and high temperatures. If lodging is not uniform across replicates, then differential deterioration of stalks may occur. If this is the case then it may be that indirect selection for CCS in cane grown in separate plots to the yield trials and managed to remain erect may provide a better indicator of relative CCS of experimental clones compared with standards, compared with measurement in the extremely variable conditions in the yield trials. Recent research in the Burdekin (Jackson and Morgan, 2003) illustrates that indirect selection for CCS in cane managed to remain erect is

effective. While this approach would mean that separate plots would need to be grown, such plots would only need to be single row plots (given CCS is not greatly affected by competition effects, unlike cane yield).

(iii) Consideration should be given to a multi-stage selection process, and use of farms in addition to Frank Wise Institute for conducting evaluation trials.

Because the ORIA industry is very small, only a small program and small level of resources has been, and likely will remain, available for variety improvement. This places an ongoing constraint on design of any program. However, given the small size of the program it is particularly important that the resources available be directed toward the most cost effective program design possible.

The system used in this project involved evaluating varieties first for smut resistance in small plot trials, and then for cane yield and CCS in four row trials. It is possible that in the future that varieties obtained from BSES programs which have been screened in Indonesia for smut resistance could be put into CCS/yield trials prior to smut testing in the Ord. Smut ratings measured in Indonesia appear to correlate well with level of resistance in the Ord (Figure 1). However, overseas introductions should continue to be screened for smut resistance, given an unsatisfactory correlation between overseas ratings and level of resistance observed in the Ord (Figure 2).

It is suggested that varieties be screened for both CCS and cane yield in single row plots before being placed in multi-row plot trials. Varieties that are worse than the standards by more than 2.5 units CCS, without exhibiting particularly outstanding vigour and cane yield, could be discarded. Varieties with one unit less CCS and which have particularly low cane yield in such plots could also probably be discarded. These are suggestions, and the appropriate strategy should be determined from research to assess the relationship between performance in single row plots and multi-row plot trials for both CCS and cane yield in the ORIA. However, the end objective should be to reduce the number of inferior clones entering the more expensive multi-row plot trials.

It is suggested that the multi-row plot trials be established at two sites in the ORIA, and that at least one of these, possibly both, be conducted on commercial farms rather than Frank Wise Institute. This suggestion however is controversial and there is not uniform agreement among the project team on this matter. One of us (PJ) was keen on this suggestion, but support from local AgWA staff involved in the project was lacking.

In support of this suggestion are the following arguments. First, trials can be conducted more cheaply on a farm with a cooperative grower than on an experiment station, since costs of land preparation, and cane growing (cultivation, irrigation etc) are cheaper due to economies of scale, compared with conducting these operations only for a small area associated with a trial. Second, we currently know little about G x E interactions in the ORIA. Such interactions may occur because of, for example, crop management differences, soil cropping history differences, and many unknown factors. Thus results obtained in one trial may be misleading for predicting wider adaptation. Conducting

trials routinely on at least two sites, with varieties common across sites, would serve several advantages. It would allow the magnitude of G x E interactions in the ORIA to be determined. Second, if GE interactions exist (and they nearly always do) it would lead to better selection decisions being made. Third, the increased replication (even if no GE interactions existed) would lead to greater precision in estimating relative CCS and cane yield of varieties being evaluated.

The arguments against conducting a trial on a farm are as follows. First, some varieties in the trials will be susceptible to smut, and it is undesirable to increase the level of smut innoculum on commercial farms. Also, smut affected varieties would have a low yield, and compensation to growers for lost cane yields in these plots (if it was required by the grower) could be expensive. Second, there are inconveniences or difficulties in working in with a grower and his harvesting operations, compared with the control that is able to be maintained on an experiment station.

It is possible that both the concerns about farm trials could be addressed. First, with adequate smut screening that is now occurring before planting trials, the number of smut susceptible varieties entering yield trials should be minimized. Second, it would appear that breeding program staff in the Burdekin (which has a similar production system to the ORIA, including irrigation after planting and burning before harvest) are readily able to conduct successful trials with growers. Perhaps the reluctance to undertake farm trials in the latter respect may be associated with lack of experience in attempting such trials.

Finally, it is recommended that some type of managed commercial scale strip trial be conducted on varieties that have performed well in the 4-row trial format, and which are being considered for commercial production. Preparation and conduct of such trials could commence before commercial release of varieties, and continue following release. Results from such trials could be used to help inform growers about the worthiness, or otherwise, of newly released varieties, at the same time as they are bulking up seed, or making decisions about large scale commercial plantings on their farms.

In summary, it is recommended that a three-stage evaluation program be conducted for smut resistant varieties entering the ORIA, as follows:
(i) a 2 replicate x 1 row x 10m plot trial, for pre-screening varieties. This would discard varieties with low CCS in particular, but also those clearly not adapted to ORIA due to problems with top rot, smut susceptibility, or other obvious defects. Perhaps about 40-50% of varieties could be discarded based on results in these trials. This would also serve to bulk up planting material for the next stage. It is suggested that these plots be managed so that the cane remains erect (by limiting irrigation inputs) to ensure accurate CCS measurement and ease of sampling and obtaining planting material. Optimal selection intensity and selection criteria should be based on a small research experiment done in association with future variety introduction work, designed to examine the relationship between single row plots managed in such a manner and subsequent multi-row plot trials managed under commercial conditions in the ORIA.
(ii) 3 replicates per site x 4 rows x 10m x 2 sites trial, for screening promising varieties from stage (i) above. These could be conducted in a similar manner to current trials. It is

possible that an average across all six replicates for CCS would allow for sufficient accuracy in CCS determination. However, if not, consideration should be given to concurrent evaluation of the same set of varieties in single row plots managed to remain erect via restricted irrigation. The genetic correlation between CCS measured in such environments and under normal commercial conditions would be easily examined during the first time this was done. If it was found that the erect single row plots provided an adequate predictor of commercial CCS, then sampling for CCS in the 4 row plots at harvest could be discontinued.

(iii) A strip trial program of varieties identified in (ii) as having commercial potential. It is suggested such strips could be done on perhaps 5 or 6 farms, with weights and CCS determined in association with cane delivery to the mill. Such trials should be largely conducted by growers, following clear instructions from professional staff. The advantage to growers in conducting such trials would be to observe and accurately measure the performance of promising new varieties directly on their own farms, in order to make correct decisions on best varieties to plant more widely. Varieties in such strip trials should include 2 or 3 current commercial varieties, and 1 to 3 of the most promising varieties being considered for release or recently released. Results should be widely communicated to all growers. If strip trials were conducted on a reasonable number of farms, and fields chosen were uniform, replication within strip trials on farms would be unnecessary, with replication being obtained by pooling all strip trials together in interpretation of results and making recommendations for all growers. However, replication of at least one variety within each strip trial at least three times is desirable to assess level of repeatability within each farm, and relative reliability of results from each of the farms.

(iv) The best way to source varieties for the ORIA.

The quality of varieties released to the ORIA in the future will be related to the quality of the selection system (as per point (iii) above) and the quality of best varieties entering that system. In this project it was assumed that varieties performing well in the east coast of Queensland had a better chance of performing well than those that did not. Hence, varieties selected from these programs, including released cultivars, were introduced. Concurrent with CTA043, another project funded by SRDC, CTA028 (called the “Mega GxE project”) was being conducted. This project involved evaluating about 50 randomly selected seedling clones across sites within all sugarcane growing regions in Australia. The aim was to determine how information about relative performance of clones in any one region could predict their performance in other regions. The project was considered to be especially important to the ORIA because this region was probably too small to support its own breeding program. Varieties should be sourced from selection trials in other regions where some pre-screening had already been done, and so could be useful for picking superior varieties for the Ord. Unfortunately, the design of the trials in the Ord were compromised mainly due to the outbreak of smut. Because it was known that smut would greatly affect performance of clones in the Ord, it was decided to only include varieties in this trial exhibiting at least a moderate level of resistance based on early observations. This has reduced numbers of clones included to 32. It was also decided to only plant this trial on one location (Frank Wise Institute) and not on a farm.

This may limit the interpretation of the results, but it is still hoped that some guidance might be obtained as to the usefulness or otherwise of the east coast trials in predicting performance in the Ord. Results from this project should be finalized in 2004, with some recommendations made for the Ord.

It will also be interesting to assess the performance of overseas varieties in the ORIA for CCS and yield. Results from evaluation of clones in batches 6 and 7 should provide guidance on the relative adaptation of clones from a range of overseas countries compared with those from Australia.

It is of interest that several random (ie. non-selected) clones have shown commercial promise in the ORIA. While it is too early to make firm conclusions, this result may be indicative of the ORIA being unlike other regions in terms of variety adaptation requirements. If this is the case, then introduction of seed and evaluation of seedlings may be a cheaper and just as effective option as introduction of setts from varieties selected elsewhere. Seed should be preferentially sought from varieties identified as performing well in the ORIA based on trials conducted to date, and of course smut resistance in parents would be a pre-requisite.

In summary, the issue of where best to source germplasm in future for entry into selection trials in the ORIA is important and results soon to be obtained in CTA028 and from evaluation of overseas program varieties will be important in determining directions in this regard. In the immediate future, it is recommended that varieties from Australian breeding programs which have already been identified as being smut resistant in trials in Indonesia, be imported to the ORIA and evaluated for agronomic suitability.

9. Publications relating to project activity:

Engelke, J.H., Egan, B.T., Sherrard, J.H., Triglone, T.and Jackson, P.A. 2001. Sugarcane smut: successful management in the Ord. *Proc. Aust. Soc. Sugar Cane Technol*. pp. 268-273.

McKirdy, S.J., Riley, I.T.and Egan, B.T. 1999. Development and implications of the sugarcane smut epidemic in the Ord River Irrigation Area. *Proc. 12th Biennial Conf. Australasian Plant Path. Soc.* Canberra, Australia, p 193 (Abstract).

Riley, I.T., Jubb, T., Egan, B.T. and Croft, B.J. 1999. First outbreak of sugarcane smut in Australia. *Proc. Internat. Soc. Sugar Cane Technol*. 23: 333-337.

10. References

Ferriera, S. A. and Comstock, J.C. 1989. Smut. In: Ricaud, C., Egan, B.T., Gillespie, A.G. Jr and Hughes, C.G. eds. Diseases in Sugarcane – Major diseases. Elsevier Science Publishers, Amsterdam, 211-229.

Jackson, P.A. and Morgan, T.E. 2003. Early stage selection for commercial cane sugar (CCS) in sugarcane clones: effects of time of sampling and irrigation. *Aust J. Agric. Res.* 54: 389-396.

Appendix 1. List of clones introduced to the Ord, place of origin, year of introduction to the Ord, trials each was included in (Y indicates it was included in the trial), and level of smut infection (% of stools infected when maximum level of infection of the trial was obtained). ST1, ST2, ST3 and ST4 refer to smut trials 1 to 4, respectively. YT1, YT2, YT3, YT4 refer to yield trials 1 to 4 respectively.

Year of Introduction	Batch	Variety	Origin	ST1	YT1	ST2	YT2	ST3	YT3	GxE	ST4	YT4	SMUT %
1980	Prior	H51-8194	Hawaii	Y									17%
1980	Prior	NCO310	South Africa	Y		Y		Y			Y		92%
1980	Prior	Q101	QLD BSES	Y		Y	Y				Y		40%
1980	Prior	Q107	QLD BSES	Y		Y							57%
1980	Prior	Q113	QLD BSES	Y									72%
1980	Prior	Q115	QLD BSES	Y									94%
1980	Prior	Q117	QLD BSES	Y		Y		Y					96%
1980	Prior	Q120	QLD BSES	Y									48%
1980	Prior	Q121	QLD BSES	Y									98%
1980	Prior	Q91	QLD BSES	Y									100%
1980	Prior	Q95	QLD BSES	Y		Y	Y	Y	Y		Y		2%
1980	Prior	Q96	QLD BSES	Y	Y	Y	Y	Y	Y	Y	Y	Y	35%
1980	Prior	Q99	QLD BSES	Y	Y	Y	Y	Y	Y	Y	Y	Y	3%
1997	1	84-255-10	CSR Macknade	Y									100%
1997	1	84-255-4	CSR Macknade	Y									100%
1997	1	84-608-3	CSR Macknade	Y									79%
1997	1	86-1151-3	CSR Macknade	Y									100%
1997	1	87-105-10	CSR Macknade	Y						Y			83%
1997	1	87-628-3	CSR Macknade	Y									100%
1997	1	88-271-6	CSR Macknade	Y									100%
1997	1	88-402-2	CSR Macknade	Y									84%
1997	1	89-503-10	CSR Macknade	Y	Y					Y			42%
1997	1	89-518-6	CSR Macknade	Y	Y	Y	Y			Y			6%
1997	1	89-680-3	CSR Macknade	Y	Y	Y							8%
1997	1	89-680-6	CSR Macknade	Y		Y	Y			Y			0%
1997	1	90-110-9	CSR Macknade	Y						Y			64%
1997	1	90-77-2	CSR Macknade	Y						Y			100%
1997	1	BMQ89-14	CSR Macknade	Y	Y								80%
1997	1	BMQ89-15	CSR Macknade	Y	Y								95%
1997	1	BMQ89-77	CSR Macknade	Y	Y								100%
1997	1	H73-6110	Hawaii	Y									0%
1997	1	KQ88-8075	QLD CSR Kalamia	Y	Y								75%
1997	1	KQ91-31405	QLD CSR Kalamia	Y	Y			Y					48%
1997	1	KQ91-31508	QLD CSR Kalamia	Y	Y			Y					42%
1997	1	Mida[◊]	CSR Macknade	Y	Y	Y	Y	Y	Y				0%
1997	1	MQ74-110	CSR Macknade	Y	Y								100%
1997	1	MQ79-141	CSR Macknade	Y	Y								68%
1997	1	MQ87-155	CSR Macknade	Y	Y								77%

Year of Introduction	Batch	Variety	Origin	ST1	YT1	ST2	YT2	ST3	YT3	GxE	ST4	YT4	SMUT %
1997	1	ORPHEUS	CSR Macknade	Y	Y	Y	Y	Y	Y				15%
1997	1	PELORUS	CSR Macknade	Y	Y								44%
1997	1	Q125	QLD BSES	Y	Y	Y	Y						0%
1997	1	Q127	QLD BSES	Y	Y								100%
1997	1	Q138	QLD BSES	Y	Y					Y			100%
1997	1	Q142	QLD BSES	Y	Y	Y	Y						3%
1997	1	Q155	QLD BSES	Y	Y	Y	Y						0%
1997	1	Q157	QLD BSES	Y									100%
1997	1	Q161	QLD BSES	Y	Y	Y							70%
1997	1	Tellus$^{\phi}$	CSR Macknade	Y	Y								97%
1998	1.1	89-338-1	CSR Macknade	Y									100%
1998	1.1	89-393-3	CSR Macknade	Y		Y	Y			Y			0%
1998	1.1	90-77-5	CSR Macknade	Y		Y	Y						17%
1998	1.1	BMQ89-338	CSR Macknade	Y									100%
1998	1.1	CP74-2005	USA Canal Point	Y		Y							13%
1998	1.1	EOS	QLD CSR	Y									100%
1998	1.1	MQ87-1069	CSR Macknade	Y									100%
1998	1.1	Q122	QLD BSES	Y	Y								100%
1998	1.1	Q124	QLD BSES	Y	Y		Y			Y			42%
1998	1.1	Q145	QLD BSES	Y		Y		Y					24%
1998	1.1	Q159	QLD BSES	Y									100%
1998	1.1	Q162	QLD BSES	Y									100%
1998	1.1	Q164	QLD BSES	Y									100%
1998	2	84-608-10	CSR Macknade	Y		Y	Y						21%
1998	2	84-608-6	CSR Macknade	Y						Y			100%
1998	2	89-247-5	CSR Macknade	Y		Y	Y						4%
1998	2	89-393-1	CSR Macknade	Y		Y	Y						0%
1998	2	89-503-6	CSR Macknade	Y									100%
1998	2	89-605-1	CSR Macknade	Y									92%
1998	2	90-83-5	CSR Macknade	Y		Y	Y			Y			4%
1998	2	KQ87-7339	QLD CSR Kalamia	Y									100%
1998	2	KQ91-1003	QLD CSR Kalamia	Y									100%
1998	2	MQ63-693	CSR Macknade	Y									94%
1998	2	MQ80-805	CSR Macknade	Y			Y						3%
1998	2	MQ84-524	CSR Macknade	Y									97%
1998	2	MQ87-540	CSR Macknade	Y									85%
1998	2	MQ88-2022	CSR Macknade	Y		Y	Y						0%
1998	2	Q130	QLD BSES	Y		Y	Y						4%
1998	2	Q135	QLD BSES	Y		Y	Y	Y		Y			24%
1998	2	Q137	QLD BSES	Y									84%
1998	2	Q150	QLD BSES	Y									97%
1998	2	Q154	QLD BSES	Y									97%
1998	2	Q158	QLD BSES	Y									100%
1998	2	ROC-1	Taiwan	Y									67%

Year of Introduction	Batch	Variety	Origin	ST1	YT1	ST2	YT2	ST3	YT3	GxE	ST4	YT4	SMUT %
1998	2	TS68-830	Thailand	Y									100%
1998	2	H78-7234	Hawaii	Y									67%
1999	3	67N3184	QLD BSES			Y							100%
1999	3	KQ88-8151	QLD CSR Kalamia			Y	Y	Y	Y				0%
1999	3	KQ91-2616	QLD BSES			Y	Y						100%
1999	3	Q141	QLD BSES			Y							100%
1999	3	Q165[ф]	QLD BSES			Y							100%
1999	3	Q171[ф]	QLD BSES			Y	Y		Y				0%
1999	3.1	95H4001	QLD BSES			Y				Y			20%
1999	3.1	95H4003	QLD BSES			Y				Y			100%
1999	3.1	95H4004	QLD BSES			Y				Y			4%
1999	3.1	95H4005	QLD BSES			Y				Y			89%
1999	3.1	95H4006	QLD BSES			Y							100%
1999	3.1	95H4007	QLD BSES			Y				Y			46%
1999	3.1	95H4008	QLD BSES			Y							100%
1999	3.1	95H4010	QLD BSES			Y				Y			97%
1999	3.1	95H4012	QLD BSES			Y							100%
1999	3.1	95H4016	QLD BSES			Y							100%
1999	3.1	95H4017	QLD BSES			Y							100%
1999	3.1	95H4018	QLD BSES			Y							100%
1999	3.1	95H4020	QLD BSES			Y							100%
1999	3.1	95H4021	QLD BSES			Y				Y			0%
1999	3.1	95H4022	QLD BSES			Y				Y			96%
1999	3.1	95H4023	QLD BSES			Y				Y			100%
1999	3.1	95H4024	QLD BSES			Y				Y			0%
1999	3.1	95H4027	QLD BSES			Y				Y			100%
1999	3.1	95H4029	QLD BSES			Y				Y			69%
1999	3.1	95H4030	QLD BSES			Y				Y			100%
1999	3.1	95H4032	QLD BSES			Y				Y			100%
1999	3.1	95H4033	QLD BSES			Y				Y			100%
1999	3.1	95H4035	QLD BSES			Y	Y			Y			28%
1999	3.1	95H4037	QLD BSES			Y							100%
1999	3.1	95H4039	QLD BSES			Y				Y			4%
1999	3.1	95H4040	QLD BSES			Y							18%
1999	3.1	95H4044	QLD BSES			Y				Y			100%
1999	3.1	95H4046	QLD BSES			Y							100%
1999	3.1	95H4047	QLD BSES			Y				Y			73%
1999	3.1	95H4048	QLD BSES			Y				Y			36%
1999	3.1	Q179[ф]	QLD BSES			Y							100%
2000	4	KQ91-21815	QLD CSR Kalamia					Y					100%
2000	4	KQ91-71304	QLD CSR Kalamia					Y	Y		Y		0%
2000	4	KQ92-21908	QLD CSR Kalamia					Y					93%
2000	4	Q133	QLD BSES					Y	Y		Y		0%
2000	4	Q176[ф]	QLD BSES					Y	Y		Y		0%

Year of Introduction	Batch	Variety	Origin	ST1	YT1	ST2	YT2	ST3	YT3	GxE	ST4	YT4	SMUT %
2000	4	Q177[Φ]	QLD BSES					Y	Y		Y		0%
2000	4	Q180[Φ]	QLD BSES					Y					86%
2000	4	Q183[Φ]	QLD BSES					Y					60%
2000	5	79S2954	QLD BSES					Y					70%
2000	5	85A2234	QLD BSES					Y					100%
2000	5	86A4014	QLD BSES					Y					100%
2000	5	87A1413	QLD BSES					Y	Y		Y		40%
2000	5	88A1515	QLD BSES					Y					78%
2000	5	90A428	QLD BSES					Y					88%
2000	5	BMQ89-155	CSR Macknade					Y					100%
2000	5	F172	Formosa (Taiwan)					Y	Y				21%
2000	5	F177	Formosa (Taiwan)					Y					60%
2000	5	KQ92-20111	QLD CSR Kalamia					Y					89%
2000	5	KQ92-32413	QLD CSR Kalamia					Y					100%
2000	5	MQ89-673	CSR Macknade					Y	Y				0%
2000	5	MQ90-217	CSR Macknade					Y			Y		100%
2000	5	Q144	QLD BSES					Y					96%
2000	5	Q146	QLD BSES					Y	Y		Y		0%
2000	5	Q149	QLD BSES					Y	Y		Y		0%
2000	5	Q151	QLD BSES					Y	Y		Y		0%
2000	5	Q156	QLD BSES					Y	Y		Y		25%
2000	5	Q162	QLD BSES					Y					100%
2000	5	Q172[Φ]	QLD BSES					Y	Y		Y		6%
2000	5	Q173[Φ]	QLD BSES					Y	Y		Y		0%
2000	5	Q175[Φ]	QLD BSES					Y	Y		Y		0%
2000	5.1	PS77-1553	Indonesia					Y					100%
2000	5.1	PS79-208	Indonesia					Y					96%
2000	5.1	PS79-82	Indonesia					Y	Y				28%
2000	5.1	PS80-1007	Indonesia					Y			Y		67%
2000	5.1	PS80-847	Indonesia					Y					63%
2000	5.1	PS81-1337	Indonesia					Y					100%
2000	5.1	PS81-5132	Indonesia					Y					90%
2000	5.1	PS82-13	Indonesia					Y					55%
2000	5.1	PS82-3605	Indonesia					Y					86%
2001	6	68W1049	South Africa								Y		69%
2001	6	78F1025	South Africa								Y		74%
2001	6	86C451	QLD BSES								Y		100%
2001	6	BJ7452	Jamaica								Y		53%
2001	6	BT65152	Barbados								Y		69%
2001	6	C1616-75	Cuba								Y		60%
2001	6	CASSIUS	QLD CSR								Y	Y	0%
2001	6	C-GD-24	China								Y	#N/A	56%
2001	6	CL74-1217	USA Florida								Y		76%
2001	6	CO8232	India								Y	Y	0%

Year of Introduction	Batch	Variety	Origin	ST1	YT1	ST2	YT2	ST3	YT3	GxE	ST4	YT4	SMUT %
2001	6	CP75-1322	USA Canal Point								Y	Y	0%
2001	6	EAK7076	East Africa								Y		100%
2001	6	H60-3802	Hawaii								Y	Y	0%
2001	6	IAC52-150	Brazil								Y		90%
2001	6	JA64-19	Cuba								Y		79%
2001	6	LF68-10140	Fiji								Y		100%
2001	6	MS70-611	China								Y	Y	0%
2001	6	N14	South Africa								Y	Y	0%
2001	6	N17	South Africa								Y	Y	0%
2001	6	N19	South Africa								Y		88%
2001	6	N22	South Africa								Y	Y	0%
2001	6	PHIL66-07	Philippines								Y		88%
2001	6	Q129	QLD BSES								Y	Y	0%
2001	6	Q182[◊]	QLD BSES								Y		0%
2001	6	R80-542	Reunion								Y		100%
2001	6	R81-970	Reunion								Y		39%
2001	6	RB76-5418	Brazil								Y		55%
2001	6	RB80-5004	Brazil								Y		85%
2001	6	SP79-2313	Brazil								Y		29%
2001	6	TC4	Malaysia								Y		43%
2001	6	TC5	Malaysia								Y	Y	0%
2001	6	TC6	Malaysia								Y		53%
2001	6	TS68-2599	Taiwan								Y		100%
2001	6	TUC74-24	Argentina								Y	Y	0%
2001	6	VMC67-315	Philippines								Y	Y	0%
2001	6.1	CP81-1405	USA Canal Point								Y		17%
2001	6.1	CP88-1409	USA Canal Point								Y		11%
2001	6.1	CP88-1508	USA Canal Point								Y		46%
2001	6.1	CP88-1540	USA Canal Point								Y		0%
2001	6.1	CP88-1762	USA Canal Point								Y	Y	0%
2001	6.1	CP92-1213	USA Canal Point								Y		44%
2001	6.1	CP92-1641	USA Canal Point								Y	Y	0%
2001	6.1	CP92-1666	USA Canal Point								Y		33%
2001	6.1	H78-3567	Hawaii								Y		0%
2001	6.1	H78-3606	Hawaii								Y		0%
2001	6.1	H83-7206	Hawaii								Y		0%
2001	6.1	H84-0778	Hawaii								Y		0%
2001	6.1	H85-7362	Hawaii								Y		96%
2001	6.1	H87-4094	Hawaii								Y		0%
2001	6.1	H87-4319	Hawaii								Y		33%
2001	6.1	HCP85-845	USA								Y	Y	0%
2001	6.1	HCP91-555	USA								Y	Y	4%
2001	6.1	LCP85-384	USA								Y	Y	0%
2001	6.1	LCP86-454	USA								Y	Y	0%

Year of Introduction	Batch	Variety	Origin	ST1	YT1	ST2	YT2	ST3	YT3	GxE	ST4	YT4	SMUT %
2001	6.1	M1176-77	Mauritius								Y		0%
2001	6.1	M1551-80	Mauritius								Y		95%
2001	6.1	M1658-78	Mauritius								Y		88%
2001	6.1	M2350-79	Mauritius								Y		38%
2001	6.1	M261-78	Mauritius								Y		92%
2001	6.1	M52-78	Mauritius								Y		68%
2001	6.1	N23	South Africa								Y	Y	0%
2001	6.1	N24	South Africa								Y		73%
2001	6.1	N25	South Africa								Y		53%
2001	6.1	N26	South Africa								Y	Y	0%
2001	6.1	N28	South Africa								Y	Y	13%
2001	6.1	N29	South Africa								Y		12%
2001	6.1	N30	South Africa								Y		26%
2001	6.1	N31	South Africa								Y		75%
2001	6.1	R84-0075	Reunion								Y		94%
2001	6.1	R84-0408	Reunion								Y		100%
2001	6.1	R84-0472	Reunion								Y		94%
2001	6.1	R85-0252	Reunion								Y		100%
2001	6.1	R85-0348	Reunion								Y		93%
2001	6.1	R85-0449	Reunion								Y		0%
2001	6.1	R85-0579	Reunion								Y		49%
2001	6.1	R85-0699	Reunion								Y		100%
2001	6.1	R85-0991	Reunion								Y		24%
2001	6.1	R85-1102	Reunion								Y		36%
2001	6.1	R85-1157	Reunion								Y		43%
2001	6.1	R85-1238	Reunion								Y	Y	3%
2001	6.1	R85-1334	Reunion								Y		92%
2001	6.1	ROC13	Taiwan								Y	Y	0%
2001	6.1	ROC15	Taiwan								Y		73%
2001	6.1	ROC16	Taiwan								Y		46%
2001	6.1	SP77-5181	Brazil								Y		92%
2001	6.1	SP79-2233	Brazil								Y		100%
2001	6.1	SP80-1816	Brazil								Y		0%
2001	6.1	SP80-1836	Brazil								Y		0%
2001	6.1	SP80-1842	Brazil								Y		51%
2001	6.1	SP80-185	Brazil								Y	Y	6%
2001	6.1	SP81-1763	Brazil								Y		31%
2001	6.1	SP81-3250	Brazil								Y		40%
2001	6.1	SP83-5073	Brazil								Y	Y	0%
2001	6.1	TCP87-3388	USA								Y	Y	0%
2001	6.1	CP89-2377	USA								Y		96%
2002	7	BN89-3086	??NSW										
2002	7	BN89-3107	??NSW										
2002	7	CL61-620	LOUSIANA										

Year of Introduction	Batch	Variety	Origin	ST1	YT1	ST2	YT2	ST3	YT3	GxE	ST4	YT4	SMUT %
2002	7	CO1007	India										
2002	7	CO7709	India										
2002	7	CO7804	India										
2002	7	CO8231	India										
2002	7	CP63-588	USA Canal Point										
2002	7	CP67-412	USA Canal Point										
2002	7	CP70-1133?	USA Canal Point										
2002	7	CP72-2086	USA Canal Point										
2002	7	CP72-356	USA Canal Point										
2002	7	CP75-1082	USA Canal Point										
2002	7	DB701-72	Guyana										
2002	7	H70-6957	Hawaii										
2002	7	H74-4527	Hawaii										
2002	7	IAC58-480	Brazil										
2002	7	M1030-71	Mauritius										
2002	7	M447 67	Mauritius										
2002	7	MQ84-88	QLD CSR Macknade										
2002	7	N18	South Africa										
2002	7	N21	South Africa										
2002	7	PHIL66-07	Phillipines										
2002	7	Q170[(])	QLD BSES										
2002	7	Q190[(])	QLD BSES										
2002	7	RB72-1012	Brazil										
2002	7	RB72-5147(?)	Brazil										
2002	7	RB72-5828	Brazil										
2002	7	RB73-9735	Brazil										
2002	7	ROC10	Taiwan										
2002	7	ROC9	Taiwan										
2002	7	SP70-1143	Brazil										
2002	7	SP70-1284	Brazil										
2002	7	SP71-1406	Brazil										
2002	7	SP71-6180	Brazil										
2002	7	SP71 8210	Brazil										
2002	7	TUC71-16(?)	Argentina										
2002	7	TUC71-7	Argentina										
2002	7	VMC71-238	Phillipines										
2002	7	VMC71-39	Phillipines										
2002	7	VMC73-229	Phillipines										
2002	7.1	B75-466	France - ex Barbados										
2002	7.1	B77-602	France - ex Barbados										
2002	7.1	B78-208	France - ex Barbados										
2003	8	B80-251	France - ex Barbados										
2003	8	B80-689	France - ex Barbados										
2003	8	B82-238	France - ex Barbados										

Year of Introduction	Batch	Variety	Origin	ST1	YT1	ST2	YT2	ST3	YT3	GxE	ST4	YT4	SMUT %
2002	7.1	BBZ82-57	France - ex Barbados										
2002	7.1	BJ70-15	France - ex Barbados										
2003	8	BJ74-65	France - ex Barbados										
2002	7.1	BJ75-04	France - ex Barbados										
2002	7.1	BJ76-27	France - ex Barbados										
2002	7.1	BJ82-119	France - ex Barbados										
2002	7.1	ROC 14	PRC										
2002	7.1	BJ82-26	France - ex Barbados										
2003	8	BR82-30	France - ex Barbados										
2002	7.1	BT74-209	France - ex Barbados										
2002	7.1	CC84-75	Colombia										
2003	8	CC85-6311	Colombia										
2002	7.1	CC85-68	Colombia										
2003	8	CC87-434	Colombia										
2003	8	CC89-2000	Colombia										
2002	7.1	CP86-1633	USA Canal Point										
2002	7.1	CP89-2376	USA Canal Point										
2002	7.1	CP89-2377	USA Canal Point										
2002	7.1	CP94-1100	USA Canal Point										
2002	7.1	CP94-1340	USA Canal Point										
2002	7.1	CP94-1607	USA Canal Point										
2003	8	CR74-250	France - ex Barbados										
2002	7.1	CR80-291	France - ex Barbados										
2002	7.1	D84-15	France - ex Barbados										
2002	7.1	DB71-60	France - ex Barbados										
2002	7.1	DB75-159	France - ex Barbados										
2003	8	DB78-69	France - ex Barbados										
2002	7.1	H73-3775	Hawaii										
2002	7.1	H73-5659	Hawaii										
2002	7.1	H75-6104	Hawaii										
2002	7.1	H79-2583	Hawaii										
2002	7.1	H79-7808	Hawaii										
2002	7.1	H80-4551	Hawaii										
2003	8	H81-6025	Hawaii										
2002	7.1	M1246-84	Mauritius										
2003	8	M1334-84	Mauritius										
2003	8	M1394-86	Mauritius										
2003	8	M1400-86	Mauritius										
2002	7.1	M96-82	Mauritius										
2003	8	N27	South Africa										
2003	8	N35	South Africa										
2003	8	R570	France - ex Reunion										
2002	7.1	SP83-2487	Brazil										
2002	7.1	SP84-1431	Brazil										

Year of Introduction	Batch	Variety	Origin	ST1	YT1	ST2	YT2	ST3	YT3	GxE	ST4	YT4	SMUT %
2002	7.1	SP84-2025	Brazil										
2003	8	SP84-5560	Brazil										
2002	7.1	SP85-3877	Brazil										
2002	7.1	SP85-5077	Brazil										
2002	7.1	SP86-155	Brazil										
2003	8	SP87-344	Brazil										
2002	7.1	SP87-365	Brazil										
2002	7.1	SP87-396	Brazil										
2002	7.1	ROC 17	PRC										
2002	7.1	ROC 11	PRC										
2002	7.1	CP81-1405	USA Canal Point										
2002	7.1	LCP85-384	Lousiana Canal Point									Y	
2002	7.1	SP80-3280	Brazil										
2002	7.1	SP71-8210	Brazil										

Appendix 2. Protocol for introduction of cane to the ORIA. This was signed by the Director General of Agriculture Western Australia on 15 June, 2000.

ALTERNATIVE PROTOCOL FOR GROWTH IN QUARANTINE AND DISEASE SCREENING OF SUGAR-CANE SETTS TO BE IMPORTED INTO WESTERN AUSTRALIA ABOVE 26 DEGREES SOUTH FROM QUEENSLAND

I, Graeme Albert Robertson, Director General of Agriculture, appointed for the purposes of the Agriculture Act 1988, and acting in that capacity for the purposes of Regulation 5 of the Plant Diseases Regulations 1989 hereby approve the following alternative conditions for setts to those in section 2 of the "protocol for growth in quarantine and disease screening of sugar-cane propagating material to be imported into Western Australia above 26 degrees south from other states and territories" which I approved on 15 November 1998.

Setts to be certified by a Plant Pathologist (approved by the Chief Quarantine Officer (Plants)) as follows.

(i) Plant Source Collection

(a) Either collected from an area free from Fiji disease and that the plants were visually free from Fiji disease;
OR derived from parent plants that had been grown in an insect proof glasshouse approved by the Chief Quarantine Officer (Plants) and tested and found free from Fiji disease by a PCR-based (polymerase chain reaction) diagnostic test.

AND

(b) Either collected from an area where sugar-cane mosaic virus has not been found for at least five years;
OR derived from parent plants that had been grown in an insect proof glasshouse approved by the Chief Quarantine Officer (Plants) and tested and found free from sugar-cane mosaic virus by a PCR-based (polymerase chain reaction) diagnostic test.

AND

(c) Either collected from an area where leaf scald disease has not been found for at least 5 years, or from parent plants grown in an apparently leaf scald free location and derived from setts soaked in water at ambient temperatures for 40-48 hours followed by hot water treatment at 50^0 C for 3 hours.

AND

(d) Derived from parent plants that have been tested and found free from ratoon stunting disease by immunofluorescence *or* phase contrast microscopy of xylem sap or by ELISA.

AND

(e) Grown in a 'Special Plot' operated by CSR, CSIRO, BSES or the local Cane Protection and Productivity Board (CPPB), and which is either in semi-isolation or on a farm with an excellent history for freedom from major diseases. The plot is not to be adjacent to a field with RSD. The plot should be planted with Cold Soak/Long Hot Water Treated (CS/LHWT) setts from known healthy sources, tested for RSD, or with first progeny of treated setts taken from CPPB Clean Seed Plots.

(ii) Treatment after collection

(a) Thoroughly inspected and found free from pests, diseases and soil.
AND

(b) Leaf sheaths removed and the setts thoroughly washed with soapy water.

AND

(c) Cut into one-eye setts, with the ends and any tissue rots cut off and the waste material safely disposed of by autoclaving or incineration.

AND

(d) The one-eye setts soaked in water at ambient temperature for 40-48 hours and then in hot water (50^0C) for 3 hours to control chlorotic streak, leaf scald and ratoon stunting diseases.

AND

(e) Dipped in a fungicide for control of pineapple disease at the manufacturer's recommended rate and planted in sterilised potting medium or a vermiculite/perlite mixture with no organic matter or soil.

(iii) Growth in a quarantine glasshouse

(a) Varieties to be tested for RSD, then setts from tested stools given CS/LHWT prior to quarantine glasshouse planting in Brisbane.

AND

(b) Grown under quarantine for one year in an insect proof facility (approved by the Chief Quarantine Officer (Plants)) and regularly inspected for disease.
AND

(c) Test for RSD-freedom prior to sending to Western Australia.

(iv) Growth in Western Australia north of 26 degrees south

(a) After the prescribed period in the quarantine glasshouse (section 2(iii)), the sugarcane clones shall be certified by a Plant Pathologist (approved by the Chief Quarantine Officer (Plants)) as meeting the approved protocol for entry into the area of Western Australia north of 26 degrees south. Note - Under Commonwealth Quarantine Proclamation No 55P the Director of Quarantine is required to issue a permit.

AND

(b) Setts are to be planted in open quarantine north of 26 degrees south, isolated from the nearest field grown cane by 500m and inspected regularly by an Agriculture Western Australia Plant Pathologist or other Plant Pathologist (approved by the Chief Quarantine Officer (Plants)) for one crop cycle of 10-12 months. If at the end of the crop cycle the Agriculture Western Australia Plant Pathologist declares that the sugar-cane is free from disease it is to be released from quarantine.

_____ _____

SIGNED DATE