FINAL REPORT

GRDC
GRAINS RESEARCH & DEVELOPMENT CORPORATION

PBC00001

Economic analyses of gene deployment strategies for high priority exotic pests and chemical supply to manage pest incursions

PROJECT DETAILS

PROJECT CODE:	PBC00001
PROJECT TITLE:	ECONOMIC ANALYSES OF GENE DEPLOYMENT STRATEGIES FOR HIGH PRIORITY EXOTIC PESTS AND CHEMICAL SUPPLY TO MANAGE PEST INCURSIONS
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Summary

This project has reviewed the threat posed by six high priority pests to the Australian cereal industry. The current preparedness of Australian cereal breeding in terms of pre-breeding and breeding to develop resistant lines for these pests has been assessed. Following on from this analysis, a gene deployment strategy has been outlined. An economic investment analysis has also been undertaken to determine the returns to pre-breeding for the six pests.

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The information contained in these older reports is now several years old, and may have been wholly or partially superseded or built upon in subsequent work funded by GRDC or others. Readers should be aware that more recent research may be more useful for their needs. Findings related to agricultural chemical use are also potentially out of date and are not to be taken as a recommendation for their use.

Conclusions

This project assembled a large data set for six pests to develop a detailed spatial and temporal simulation model to predict how exotic pests interact with cereal crops. The return to pre-breeding investment depends on this interaction hinging on gains from having breeding material available sooner when an incursion occurs. The analysis assumes a simple choice between always being ready (pre-breeding investment) and waiting for an incursion before fast-tracking breeding investment.

Chemical use or other management adaptations are the immediate response to incursions and can be effective. Investment into breeding can be fast tracked after an incursion. Thus the return to pre-breeding investment is limited by the delay without pre-breeding, management alternatives and adoption rates of resistant varieties. These limitations have been observed in other regions, especially the United States (US) with Russian wheat aphid (RWA) (Christopher et al., 2014).

Of the pests investigated, exotic wheat stem rust, RWA and barley stripe rust (benefit cost ratios (BCR) of 29, 14 and 13, respectively, over 50 years) give a relatively high investment return. This is due to significant yield effect, rapid spread and widespread suitability. In addition, exotic wheat stem rust and barley stripe rust have a relatively high incursion probability. RWA has a low incursion probability (one in 90 years), but is offset by higher average yield losses. Ranking of pests by return to investment is insensitive to parameter changes.

Despite industry returns from pre-breeding, commercial investment is unlikely because:
1) End point royalties to cereal breeders only capture a fraction of the industry benefits of having a resistant variety.
2) 'Genetic' spillover effects mean commercial benefits are short lived.
3) New resistant varieties are not always widely adopted.
4) Investing in pre-breeding is intrinsically high risk as the model investment return in all cases is zero.
5) Waiting for the pest incursion to occur may be a more profitable strategy for breeders.

Therefore, industry benefits from pre-breeding investment would depend upon industry funding. There is the potential for market failure where cereal breeders focus on yield and quality traits at the expense of pest resistance.

The methods developed could be readily extended to assess investment in cereal breeding for other traits or response options. Further research opportunities are suggested by the project analysis and results.
1) The spatially explicit data for cereal production area and pest suitability could provide the basis of a valuable input into GRDC projects to estimate regional costs and benefits of pest research.
2) For high priority and some endemic pests, key quantitative information critical to modelling studies of the regional impacts, such as spread and growth rates, dispersal distances and economic impact, such as range of yield losses and damage and the frequency of such losses, is not readily available.
3) There is limited understanding of how growers select cereal varieties. A choice survey would have helped to understand the adoption decision for new varieties.

The limitations of this study include uncertainty of pest incursions and spread process and the restrictive assumptions within the economic analysis. With more resources, the economic model could be expanded to include more variables.

Recommendations

1. Pre-breeding for exotic wheat stem rust, RWA and barley stripe rust should be considered for ongoing investment.

2. Quantitative methods of risk and investment analysis should be applied for estimating expected benefits of preparedness.

3. Regular assessments should be made of the risk of incursion and the research capacity in Australia and internationally to mount a pre-breeding response in the event of an incursion.

4. GRDC may consider developing geographic information systems (GIS) databases of the spatial distribution of cereal production so that the production at risk can be rapidly assessed in the event of an incursion.

5. Develop pre-breeding research programs based on sustainable gene deployment strategies and cooperation between cereal breeders. This would ensure the sustainable deployment of resistant genes. This would avoid the deployment of single genes susceptible to rapid resistance breakdown for short term commercial gains.

6. Make available overseas screening for advanced breeding material to identify resistance in Australian breeding lines to exotic pests and pathogens.

7. Further research opportunities in this area are suggested by the analysis and results of this project:
a. The project generated spatially explicit data for cereal production area and pest suitability. This could provide the basis of a valuable input into GRDC projects as a way of estimating regional costs and benefits of pest research projects.

b. For high priority pests and some endemic pests, key quantitative information characteristics such as spread and growth rates, dispersal distances and economic impacts like ranges of yield losses and damage and the frequency of such losses, is not readily available. These data are critical to modelling studies of the regional impacts of pests and would help the industry prioritise its research.

c. There is limited understanding of how growers select cereal varieties. A variety choice survey would have helped to understand the adoption decision for new varieties. This would help to predict how growers would respond to an incursion in terms of variety adoption, or cultural alternatives such as spraying.

d. The economic model could be developed further to include a wider range of adaptation strategies for growers, including changing cropping rotations, a larger set of cultural methods and integrated pest management options.

Outcomes

The main benefit of this project is that it provides an integrated crop science and economic analysis of returns from cereal pre-breeding for exotic pests that could be readily applied to any crop and pest. The framework developed will allow GRDC to prioritise investments related to pre-breeding for exotic pests and increase the return on those investments. Other benefits include the provision of updated threat reports for the high priority pests, a review of the current state of preparedness of cereal breeding in Australia to respond to a pest incursion and updated pest suitability maps derived from Climex.

In relation to PBCRC2013, the project provides some estimated predictions of the demand for fungicides and insecticides as a result of an incursion.

Economic
The Australian wheat and barley industry is worth approx. $6.9 billion. Investment in pre-emptive pre-breeding for resistance to high priority pests and pathogens could save the industry tens of millions of dollars. If an incursion was to occur, pre-breeding enables the deployment of resistant varieties sooner. For example, it has been estimated that $23.7 million of losses would be avoided by pre-emptively breeding for resistance to RWA. Between $3 million and $4 million per annum is currently invested by GRDC in pre-emptive pre-breeding, with a similar or greater amount invested by other research partners. This project will provide a rational basis for ongoing investment in this area of research and pre-breeding.

Environmental

By clarifying the relative costs of pesticide treatments and the benefits of pre-breeding, this study provides an economically rational basis for investment in developing resistance to exotic pests and pathogens. This may contribute to reducing the negative effects of fungicides and pesticides on the environment. Reduced crop losses from pests and pathogens also allow production levels to be maintained without the expansion of cropping into less productive regions.

Social
By improving preparedness for potential incursions of exotic pests and pathogens, the risk to rural incomes is reduced. As a result, the resilience of rural communities is improved.

Achievements/Benefits

The project was an inter-disciplinary collaboration between a cereal breeder (Mandy Christopher, Queensland Department of Agriculture and Fisheries (QDAFF)) and an economist (Ben White, University of Western Australia (UWA)). The project had an Australia wide perspective on the question about how GRDC should allocate research resources in pre-breeding and breeding between a set of six high priority pests and diseases. It was immediately established that very little work had previously been done on the economics of cereal breeding for potential threats. Therefore, this project drew on information from the US and other regions where the pests and pathogens are found to (1) understand their biology in agricultural systems and how this could inform theory on how they may behave in Australia, and (2) study how incursions in the recent past were managed, and to draw lessons from this hindsight, which could help Australia avoid or manage similar incursions. This was followed up by in-depth meetings with cereal breeders (see report Current exotic pest breeding priorities for Australian winter cereal breeders', Attachment 1). It is apparent that cereal breeders do not devote a lot of resources to exotic pests and pathogens since there are no immediate returns. The intelligence gathered on the pests and diseases is summarised in the Threat report (Attachment 7). This analysis led to recommendations for a gene deployment strategy (Attachment 3).

The economic analysis is built on crop science evidence. The first step was a review of the costs of breeding and pre-breeding. This demonstrated how much it costs to establish adapted resistant lines for pests and diseases such as RWA and Karnal bunt. The cost of taking adapted lines through to new varieties was also established. The final step in the economic analysis was to set up an investment appraisal model. Investing in pre-breeding for an exotic pest or disease is equivalent to investing in a financial option in the sense that GRDC pays a premium (to fund research), but the research only generates a return if the pest or disease becomes established in Australia. When a pest or disease initially emerges, the first response is to apply a pesticide or fungicide. New varieties generally only become available after a delay of between five to ten years, once the resistant genes have been incorporated into commercial varieties. The return to investment in pre-breeding comes from the reduction in the delay time. However, the expected return to pre-breeding is highly variable for different pests and diseases. Climex modelling, undertaken as part of the project, shows that the suitability of Australia for the emergency pests and pathogens is highly variable as are the predicted yield effects. For instance, Karnal bunt is expected to be significant only in regions that are not too hot, dry, cold or wet, whereas RWA is predicted to be widespread. Furthermore, Karnal bunt generally has a small yield effect and even at negligible levels will have a biosecurity effect that leads to a price reduction. In contrast, RWA will have a significant yield effect, but no biosecurity effect.

A series of reports have been produced by this project, which provide a sound economic and scientific basis for GRDC and other research investors to make decisions about investment in pre-emptive pre-breeding for resistance to exotic plant pests and pathogens in wheat and barley and presents information about the supply of necessary chemicals to manage incursions.

Reports include:
o Current exotic pest breeding priorities of Australian winter cereal breeders (discussions with breeders) incorporating past achievements, and future directions for pre-emptive pre-breeding for wheat and barley pests and diseases with supplement: Past breeding and pre-breeding for high priority exotic plant pests and pathogens (discussions with pre-breeders and pathologists).
o Exotic pest and pathogen incursions: Case studies of economic impact and resulting changes to management practices (RWA and Karnal bunt in the USA).
o A review of relative risks, likely area of impact, potential economic impact of an incursion of six target pests and diseases in Australia.
o Strategies for deployment of resistant breeding lines for exotic pests and pathogens.
o Costs of cereal pre-breeding and breeding for high priority exotic pests.
o The economic return to cereal pre-breeding for exotic pests and diseases.

Information on pre-emptive pre-breeding has been used to discuss with plant breeding companies, pre-breeders and researchers, strategies for preparedness for exotic pests and pathogens.

The project's main achievements are:

1. Update the evidence on threats.

2. Review the state of preparedness of cereal breeding.

3. Provide a gene deployment strategy for the six pests.

4. Provide an investment analysis framework for pre-breeding investment.

Other research

The project highlighted the opportunity for further research on three key issues:
1. How do cereal breeders determine breeding priorities and how do they trade off risk and return?
2. How do growers select cereal varieties on the basis of variety characteristics, risks and return?
3. What is the economics of gene deployment when there are a finite number of genes to convey resistance and the pest has the capacity to overcome single gene resistance more rapidly than multiple gene resistance (pyramiding)?

Intellectual property summary

GRDC to screen the future publications of the outcome of the economic analysis.

Additional information

Publications

White B, Christopher M, Day C, van Klinken R. 2014. Economic analysis of gene deployment strategies for high priority exotic pests and chemical supply to manage pest incursions. Plant Biosecurity CRC Science Exchange.
White B, Christopher M. 2013. Exotic pest and pathogen incursions: Case studies on economic impact and changes in management practices. 16th Aust Barley Tech Symposium.
White B, Christopher M. 2013. Exotic pest and pathogen incursions: Case studies on economic impact and changes in management practices. Wheat Breeding Association.
Christopher M. 2013. Approaches to breeding using quantitative resistance. Durable Resistance Workshop, Australasian Plant Pathology Society Conference.
White B. 2013. Real options for cereal breeding: Should we invest in resistance to pests that are not found in Australia? 59th National Australasian Agricultural and Resource Economics Society Conference.

Attachments

1. Current exotic pest breeding priorities of Australian winter cereal breeders.

2. Exotic pest and pathogen incursions: Case studies of economic impact and resulting changes to management practice.

3. Strategies for deployment of resistant breeding lines for exotic pests and pathogens.

4. Past achievements, and future directions for pre-emptive pre-breeding for wheat and barley pests and diseases.

5. Past breeding and pre-breeding for high priority exotic plant pests and pathogens.

6. Threat report.