Field studies and management of crown rot in the Northern Region

Summary
This project examined the epidemiology of crown rot (CR) in cereals, with a particular emphasis on management and environmental effects on inoculum, and the role of nitrogen (N) in the disease cycle. The quantity of infested residue was shown to be the most important determinant of the incidence of infected plants, and a simple method was developed for estimating this on-farm. Factors affecting the decline in inoculum with time were identified. High levels of N increased susceptibility of plants, regardless of genotype. The results help to explain the findings of field trials and form the basis for a simple set of rules for predicting the risk of disease and effects of management.

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Conclusions

The most important factor determining the incidence of CR is the quantity of inoculum at the time of sowing. In-crop factors can influence severity and actual yield loss, but these cannot be readily predicted at the times when management decisions need to be made. Decisions must therefore be made on estimates of risk, which are derived from predicted incidence using parameters which can be measured before harvest of the previous crop or before sowing.

The quantity of inoculum produced in a wheat crop can be estimated by multiplying the yield by the proportion of mature plants showing stem browning. This has a simple mathematical relationship to the proportion of plants that will become infected in the following season, and can be used to place crops into risk categories.

The rate of decline in inoculum with time up to two years is directly related to the heat sums of rainy days. With this knowledge, rules can be developed to account for seasonal effects on stubble breakdown and fungal mortality during long fallow or rotation.

High N increases the incidence of plants that become infected, and the severity of symptoms. This may be offset by higher yields if sufficient water is available. Nitrogen should not be added in excess of the capacity of the crop to use it, given likely water availability.

Under normal conditions, plants only become infected if they are touching a source of inoculum. Minimising dispersal of stubble, and planting between old rows, will reduce infection in low- and medium-risk crops.

A wide range of fungi is involved in displacing the CR fungus from stubble. Displacement is fastest under warm, wet conditions. The main factor limiting the rate of displacement when water and temperature conditions are suitable is the low N content of straw. Adding nitrogen favours other, competing fungi much more than it assists the CR fungus.

A single year out of cereals does not significantly reduce the inoculum potential of infested stubble. Two-year breaks are required to reduce, rather than delay, the progress of CR epidemics.

Recommendations

The model for year-to-year disease progress identified in this project needs to be applied to interpretation of experimental data on CR. This is particularly true for work on short rotations where conclusions based on single years of disease assessment are misleading.

The feasibility of applying nitrogen to stubble to reduce inoculum should be explored. The best opportunity may be when applying N to rotation crops.

Despite a ‘Strategic Initiative’ on CR, research outputs have not been brought together in a coordinated manner. A lot of work has still not been published or made widely accessible. There is scope for a workshop or other structure with a proper
synthesis of work on CR over the past decade as an outcome.

Outcomes

The expected outcome is increased yields of wheat, durum and barley in the Northern Region (NR) through improved management of CR. Being able to define more precisely when management for CR is required will assist growers to avoid crop losses when risk is high, and to avoid unnecessary management expenses when risk is low. Growers are also more likely to take steps to manage crown rot if they can clearly identify the level of risk to their crop and understand how management practices or environmental conditions will alter that risk.

Achievements/Benefits

The basic principles for management of CR have been known for some time. Many growers successfully avoid losses from this disease by using rotations and other strategies. Despite this, CR has remained a problem for many growers. This is in part because recommendations for management have been general, and thresholds for management were not defined. There is a large body of information from field trials and surveys on the effects of management practices on CR. When this project started, it was difficult to translate this into specific recommendations for a farm or paddock as many aspects of the epidemiology of the disease were not well understood. This project aimed to fill in these gaps by studying the effects of environment and management on the levels of inoculum of the CR fungus and the role of N in the disease cycle. It also established basic epidemiological and biological principles for generalising field trial findings to a wider range of environments. It was designed to complement other projects within the ‘Strategic Initiative’ on CR.

The effect of N on disease incidence and severity was studied in a series of experiments in controlled environments and in the field. In initial pot trials, levels of urea equivalent to 100kgN/ha were shown to increase the severity of stem browning in a range of genotypes of wheat, barley and triticale. This was confirmed in more precise experiments with bread wheat, durum and oats. Real-time polymerase chain reaction (PCR) did not detect any difference in fungal colonisation in high N treatments, and there were generally no interactions between fungal infection and N level in their effects on growth or water use. An interesting observation was that growth of oats was reduced by CR infection to the same degree as wheat, even though symptoms were very mild. In two field trials, high levels (100kgN/ha) increased the proportion of plants infected by natural inoculum, but there was no interaction with genotype. This showed that all genotypes tested were equally affected by the N treatment. In the field, there was no indication of a differential yield loss from CR in the high N treatments, presumably because of a compensating increase in yield from the higher N. Overall, these experiments showed that high levels of N increased the susceptibility of plants to infection. They also increased the severity of symptom expression. However, this did not lead to increased yield losses in the absence of water stress.

Nitrogen was shown to be an important factor limiting the ability of other microorganisms to displace the CR fungus from infested straw. This was true both when specific antagonists were inoculated onto straw, and when infested straw was exposed to the native microflora from cropping soils. In pot experiments, spraying urea, nitrate or ammonium N onto straw on black soil at 100kgN/ha caused a very high level of displacement of *Fusarium pseudograminearum* over 16 weeks, compared with negligible displacement when no N was added. This suggests a potential strategy for reducing inoculum in the field but it would be difficult to use economically.

Management by precision planting between rows relies on an understanding of the spatial aspects of infection. The effect of distance between inoculum source and the plant base was tested. Incidence of infection declined from over 50% when infested residue was in contact with plants, to 15% at 2mm, and negligible levels when more than 5mm away. This confirmed anecdotal reports of the importance of stubble-to-plant contact. Plant-to-plant contact was also found to be necessary for infection to spread between plants under typical conditions where spores were not formed. At a larger scale, distribution of the pathogen within fields tended to be heterogeneous and random. Stubble was sampled from several paddocks and fractionated into standing and lying components, as well as size classes of buried fragments. These were counted and weighed to provide a profile of the inoculum. An attempt was made to determine the minimum size of fragment which would be infective, however, this was inconclusive because of the low proportion of small residue pieces that were actually colonised by the fungus. It appeared that any visible piece of residue that contained the fungus was capable of causing infection. Of the spatial experiments, by far the most important finding was confirming the need for close proximity or contact between the source of inoculum and the plant for infection to occur.

Rotation depends on the death of the pathogen in plant residues during the period when susceptible crops are not growing.
This is caused both by the decomposition of residues, and by displacement of the pathogen from the residues by other organisms. Experiments were carried out to explore the factors that control the rate of these processes. Fungi were isolated from standing wheat stubble at the end of the summer fallow, and tested for their interactions with *F. pseudograminearum*. A novel assay system was developed to allow study of the effects of temperature, water availability and nutrients on pathogen displacement with much more precision than previous methods. Displacement rate for a range of fungi was most affected by temperature. The strongest antagonists were restricted to the wettest categories. Some moderately effective antagonists maintained their displacement activity under drier conditions, suggesting that they would continue to be active as straw dried out after rain. Attempts were made to manipulate the duration of wetness of straw with a misting system, but this was difficult to use, therefore displacement was studied using natural rainfall events, with a modified leaf wetness sensor to estimate straw wetness. A wide range of models were tested with the data, but the best fit was a simple model based on the sums of mean temperature of days on which rain fell. This was validated against published data for stubble decomposition and *Fusarium* displacement from Australia and North America, with very good fits for periods of up to two years. This allows a simple way of estimating the effects of environmental variation on decline of inoculum during periods of long fallow or rotation.

The infective potential of straw which had been subject to displacement of *F. pseudograminearum* by antagonists for periods equivalent to short fallows was studied. Significant levels of displacement under ideal conditions did not result in a reduction in the proportion of plants infected. This indicates that there is a threshold time up to which stubble maintains its ability to infect plants, before real decline in inoculum potential occurs. This has implications for understanding the effects of rotations on the disease. When combined with the epidemiological analyses described below, these results show that the apparent reduction in CR incidence following a single rotation crop is due to a delay in epidemic progress, rather than a real decline in the disease.

An epidemiological analysis of CR epidemics was undertaken, based on published data from long-term field trials at Moree (Burgess) and Billa Billa (Wildermuth). An initial assumption was that environment, and especially rainfall, would have a large effect on the incidence of infection and carryover of inoculum. The first step was to determine the underlying pattern of disease progress over several seasons as epidemics develop. This was found to be logistic growth. The infection rate, calculated from change in incidence between successive seasons, was compared with all factors suggested to affect CR levels. The most important of these were then used to develop multiple regression models for predicting the incidence of disease. Surprisingly, almost all of the variation in disease incidence between seasons could be explained by combinations of yield and incidence of disease in the previous season. The square root of the product of yield and incidence was the best predictor. Incidence could be measured by isolation (Moree) or visually for stem browning (Billa Billa). There was a small additional effect of summer rainfall, with slightly lower incidence after wet summers. This was related to the role of temperature and rainfall in displacement of the pathogen from residues.

The models were simplified for use in a decision-making aid. The yield, in tonnes per hectare (t/ha), and incidence in percentage (%), are multiplied to give an index which places the following crop into a risk category. The risk categories are high, where loss from crown rot is certain; medium, where losses could be high under adverse conditions but acceptable under good conditions or with appropriate management; and low, where losses to CR will be small relative to other factors affecting yield. The thresholds for these categories are based both on consideration of disease progress between seasons, and what is achievable with good management. An alternative method of placing crops into risk categories is a history score, based on an analysis of the rate of increase in incidence between seasons and the rate of breakdown of residues. The number of susceptible crops in the past five years is counted, and then the number of years since the last susceptible crop is subtracted to give a score that places the next crop in a risk category. A set of rules is used to place crops that are close to the boundaries between categories in the higher or lower category, depending on weather and management factors. The history score is also modified by rules based on the yield of the last susceptible crop.

The overall benefit should be management advice that is more specifically tailored to individual farms or paddocks. The experimental work in this project contributes to a better theoretical understanding of the disease, which improves confidence in conclusions drawn from past and current work. The analytical components of the project provide a simple tool which can be used on-farm to support decision making.

**Other research**

During the project, the opportunity arose to collaborate with Sukumar Chakraborty (CSIRO) and Steven Simpfendorfer (NSW Department of Primary Industries (DPI)) on a project examining the pathogenicity and variability of fungi causing head blight.
and CR in Australia. Most of the work was carried out by PhD student Olufemi Akinsanmi, based in Dr Chakraborty's laboratory. This was highly productive, resulting in five research papers and a contribution to a review paper.

An outbreak of head blight in southern New South Wales led to collaboration with Mui-Keng Tan, Steven Simpfendorfer and Gordon Murray (all NSW DPI) in a project determining the causal fungi. Morphological identifications were done at the University of New England (UNE) in a double-blind conformation of molecular identifications. This was published in 2004.

Two sabbatical visitors to UNE worked on aspects related to the project. Mrs Kularajany Niranjan from the University of Jaffna, Sri Lanka, did initial work on the identification of fungal antagonists of CR in straw, and development of a bioassay system for measuring displacement. Dr Gholamreza Haddadchi, Gorgan University, Iran, compared defence reactions of susceptible and tolerant wheat varieties.

The work on CR led to an invitation to contribute to a book chapter on soil-borne diseases of wheat, co-authored with Richard Smiley (Oregon State University), Phillipe Lucas (INRA, France) and Timothy Paulitz (USDA-ARS). The UNE contributions were on common root rot and CR.

**Intellectual property summary**

The outputs of the project are not considered to be commercial in nature. Therefore no strategies have been identified for commercialisation.

**Additional information**


Additional information is provided in the attachment to this report.

* AttachUNE62. An outline of a system for predicting and managing risk of crown rot is attached.

The recommendations are based on the experimental results and epidemiological analyses from this project.