How crown rot disease severity affects yield loss in wheat

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Take home message

While seasonal conditions are the strongest factors controlling disease expression and yield loss due to crown rot, host resistance has been shown to mediate the effects of this disease. More recently, the role of tolerance to crown rot has been described, providing growers with additional opportunities to limit the impact of crown rot.

Background

Crown rot of wheat is an insidious disease, caused by the fungus *Fusarium pseudograminearum;* a stubble borne pathogen which causes significant damage in no-till farming systems. The disease is of significant concern where wheat is grown under water limited conditions and can be found in all cropping regions in Australia. The impact of this disease is exacerbated by post anthesis drought, leading to premature ripening of infected tillers and the formation of characteristic whiteheads. These whiteheads can either be completely devoid of grains, or contain shrivelled grains, resulting in an increase in screenings and subsequent yield and quality downgrades. A more diagnostic symptom is the light honey-brown to dark-brown discolouration on the base of infected tillers, extending upwards under more severe infection.

Various strategies have been proposed and implemented for managing crown rot; generally aimed at reducing the incidence of initial infection rather than mitigating the effects of subsequent colonisation. This has been achieved through a reduction in inoculum levels by rotation away from susceptible hosts (Simpfendorfer et al., 2003), or by avoiding inoculum in the field by inter-row sowing, stubble management and other cultural practices (Verrell et al., 2017). While individually and in concert, these approaches can provide some benefit to growers, they alone do not provide complete protection; thus an integrated disease management strategy which includes improved varietal performance is required.

Growing resistant cultivars has long been recognised as an effective strategy for minimising the damage caused by crown rot. Resistance is defined as the ability of a plant to restrict initial infection or supress pathogen spread or multiplication (Bos and Parlevliet, 1995). With respect to crown rot, this is generally measured by the reduction in severity of the characteristic stem browning in infected tillers; a trait that is directly linked with the amount of fungus in the plant.

Resistance ratings are a well-accepted tool for varietal selection by growers. However, this rating system does not consider the impact of tolerance on the performance of a variety under crown rot. Tolerance is the ability of a host to limit the damage or impact of a pathogen, irrespective of the severity (Kause and Ødegård, 2012). This trait has been observed both in un-released breeding material and in a select number of varieties and represents an additional opportunity for growers to limit the impact of crown rot. This paper describes the relationship between resistance, tolerance, disease severity and yield loss due to crown rot.

Yield loss experiments

A series of four crown rot yield loss experiments were conducted over two years in 2017 and 2018. These trials were part of an ongoing pre-breeding program improving resistance and tolerance to crown rot. In these experiments, between 50 and 200 breeding lines and varieties were planted in paired plots with and without inoculum to assess the amount of yield lost due to this disease.

Yield loss was calculated by regressing yield under disease against disease free conditions in each trial. The slope for this regression determines the average yield loss in the trial, and deviation from the average yield loss is reported. By calculating yield loss in this manner, the effect of environment can be factored, allowing for effective comparisons between trials.

In addition, the severity of infection for each genotype was measured by assessing the extent of spread of the characteristic stem browning systems up the tiller. These trials were conducted in Toowoomba and Pampas in 2018, and Narrabri in 2017 and 2018 across a range of seasonal conditions.

Relationship between disease severity and yield loss

Surprisingly, to date there has been little work completed assessing the relationship between disease severity and yield under crown rot (Kelly et al., 2016; Forknall et al., 2019), and in the main, it is left largely as an assumption that a reduction in disease levels in the stem will have a uniformly positive impact on genotype yield. Despite this, resistance ratings are a well-accepted tool for varietal selection by growers (Matthews and McCaffery, 2019).

To establish the relationship between disease severity and yield loss, correlations between these traits were calculated for each trial (Table 1). In all these trials, there was a moderate to strong relationship between disease severity and yield loss. This indicates that with increasing disease severity (measured as extent of stem browning), there is an increase in yield lost due to crown rot. While this result is logical and, in many respects, to be expected, its importance cannot be overstated as it validates the use of resistance as a tool for growers to limit the amount of yield lost due to crown rot. Resistant varieties display reduced disease severity, and therefore by selecting varieties with higher resistance ratings, growers will experience less yield loss in seasons favourable to crown rot expression.

Table 1. Correlation between yield loss and disease severity for each of the crown rot yield loss trials. A value of 1 would indicate that with an increase in disease severity, there would be a direct proportionate increase in yield loss. Conversely, a correlation of 0 would indicate there was no relationship between severity and yield loss.

Trial	Correlation between yield loss and disease severity
2017 Narrabri	0.67
2018 Narrabri	0.83
2018 Pampas	0.32
2018 Toowoomba	0.61

In these trials, while there was a moderate relationship between disease severity and yield loss, the rate of yield loss in any genotype was only partially explained by the extent of stem browning symptoms (severity). Indeed, if the degree of disease severity alone was solely responsible for the yield response to crown rot in the trials reported here, then the genetic correlation between these traits would be expected to be approaching one. Instead, this value ranged from 0.32 to 0.83 under different conditions, suggesting that yield loss can be impacted independently of disease severity. This is an important consideration, as it indicates that traits other than resistance can be used to manage crown rot. Broadly speaking, the genetic traits that mitigate yield loss independently of resistance are described as tolerance.

Tolerance to crown rot

While breeding for tolerance is a relatively new area of research, this trait is already being used by industry for managing crown rot. Wheat breeding companies have anecdotal evidence (Lush and Lu, 2018) from multi-site-season yield loss experiments, that the moderately susceptible to susceptible variety Suntop⊕ had reduced yield loss to crown rot than other cultivars with similar resistance ratings. This echoes the findings of Forknall et al. (2019) (DAW00025) and those from this breeding program that Suntop⊕ was more tolerant than many other cultivars. Similarly, Lancer⊕ and Mace⊕ also lost less yield than expected given their observed disease severity. Given that the option to grow tolerant cultivars is now available, many farm advisers believe that tolerance can be used to minimise the impact of crown rot on yield. However, while variety guides publish resistance ratings for a wide range of diseases, including crown rot (Matthews and McCaffery, 2019), information on the tolerance ratings of individual varieties for crown rot is hard to find.

A methodology developed within the GRDC crown rot pre-breeding program (US00075) (Kelly et al. 2016) allows an estimate of the tolerance of a genotype to be calculated relatively efficiently. This methodology first estimates the average relationship between yield loss and disease severity in a yield loss trial. A variety's tolerance is then estimated based on a deviation from this relationship. Varieties that lose less yield than expected given the amount of stem browning symptoms (disease severity) are considered tolerant, while those that lose more yield than expected given the amount of disease severity are intolerant. These values have been calculated for a select number of varieties as part of the pre-breeding program (Figure 1).

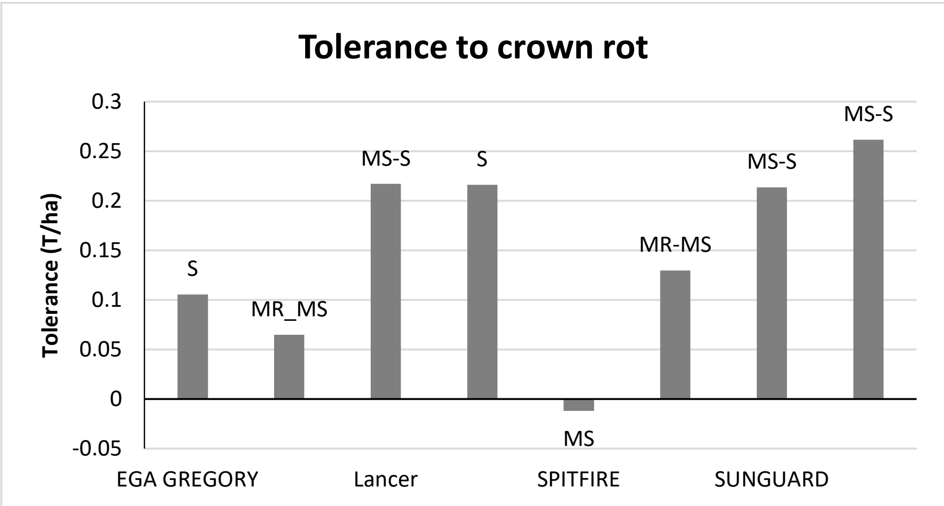

Figure 1. Average tolerance of a select number of varieties across four trials in 2017-2018 (column) and NVT resistance ratings (text above column). Tolerance is measured as the deviation (in t/ha) from the variety's expected yield loss given the amount of disease severity observed. Varieties that have high tolerance values lose less yield than expected given their observed disease severity. Varieties with negative tolerance values lose more yield than expected given the observed disease severity and are intolerant.

While this set of data only represents a small number of varieties relevant to growers and advisors, a larger series of experiments supported by Sydney University is currently underway to estimate the level of tolerance in a wider set of elite northern varieties. Nevertheless, this preliminary data demonstrates that in the trials presented, a yield improvement of as much as 300kg/ha was achieved between two varieties (Suntop⫯ and Spitfire⫯) with similar resistance ratings due to improved tolerance to crown rot (independent of yield potential).

This study also demonstrates the lack of a relationship between resistance and tolerance to crown rot. According to the NVT resistance ratings, the most tolerant varieties in this study were moderately susceptible to susceptible to crown rot, while the most resistant variety (EGA Wylie⫯) displayed only a very low level of tolerance. This highlights the importance of considering both resistance and tolerance ratings separately to provide growers and advisors more information as to the likely response of a variety when grown under crown rot pressure.

The impact of resistance on the rate of inoculum build-up for following seasons however needs to be considered. This relationship is well understood for root lesion nematodes (*Pratylenchus* spp.), where tolerant varieties can provide relief from impact from the disease but still allow multiplication of nematodes, increasing inoculum load for subsequent seasons. Resistant varieties conversely restrict nematode reproduction, reducing impact of this disease in future seasons. It is not clear whether this relationship holds true for crown rot given the ability of the crown rot pathogen to grow saprophytically in senesced plant tissue. However, high inoculum levels are frequently observed following highly susceptible varieties, suggesting that at least in-part resistance plays a role in limiting inoculum build-up.

Of further interest is the relative importance of resistance versus tolerance as genetic tools for managing the impact of crown rot. While the data available is still inconclusive, there appears to be a trend towards a higher correlation between severity and yield loss under conditions less conducive to disease expression, and a lower correlation when post anthesis stresses (drought and heat) enhance crown rot yield loss symptoms. This suggests that in seasons with tougher finishes where crown rot significantly affects yield, varietal tolerance will play a more important role in maintaining yield, compared to resistance. While research in this area is still ongoing, this observation stands to reason, given that tolerances to abiotic stresses are believed to play a major role in reducing the yield loss due to crown rot.

Conclusions

Resistance is an effective tool in reducing disease severity and maintaining yield under crown rot pressure. However, while there are varieties with moderate levels of resistance, most high yielding varieties are still relatively susceptible to crown rot. Tolerance represents an additional genetic tool for mitigating the effects of this disease. Selecting more tolerant varieties and breeding for improved tolerance to crown rot represent both short- and long-term opportunities for managing the impact of this disease.

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