

FINAL REPORT

GM solutions to root diseases of cereals - A situation analysis and business case

DAQ00165

Project Details

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Summary

Root disease causes about \$503 million in losses annually to Australia's wheat and barley industries. Because of these large losses and in many cases the difficulty in reducing these losses through breeding or management, root diseases are candidates for solutions through genetic modification (GM). Through an extensive review of the scientific literature and patents, a range of approaches to GM solutions to root diseases are critically discussed. Given the high cost of regulatory approval for GM crops and a complex intellectual property (IP) landscape, it is likely that research in this area will be done in collaboration with international partners.

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Conclusions

Root disease is a major limitation for production and profitability for the Australian cereal industry. Current methods of minimising losses through conventional breeding and management have been successful. However, future gains from these approaches are likely to continue to be incremental. GM technology could bring about a step-change in reducing losses due to root disease.

Published research and patents indicate considerable activity in foliar fungal resistance in cereals, particularly to *Fusarium* head blight and powdery mildew. There is also research activity on fungal and nematode resistance in roots for other crop species, particularly maize and soybean. However, there has been little specific research in developing GM resistance to root diseases of cereals. It is unlikely that GM root disease resistance in cereals will become available without Australia playing a role in fostering this research.

The Australian research community could contribute significantly to bringing about GM cereals that are resistant to root disease by applying expertise in biotechnology, plant pathology and breeding. By further developing links between research groups around Australia, this capacity could be enhanced. At some point on the path to delivery it is likely that international partners will be involved, through access to genes and technologies and to markets for the technology outside of Australia. This is likely to include combining root disease resistance with other traits in new cereal germplasm and applying developed technology to other crops.

Risks to this approach are technical, commercial and social. Considerable resources would be required to identify the best genes for imparting high levels of resistance to a broad set of pathogens. Access to intellectual property would need to be negotiated or would require 'work around' solutions to be found. Commercial arrangements would need to balance the advantage of sharing risk with benefits to the Australian industry. Acceptance of GM wheat for human consumption is likely to improve over time. GM coarse grains for animal feed are already well accepted and this could be extended to feed wheat with controlled segregation.

The Australian grains industry would gain significant financial benefit by having early access to root disease resistance technologies in adapted Australian varieties. It is likely that Australian investment in development of GM cereals resistant to root disease would be cost effective in the longer term.

Recommendations

It is recommended that the GRDC considers investment in the area of GM solutions to root diseases to develop a strategy based on sound current knowledge for the engagement of the Australian grains industry with GM technology for solutions to root diseases and pests of cereals. Ultimately, if GM solutions are pursued and found to be successful, Australian cereal growers will have at least the same access as their competitors to technologies and cereal varieties resistant to root diseases developed using GM. Application of these technologies could also benefit cereal growers internationally.

Achievement/Benefit

Executive Summary

Root pests and diseases cause \$503 million in losses to the Australian wheat and barley industry annually. The proportional loss is similar to losses in comparable cropping regions internationally. The most significant root and crown fungal diseases of wheat and barley in Australia are crown rot (CR), *Rhizoctonia* barepatch, common root rot (CRR) and take-all. Of the nematodes, cereal cyst nematode (CCN) and the root lesion nematodes (RLN) *Pratylenchus neglectus* and *Pratylenchus thornei* are of most significance.

Current methods of minimising losses through conventional breeding and management have been successful. Future gains from these approaches however are likely to continue to be incremental. The next step change in overcoming losses due to these diseases is likely to be through GM technology.

The main bottleneck in this process is the identification of genes and combinations of genes to produce crops with a high level of resistance and a broad spectrum of pathogens, but without reducing yield potential. Classes of mechanisms identified in this study as most worthy of investigation as potential sources of GM fungal resistance are:

- Gene switches. This approach will be useful if gene action can be controlled to overcome negative pleiotropic effects.
- Pathogenesis-related proteins. Combinations of these will likely be required to achieve a high level of resistance. Proteins which potentially have toxic or allergenic effects on non-targets, including humans, will need to be avoided, since methods for restricting the part of the plant in which they are expressed are often 'leaky'.
- Anti-microbial peptides. These can vary in their level and specificity of activity, and ability to achieve expression in transformed plants. They may be deleterious to the host plant if expressed at too high a level. Thionins in particular can be toxic to mammals.
- Genes from other sources. Such genes are often highly specific to a target pathogen, so may need to be used in combinations. Ribonucleic acid interference (RNAi) is yet to be a proven approach against fungi but may be very useful. *Trichoderma harzianum* endochitinase (Ech42) has considerable promise as a source of GM fungal resistance.

The most promising approaches reported to date are:

1. the expression of fungal or actinomycete bacterial chitinase genes for resistance to fungal root diseases, ideally with the co-expression of one or more peptides with the capacity to disrupt the plasma membrane and
2. RNAi and *Bacillus thuringiensis* (Bt) technologies for nematode resistance. To achieve the required level of durable resistance it is likely that more than one transgene with different actions will need to be combined and/or combined with natural resistances.

Published research and patents indicate considerable activity in foliar fungal resistance in cereals, particularly Fusarium head blight and powdery mildew. There is also research activity in fungal and nematode resistance in roots for other crop species, particularly maize and soybean. However, there has been little specific research in developing GM resistance to root diseases of cereals. It is unlikely that GM root disease resistance in cereals will become available without Australia playing a role in fostering this research.

Most patents in the field claim potential application to a broad range of fungi, nematodes and/or other pests. Some patents report testing of GM resistance mechanisms in a few plant and pest species. Few refer specifically to cereals, or the pathogens which cause root diseases in cereals. None refer specifically to GM solutions to root diseases of cereals. This means that rather than developing a business case for applying specific solutions to specific root diseases in cereals, research is required to test some 'best bet' solutions against the suite of diseases which impact cereal roots in Australia.

The Australian research community could contribute significantly to bringing about GM cereals that are resistant to root disease, through applying expertise in biotechnology, plant pathology and breeding. By further developing links between research groups around Australia, this capacity could be further enhanced.

Risks to this approach are technical, commercial and social. Considerable resources would be required to identify the best genes for imparting high levels of resistance to a broad set of pathogens. The cost of deregulation of a GM event for international commercialisation is up to \$16 million, not including research costs, and takes from six to 13 years from gene discovery to market release. The Australian wheat and barley industry, worth around \$4,680 million annually, is not large enough to justify bearing this cost alone.

The patent landscape is complex. Access to intellectual property (IP) would need to be negotiated or require 'work around' solutions to be found. However, the imminent expiry of some broad enabling technology patents from the late 1990s may broaden opportunities in the near future. Partnerships with international collaborators will assist with access to the required technical IP and will help access international markets for GM root disease resistance technologies for use in winter cereals and other crops, including the high value crops maize and soybean. Commercial arrangements would need to balance the advantage of sharing risk with benefits to the Australian industry.

Acceptance of GM wheat for human consumption is likely to improve over time. The stacking of root disease resistance genes with genes conferring perceived benefit to consumers may make transgenic wheat more acceptable to consumers. GM coarse grains for animal feed are already well accepted and this could be extended to feed wheat with controlled segregation.

A survey to gauge the opinions of stakeholders on the potential for GM to contribute to resistance to root diseases in cereals was conducted. Most respondents agreed that GM is a viable way of addressing resistance to root diseases in cereals. The majority said that Australia and/or GRDC should invest in research in the area of GM resistance to root diseases, but this opinion was not unanimous.

The Australian grains industry would gain significant financial benefit by having early access to GM root disease resistance technologies in adapted Australian varieties. It is likely that Australian investment in development of GM cereals resistant to root disease would be cost effective in the longer term.

Other Research

The report identified strategies for developing GM resistance to root diseases in cereals. Business models for conducting that research are discussed. Opportunities would be created by bringing together expertise in molecular biology and pathology in Australia and developing, or broadening, existing relationships with international companies to gain access to IP and to international commercialisation pipelines.
