Review of the R&D Response to Sugarcane Smut with Special Reference to the SmutBuster Research Program

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16-20 February, 2009

EXECUTIVE SUMMARY

The incursion of sugarcane smut in Queensland in 2006 represented a potentially severe crisis for an extremely important Australian agricultural industry. The severity of the incursion was alleviated by the preparedness of the sugarcane industry as a result of the smut incursion plan and earlier collaborative testing of germplasm for smut resistance, firstly in Indonesia and, after 1998, in Western Australia as well.

Even though the industry was well prepared, there was a huge effort to combat the disease following the incursion into Queensland, particularly during the period when eradication was considered a possibility. Much was accomplished by BSES and QDPI&F staff who were under severe pressure to address the many uncertainties created by the presence of the disease.

It was soon realised that the only solution to the problem was for the industry to adopt smut-resistant varieties. As 80% of the commercial crop consisted of smut-susceptible varieties, this required a comprehensive review of the sugarcane improvement program with the objective of developing resistant varieties with acceptable agronomic performance in the shortest possible time. An appropriate program was developed, and was funded by BSES, CSIRO, QDPI&F, and SRDC. Some of the funding provided by the Federal Government, through SRDC, included a requirement to review the smut resistance breeding strategy early in 2009.

The outcomes in terms of adoption of new, smut-resistant varieties by growers and the adoption of smut-resistance breeding strategies by the BSES-CSIRO sugarcane improvement program appear to have been very effective. Resistant varieties are being widely adopted, additional resistant varieties are being released to the industry, and a comprehensive research program was developed to minimise the effect of sugarcane smut on the industry.

In order to ensure the recovery of valuable genes for agronomic traits in germplasm classified as susceptible, the SmutBuster sub-program was initiated. This was to enable accelerated development of smut-resistant

clones with high agronomic value. SmutBuster includes a substantial research component addressing a wide range of screening methods.

Having received presentations by participants in the BSES-CSIRO sugarcane improvement program, 16-19 February, 2009, the review panel commissioned to examine the R&D response to sugarcane smut make the following specific recommendations:

Recommendation 1*: One more series of SmutBuster crosses should be initiated. An assessment of progress should then be made to decide when to curtail the program.*

Recommendation 2*: The panel recognises the significant value inherent in crossing to and among varieties classified as susceptible, and the further use of smut-susceptible varieties is likely to be justified beyond the life of the SmutBuster program.*

Recommendation 3*: The level of resistance in SmutBuster crosses should be assessed by ratooning the inoculated disease trials rather than ploughing those trials out after the plant crop.*

Recommendation 4*: An assessment of the relative agronomic performance of SmutBuster crosses should be made by including a random sample of SmutBuster crosses in Stage 1 of the core program.*

Recommendation 5*: Continue epidemiological research related to disease expression, severity, and rates of disease increase in ratoon crops.*

Recommendation 6*: The research comparing incidence and severity in inoculated tests should be continued in all smut-resistance screening trials.*

Recommendation 7*: Evaluate the effect of age and bud position on response to inoculation to improve the reliability and consistency of results from smut-screening trials.*

Recommendation 8*: We support the continuation of experiments to confirm that the accelerated methods of assessment give a true reflection of smut development under conventional farming practices.*

***Recommendation 9**: Preliminary research already under way on pathogen assays using tissue staining and other approaches should be continued under the auspices of SmutBuster, but their potential should be critically evaluated in June 2010.*

***Recommendation 10**: Due to the complex nature of the sugarcane genome, the progress of molecular marker research was expected to be difficult, and this was reflected by progress for selection of markers for smut resistance. Therefore, unless further progress can be made, specific investment for smut resistance selection should be curtailed.*

***Recommendation 11**: We recommend that 400 preliminary selections from the CAT stage for one region be tested using the NIR bud- scanning method and in inoculated trials on the smut farm. Selections from the two methods should be compared in a further inoculated and NIR trial. This should be continued for several cycles to establish the utility of the NIR method for evaluating smut response.*

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1. Introduction

Sugarcane smut was found in the Isis mill area of the Queensland sugar industry in June 2006. BSES Limited (BSES), the principal R, D & E organisation serving the industry, and the Queensland Department of Primary Industries and Fisheries (QDPI&F) immediately responded to the outbreak by quarantining the farm on which the disease was found and other smut-infested farms in the vicinity. Initially, there was a massive effort directed towards the eradication of the disease. However, within five months, it became clear that it would be impossible to contain the disease. BSES, and its partner in genetic improvement, CSIRO Plant Industry, then assumed lead responsibility for the R&D response to controlling the disease.

Based on information from other countries that had controlled smut, it was obvious that the only economic method of control was resistant varieties. It was important to reduce productivity losses from the release of unproductive but resistant varieties, and minimise the extended impact on the breeding program. BSES-CSIRO had already recognised the problems they would face if smut were to arrive and had developed new strategies to breed resistant varieties that had acceptable productivity in addition to the pre-emptive work carried out since 1997. Funding, initially, was provided by BSES, CSIRO and QDPI&F. In 2008, the Federal government provided $2m for the production of improved sugarcane varieties, and this funding was provided through SRDC. The BSES-CSIRO sugarcane improvement joint venture was successful in obtaining the funding for work towards the development of productive, smut-resistant varieties in a project called SmutBuster.

The SRDC-BSES research agreement for the SmutBuster project includes a requirement to review the breeding strategy for smut resistance

> "We will review our smut resistance breeding strategy early in 2009."
> "Report on smut resistance breeding strategy delivered (by May 2009)"

In January 2009, BSES commissioned Professor Jeff Hoy, Louisiana State University, Professor Bob McIntosh, University of Sydney, and Dr Mac Hogarth, formerly with BSES and SRDC, to conduct the review.

2. Review of smut-resistance breeding strategy

The terms of reference for the review were:

1. Review the impact of the smut incursion on the BSES-CSIRO breeding program
2. Review the response of the plant breeding program through the smut incursion and breeding strategy
3. Review the communication strategy and the adoption of smut resistant varieties by industry
4. Recommendations for improvement to the current program
5. Any other comments on the BSES-CSIRO breeding program

As part of the review, we were asked specifically to consider the SmutBuster project as required by SRDC.

2.1. TOR1. Review the impact of the smut incursion on the BSES-CSIRO breeding program

In 2006, 70-80% of the sugarcane crop was susceptible to smut, creating the potential for a catastrophic economic loss. In addition, about 80% of the parent collection was classified as susceptible, and the loss of this parental material would have a prolonged and severe effect on the ability of the sugarcane improvement program to maintain and improve productivity. This was recognised in the 1990s, and BSES, with funding from SRDC, developed a smut-incursion plan. In 1998, smut was found in the Ord River Irrigation Area (ORIA), and the smut-incursion plan was put into action.

In addition, BSES had already obtained funding from SRDC to conduct smut-resistance tests in Indonesia. After the smut incursion in WA, BSES staff visited Indonesia and negotiated a substantial increase in the number of varieties that could be tested annually for smut resistance. It was agreed that up to 250 varieties could be tested annually. In 1999, CSR, CSIRO and the WA Department of Agriculture, with the assistance of BSES and SRDC, commenced smut-resistance screening work in the ORIA as well.

Both commercial and parent varieties were tested for resistance. Therefore, when the smut incursion was identified in Queensland, there was a great

body of knowledge about the vulnerability of the commercial crop and the susceptibility of the parent collection.

The knowledge about the response of existing commercial varieties to the disease enabled the industry to respond rapidly by identifying smut-resistant varieties to replace susceptible ones. These varieties were made available to growers in affected areas, so that the proportion of susceptible varieties could be quickly reduced.

The sugarcane improvement program commenced breeding for smut resistance after the incursion in WA, and the pre-emptive work on disease testing facilitated the making of smut-resistant crosses. In 2000, BSES breeders and pathologists set a target that at least 50% of the crosses should come from resistant and intermediate crosses. In 2004, this was adjusted to 50% intermediate and 25% resistant x resistant crosses. This was almost achieved in 2005 and has been exceeded since.

The impact of the smut incursion on the sugarcane improvement program was reduced substantially by the outstanding pre-emptive work that had been done between 1998 and 2006 in Indonesia and the ORIA.

2.2. TOR2. Review the response of the plant breeding program through the smut incursion and breeding strategy

The sugarcane improvement program was already responding pre-emptively to a possible smut incursion when smut arrived in Queensland in 2006. In addition, prior to the smut incursion in Queensland, BSES had approved the planting of crosses with high breeding value in WA for selection of resistant varieties and parents. Following the incursion, a decision was made to undertake those tests near Bundaberg.

In response to the incursion, the BSES-CSIRO sugarcane improvement program has:

- Initiated the smut-screening program using inoculation techniques at the dedicated smut farm established near Bundaberg.

- Initiated research on the epidemiology of smut to assist in the decision process for variety release.
- Built a third photoperiod house at Meringa specifically to make crosses between smut-resistant parents.
- Commenced the SmutBuster program involving 400 crosses annually using parents with high breeding value but with smut-susceptibility levels exceeding those that are acceptable.
  - Some 30,000 seedlings are planted each year.
  - The aim of the program is to identify varieties with transgressive segregation for resistance to smut while retaining the elite characteristics of the Australian germplasm. This would accelerate the development of elite, resistant parents for the crossing program. The core program would use this germplasm as well as more exotic sources of resistance.
  - Initiated research to evaluate inoculation methods for original seedlings so susceptible plants can be eliminated rapidly.
  - Initiated a number of methods to characterise smut response, e.g. histological and chemical assay methods, NIR, and molecular markers in comparison to traditional field-based assessments.
  - Comparisons of response to inoculation vs natural infection.
  - Comparison of response ratings based on incidence or severity data.
  - Evaluation of the use of fungicides for prevention of infection following hot-water treatment during variety propagation.

The response by the sugarcane improvement program to the incursion has been rapid, comprehensive and, in our opinion, entirely appropriate. This was enabled by the pre-emptive activities undertaken as a consequence of risk analysis prior to the incursion.

In particular, the SmutBuster sub-program is well-planned, innovative and supported by appropriate research input. We believe it has a high probability of achieving significant progress in producing elite, smut-resistant lines.

2.3. TOR3. Review the communication strategy and the adoption of smut-resistant varieties by industry

There are good communication channels in the sugar industry, and these were used effectively by BSES to inform the industry about the significance of the smut incursion and the steps that would have to be taken to control the disease both prior to and after the incursion in Queensland. Various communication approaches were used including meetings with growers, printed materials, radio interviews, weekly teleconferences, and DVDs sent to all growers.

Variety guides were kept updated with the latest smut information, and this information is now on-line in QCANESelect. We understand that this information is frequently accessed by growers.

Growers were advised about the resistance levels of the varieties available to them and were encouraged to plant varieties with resistant or intermediate responses. Varieties recommended by BSES were readily adopted by growers except where there were significant constraints beyond their control such as in the Herbert where the increase in seed was delayed by one year due to flooding.

The communication strategy was very effective. The industry was well-informed at all stages of the incursion and has shown a willingness to adopt the new varieties.

2.4. TOR4. Recommendations for improvement to the current program

As the response program has only been in operation for two years, there is insufficient data to make definitive statements about the success or otherwise of the program. However, some data are available, and the results so far seem promising.

For example, consistent trials at the smut farm have provided ratings for response to smut for parent varieties and advanced clones under selection.

There has also been progress in the inoculation of seedlings for the SmutBuster program. It appears likely that this program will accomplish the objective of obtaining adequate frequencies of resistant clones from crosses involving the part of the population classified as susceptible. This is because the different genes leading to resistant responses can be accumulated in some offspring of the crosses.

One issue that needs to be addressed is the number of series of seedlings in the SmutBuster program.

Recommendation 1: One more series of SmutBuster crosses should be initiated. An assessment of progress should then be made to decide when to curtail the program.

Being a logarithmic scale, the method for rating smut response in disease is non-linear. As a result, ratings 1 to 5.9 are used for varieties with percent infection of 0 to about 30% and ratings 6 to 9 are used for the remainder up to 100%. Varieties rated >6 are classified as susceptible. This is a conservative rating scale necessitated by the urgency of the threat. It is, therefore, likely that varieties classified as "susceptible" will have genes for resistance to smut as well as desirable agronomic genes. At present, many susceptible varieties are being used as parents in the SmutBuster program but these susceptible varieties might not be used in the core program. This is entirely appropriate as it enables the sugarcane improvement program to make rapid progress in breeding resistant varieties while continuing to access the favourable agronomic genes in parents classified as susceptible. However, when the SmutBuster program concludes, the sugarcane improvement program will need to decide whether any of the varieties classified as susceptible should continue to be used in the crossing program. This decision should be based on the level of resistance in SmutBuster crosses involving the susceptible parents, the relative agronomic performance of SmutBuster crosses, and the outcome of epidemiological research on rates of disease increase in different production areas.

Recommendation 2: The panel recognises the significant value inherent in crossing to and among varieties classified as susceptible, and the further use of smut-susceptible varieties is likely to be justified beyond the life of the SmutBuster program.

Recommendation 3: The level of resistance in SmutBuster crosses should be assessed by ratooning the inoculated disease trials rather than ploughing those trials out after the plant crop.

Recommendation 4: An assessment of the relative agronomic performance of SmutBuster crosses should be made by including a random sample of SmutBuster crosses in Stage 1 of the core program.

Evidence exists that some varieties have many diseased plants with low severity in each plant and, consequently, the crop suffers minimal production loss. Research is being conducted to determine if an index relating smut incidence and severity would provide a more meaningful rating of the effect of disease on production in a commercial situation. This obviously also has relevance for the rating of varieties for use as parents.

Recommendation 5: Continue epidemiological research related to disease expression, severity, and rates of disease increase in ratoon crops.

Recommendation 6: The research comparing incidence and severity in inoculated tests should be continued in all smut resistance screening trials.

We were shown data indicating that the age and position of buds on a stalk had a significant effect on the response to inoculation. This is an important issue and requires further investigation.

Recommendation 7: Evaluate the effect of age and bud position on response to inoculation to improve the reliability and consistency of results from smut-screening trials.

At present, an accelerated testing regime is being used incorporating a 4-month plant crop followed by assessment in the ratoon crop at 3-4 months. Trials have been planted in which “normal” crops are grown with 12-month plant crops followed by normal ratoons.

Recommendation 8: We support the continuation of experiments to confirm that the accelerated methods of assessment give a true reflection of smut development under conventional farming practices.

Research is under way in the SmutBuster program on different methods to evaluate and select for resistance. Two methods attempt to evaluate the

extent of pathogen infection and two are evaluations of disease resistance in the plant. The methods are:

- A histological method to detect the extent of fungal development in bud tissue of resistant and susceptible varieties. This research is underway but data are very limited, and it is impossible to draw any conclusions about the potential of this method.
- An assay for pathogen development based on ergosterol concentration was mentioned but no data were presented.
- A comprehensive program to investigate the potential of molecular markers for parental selection for a range of economic traits including smut resistance. Progress to date is not particularly encouraging for using molecular markers as a stand alone method for selection of smut-resistant varieties. We were impressed with some of the evidence showing that molecular markers could be useful for introgressing alien chromosomes.
- Investigations using Near Infra-red Spectroscopy (NIR) on bud tissue as a means of predicting smut response have provided very encouraging results. The research is continuing to strengthen the association between NIR measures and smut disease ratings from inoculated tests.

Recommendation 9: Preliminary research already under way on pathogen assays using tissue staining and other approaches should be continued under the auspices of SmutBuster, but their potential should be critically evaluated in June 2010.

Recommendation 10: Due to the complex nature of the sugarcane genome, the progress of molecular marker research was expected to be difficult, and this was reflected by progress for selection of markers for smut resistance. Therefore, unless further progress can be made, specific investment for smut-resistance selection should be curtailed.

Recommendation 11: We recommend that 400 preliminary selections from the CAT stage for one region be tested using the NIR bud scanning method and in inoculated trials on the smut farm. Selections from the two methods should be compared in a further inoculated and NIR trial. This should be continued for several cycles to establish the utility of the NIR method for evaluating smut response.

2.5. TOR5. Any other comments on the BSES-CSIRO breeding program

We were impressed by the professionalism and dedication of the staff of the sugarcane improvement program. The collaboration between BSES-CSIRO and the Indonesian Sugar Research Institute and between BSES-CSIRO and the WA Department of Agriculture has clearly been very beneficial to the response to the smut incursion. The collaboration between scientists from BSES-CSIRO and colleagues overseas and within Australia has also been of great benefit to the program.

3. Acknowledgements

We appreciate the opportunity to review an outstanding program. We would like to acknowledge the assistance of Dr Ross Gilmour, Mr Barry Croft, Dr Mike Cox, Dr Nils Berding, Dr Shamsul Bhuiyan, Mr Trevor Willcox, Dr Scott Hermann, Dr Michael O'Shea, and BSES staff at Bundaberg and Brisbane.

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