Management of soilborne Rhizoctonia disease risk in cereal crops

**Summary**

A series of multi-year and annual field experiments in South Australia (SA), Victoria (VIC) and New South Wales (NSW) were monitored to improve the understanding of interactions between pathogen, soil and environmental factors and biological activity for long term control of rhizoctonia and to improve the prediction and management of the disease. Rhizoctonia infection and inoculum build-up occur throughout the cropping season, especially in cereal crops. Rotation with grass free non-cereal crops is an effective tool to reduce inoculum levels, disease severity and yield losses. Summer weed control and adoption of practices that promote microbial activity, disturbance below seeding depth and adequate nutrition can reduce the impact of disease on crop productivity.

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Conclusions
Rhizoctonia disease in cereal crops remains one of the key biological constraints to production and resource use efficiency. Since *Rhizoctonia solani* AG8 fungus can survive as a saprophyte in the absence of a host and it can infect a diverse range of crops and weeds, effective control of rhizoctonia disease in cereal crops requires both the reduction of the pathogen inoculum in the soil (keep low) prior to seeding, control of the infection process and an increase of the crop's ability to tolerate the infection (create environments where plant infection is reduced and plant tolerance to infection improved). This has to be achieved through management practices spread over more than one cropping season and through an integrated management strategy.
Some of the key findings include:

1. Select a non-cereal crop to reduce pathogen inoculum levels. Non-cereal crops (grass free canola and mustard, medic pastures, field peas, chickpeas and vetch) can be used as an effective management option to reduce pathogen inoculum and disease impact in cereal crops in rotation. Non-cereal crops can be infected by *Rhizoctonia*, however, most do not allow the build-up of inoculum. The effect of rotations generally lasted for one cropping season only.

2. Observation of infected crown roots late in the season (spring) would provide a visual indication of inoculum build-up which could impact the following crop.

3. Summer rainfall events of more than 20mm in a week substantially reduce the level of inoculum, whereas inoculum levels can recover during prolonged dry periods, therefore management practices that help retain moisture after a summer rainfall event will help reduce pathogen inoculum in soil.

4. Weed control during summer significantly reduced *Rhizoctonia* pathogen inoculum levels and reduced disease risk.

5. The ideal time of sampling for DNA assessment of inoculum is closer to sowing, however, as samples need to be taken earlier to allow both for processing and planning a cropping program, sampling during March may be a preferred option to identify high risk disease paddocks.

6. Soils and cropping systems that maintain higher microbial activity at the start of the season had lower disease incidence even with higher inoculum. Management practices, such as stubble retention and reduced grazing, generally promote soil microbial activity. Rhizoctonia root rot is generally worse in seasons following drought and dry summers which do not promote inoculum decline and result in lower microbial activity.

7. Avoid disc seeders in high disease risk paddocks. Soil constraints, such as compaction and herbicide residues (e.g. sulfonylurea (SU) herbicides in alkaline soils), which restrict root growth exacerbate rhizoctonia damage.

8. Uneven crop growth, instead of distinct bare patches is now the most common symptom in the majority of crop paddocks affected by rhizoctonia. Early sowing facilitates seminal roots to escape infection and reduces the severity of disease impacts.

9. Five years of implementation of conservation management practices improved disease suppression potential in the Mallee sands, but had limited impact in the calcareous alkaline soils on Eyre Peninsula. This could be partly attributed to the lower overall catabolic diversity and the diversity of *Pseudomonas* bacteria compared to soils from Waikerie and Avon (highly suppressive soil).

10. Fungicide treatments need to be used as part of an integrated management strategy to reduce disease impacts.

**Recommendations**

Improved understanding of the *Rhizoctonia* pathogen and the root rot disease has increased considerably over the past six years of research, such as the role of cleaning crops, inoculum dynamics over the year, importance of summer weed control and new fungicide application methods. This has led to the improved capability to manage rhizoctonia impacts, but the disease is still a major problem in environments and seasons most conducive to its impact e.g. low rainfall calcareous soils and low fertility soils.

In view of lack of plant resistance based options to control the disease, management of *Rhizoctonia* inoculum levels is critical to reduce rhizoctonia disease impacts on grain crops in a cropping system. Previous research on plant resistance focused on reducing the infection process only and has largely been unsuccessful until now. Preliminary observations in this project have shown significant variation in inoculum development between varieties of barley and wheat. This presents a new strategic opportunity to manage pathogen inoculum levels. This type of plant resistance will provide a comprehensive and reliable strategy to improve plant tolerance and provide significantly lower disease risk.

Research Strategy 1: Identify the mechanisms that enable some cereal varieties to limit build-up of *R. solani* AG8 and determine if the benefits justify breeders selecting this trait. This will be complemented with improved understanding of why the *Rhizoctonia* pathogen infect these crops, but not build up inoculum during the season.

1. Investigate the variation in inoculum development between cereal varieties and determine the practical significance of the reductions in inoculum that can be achieved.
2. Consult with breeding programs to identify and screen key breeding lines likely to have the desirable traits.
3. Identify the mechanisms for the strong resistance to inoculum development of *R. solani* AG8 in non-cereals.

Research Strategy 2: In-field modification of specific microbial groups with plant growth promoting capabilities

1. Investigate why certain Proteobacterial groups do not respond positively to management in alkaline calcareous soils with...
an aim to develop management options that can increase populations and activity of plant growth promoting microorganisms.

Outcomes
Rhizoctonia continues to be an important disease (average annual cost $59 million with potential costs $165 million, Brennan and Murray, 2009) in the southern and western agricultural regions, especially in lower rainfall regions.

The new knowledge obtained in this project demonstrated that the key to rhizoctonia disease control is to keep inoculum in the soil low in the crop and pasture phases and increase the ability of crops to tolerate the infection by creating environments where plant infection is reduced and plant tolerance to infection improved. Also, the success of available disease control strategies, e.g. soil disturbance, fertiliser addition or fungicides is greatest at low to medium inoculum levels and their effectiveness declines as inoculum levels increase, especially where disease suppression activity is low. This has to be achieved through management practices spread over more than one cropping season and through an integrated management strategy. Through appropriate crop choice and adoption of management practices, such as summer weed control, inoculum levels could be brought down from high to lower disease risk and bring down yield losses from higher than 40% to less than 20%, improving economic returns. Reducing the impacts of rhizoctonia disease would improve water and nutrient use efficiency in cereal crops in southern and Western Australian agricultural zones and bring associated environmental benefits.

The new information provides growers with multiple on-farm options to manage or reduce one of the key soilborne diseases to production and reduces risks associated with rainfed cropping in southern Australia. A vibrant and successful broadacre farming industry is known to make a significant contribution to the overall wellbeing of Australian rural communities.

Achievement/Benefit
Research during this project and the previous project has clearly demonstrated that effective management of rhizoctonia disease in rainfed cropping systems requires both the management of inoculum and the infection process in a multi-year crop management strategy. The success of available disease control strategies, e.g. soil disturbance, fertiliser addition or fungicides can provide good control at low to medium inoculum levels, however, their effectiveness declines as inoculum levels increase or where disease suppression activity is low.

1. Effect of summer weed management strategies - Annual field experiments:
Two targeted one-year field experiments were conducted at Karoonda (2012) and Wynarka (2013), combined with modifications to specific treatments in the multi-year field experiment at Streaky Bay to reflect summer weed control strategies. Briefly, results from these experiments showed that summer weed control:

(i) Significantly reduced *Rhizoctonia* pathogen inoculum levels at the time of sowing of following crops, whereas inoculum levels did not decline in no-weed control.

(ii) Increased plant available water (PAW) and mineral nitrogen (N) levels in the top 60cm soil profile.

(iii) Significantly reduced bare-patch disease incidence and increased plant biomass and grain yield (9%-33% loss) of the following barley crops.

Overall, weed control over summer was beneficial to rhizoctonia management by reducing pathogen inoculum and disease in the following cereal crop which complements the moisture and N conservation benefits of summer weed control. This is a concept separate to green bridge management.

2. A multi-year field experiment at Waikerie (Mallee sand) and Streaky Bay (alkaline calcareous sand) on Eyre Peninsula, SA, was monitored for inoculum changes during off-season and in-crop, disease incidence and crop performance. During 2013, a new treatment with multiple summer cultivations (3) was incorporated to evaluate its effects on pathogen DNA levels and subsequent crop performance.

Results are as follows:
- Due to the moisture stress through the anthesis and grain filling periods, grain yields in all treatments were generally low compared to previous years.
- There were no benefits in grain yields from non-cereal crops before 2012, suggesting that the benefits from reduced inoculum levels in break crops disappeared after one cereal crop in 2012. Multiple summer cultivations resulted in significantly higher grain yields compared to no-till treatments. A lack of summer weed control caused a 21% reduction in...
- The disappearance of crop rotation treatment effects on crop performance after one cereal crop also suggest that rhizoctonia disease was the major biological constraint to production in this experiment.
- Inoculum levels at sowing were generally higher than the previous year, mainly due to the long periods of dry weather during summer. These results confirm previous findings that infrequent summer and autumn rainfall would result in higher levels of Rhizoctonia inoculum at sowing.
- Inoculum build-up during crop season - Results observed at Wynarka, Karoonda and Streaky Bay clearly indicated that the sharp increase within wheat and barley crops could be mostly attributed to the rhizoctonia infection of crown roots. Overall, cereal crops (wheat and barley) increase Rhizoctonia inoculum from seedling stage to maturity in all seasons. This was observed at all sites in southern and Western Australia.
- Experiments across the lower rainfall cropping region in southern Australia (collaborative experiments conducted by the Regional Cropping Solutions (RCS) low rainfall group) indicated that grass free canola (Clearfield®, triazine tolerant (TT) and conventional), mustard, chickpeas, field peas, vetch, sown medic, pasture and fallow can result in significant reductions in Rhizoctonia inoculum in a cropping sequence. Therefore, crop rotation with a non-cereal crop is one of the best available management strategies to reduce rhizoctonia disease impact on crop production in a cropping system. Also, when a non-cereal rotation is not an option, for other agronomic or economic reasons, implementation of management practices that control rhizoctonia disease incidence or reduce its impact is critical in avoiding major crop loss from rhizoctonia disease.
- Inoculum build-up in different wheat and barley varieties - A significant variation in the level of rhizoctonia DNA build-up was observed within different varieties of barley (Streaky Bay and Karoonda experiments) and wheat (Karoonda experiment), measured at 7-16 weeks after sowing. It is hypothesised that such a variation could be either genetically controlled or due to differences in root architecture and growth pattern. This observation presents a new strategic opportunity to manage pathogen inoculum levels through plant based options. Also, a better understanding of the mechanism of inoculum build-up or reduction in non-cereal crops could also assist with finding better cereal options to control the impact of rhizoctonia disease.
- Crown root infection late into the crop season results in the build-up of R. solani AG8 inoculum in cereal crops. Therefore, observation of infected crown roots late in the season could provide a visual indication of inoculum build-up that will impact the following crop.
- Plant-soil-microbe interactions can influence the effect of rhizoctonia disease on crop yield. Results from five years of experiments indicated that the final impact of rhizoctonia disease on yield is due to a combination of inoculum level, and many other factors including the level of soil microbial activity at seedling, the amount of soil disturbance below seedling depth, N levels at seeding and constraints to root growth (e.g. compaction layers, low temperatures, soil moisture, etc). For example, soils and cropping systems that maintain higher microbial activity at the start of the season would have lower disease incidence, even in the presence of higher pathogen inoculum.
- Assessment of yield loss from rhizoctonia based on the area of distinct patches underestimates the true costs. Rhizoctonia damage to crown roots can result in significant loss (more than 10%) in wheat grain yield.

3. Disease suppression potential bioassay - Soils from selected treatments after five years of cropping in the multi-year field experiments at Waikerie and Streaky Bay were analysed for disease suppression potential in soils. At the Waikerie field experiment, there was a significant increase in the disease suppression potential in the continuous wheat treatments compared to that found at the start of the experiment in 2008, but the effect in the Streaky Bay experiment was minor and variable suggesting that the development of agronomically significant disease suppression capability in the alkaline calcareous soils may take longer than five years. Additional research is required to identify the exact time required.

4. Fungicide effects on soil biological properties (collaboration with the GRDC funded project SARDI-DAS00125) - Overall, the effects of fungicides and their application techniques i.e. band application vs. seed treatments evaluated in this study indicated variable effects on different microbial properties and biological activities. Band application effects were significantly different to that of seed application methods both on the rhizoctonia DNA and biological properties.

5. Communication
- Members of the research team made presentations at grower and adviser meetings, GRDC Updates and field walks (Vadakattu Gupta (12), Alan McKay (6) and Amanda Cook (6)).
- New knowledge was included in the root disease training (RDTs) courses held by the South Australian Research and Development Institute (SARDI).
- Scientific presentations (three oral talks and three posters) were given at National (Australian Soilborne Disease Symposium
(ASDS) meetings in 2012 and 2014) and International congress of plant pathology, Beijing, Soil Science Society of America annual meetings in Tampa, USA.

- Five articles in annual research compendia produced and distributed by Mallee Sustainable Farming Inc and EP farming group. Three articles in agricultural magazines or papers such as Ground Cover, including an article in the Pulse Supplement, The Land, Stock and Land (Gupta VVSR, Alan McKay).

6. Collaboration activities
- As part of the collaborative arrangement between this project and the SARDI-GRDC project DAS00125, soil samples collected from field experiments evaluating the efficiency of fungicides and their application techniques were analysed to determine their effects on soil biological properties including the pathogen and beneficial microbial populations and biological functions.
- Organised the annual joint meeting of all researchers involved in GRDC and SA Grains Industry Trust (SAGIT) funded rhizoctonia projects in SA and WA.
- To access field experiments with relevant treatments, value adding to ongoing investment by GRDC: RCS-low rainfall group, national crop sequencing and tactics and Mallee WUE (CSA00025).
- Maintained interaction with researchers at the Washington State University to exchange latest developments in techniques and new research concepts (co-author on a paper presented by Dr. Tim Paulitz at the ASDS meeting in Fremantle, WA).

Other Research

Preliminary investigations have been conducted to evaluate differences in inoculum build-up within varieties of wheat and barley in an experiment conducted at Karoonda in the Mallee (in collaboration with Mallee WUE - CSA00025) with and in a National Variety Trials (NVT) trial at Streaky Bay on the Eyre Peninsula (in collaboration with Andy Ware, SARDI).

Results from these experiments have identified a potential new direction for finding genetic resistance to rhizoctonia disease; previously all plant resistance work has been based on trying to reduce the infection process and has largely been unsuccessful. Genetic resistance to the inoculum development stage has not been considered. It is now known that once the inoculum levels are controlled, disease impact on crop performance becomes easier and the need for elaborate disease management options is less important.

Intellectual Property Summary

Datasets from field experiments conducted as part of this project have been used within the project and other GRDC funded projects to quantify the role of rhizoctonia management in production benefits from non-cereal crop rotations, e.g. McBeath et al. 2015, Crop and Pasture Science. 66: 566-579.

The information on the variation in the *R. solani* AG8 inoculum build-up in different wheat and barley varieties is preliminary requiring confirmation in multiple seasons.

Collaboration Organisations

Throughout the project, a collaboration was maintained with Dr. Tim Paulitz, Washington State University, regarding the dynamics of rhizoctonia inoculum and plant-pathogen interactions in cropping soils.

This has resulted in the following publication:

Paulitz, T.C., Yin, C., Hulbert, S., Schroeder, K., Schillinger, W., Mavrodi, O. Mavrodi, O., Kirkegaard, J. and Gupta, V.V.S.R. (2012). Role of microbial communities in the natural suppression of *Rhizoctonia* bare patch of wheat in the USA and Australia. 7th Australasian Soilborne Disease Symposium, 17-20th September, Fremantle, WA.

Collaboration Details

The international collaboration specifically focused on exchange of information on latest developments in methods and new knowledge related to rhizoctonia disease in crops.

Additional Information
Attachments

2. CSIRO publication.
5. MSF paper.
6. Detailed results of project.