Breeding for crown rot tolerance – can technology help?

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Key words

crown rot, breeding, variety selection

GRDC code

AGT2101-001RTX

Take home message

Research into improving phenotyping strategies for crown rot resistance and tolerance to crown rot have identified a relationship between yield loss and canopy temperature. This relationship is being used to attempt to develop higher throughput and more reliable phenotyping strategies for this disease. The aim is to enable breeders to more efficiently select for improved crown rot resistant and tolerant germplasm.

Yield loss trials conducted during the last two seasons have identified surprising amounts of yield loss, despite the favourable conditions. Losses of around 10% in elite tolerant varieties have represented production losses exceeding 0.5 t/ha, with higher losses in intolerant varieties.

Introduction

Despite significant research efforts, crown rot remains an intractable disease for plant breeders and growers alike. A number of factors contribute to this, including a lack of significantly useful genetic resources, difficulties in phenotyping (assessing germplasm for resistance and tolerance) and a lack of understanding of the mechanisms driving resistance and tolerance traits. Consequently, breeding efforts, both at a research and varietal development level, have often relied on indirect methods of selection, using proxies such as the extent of stem browning, incidences of whiteheads or yield under disease to identify germplasm with enhanced levels of resistance and/or tolerance. In an effort to improve the delivery of improved genetics to growers, recent GRDC investments have sought to improve phenotyping strategies by investigating both existing and novel phenotyping strategies. While this research is still underway, some initial findings suggest canopy temperature may be correlated with tolerance to this disease.

Proximal and remote sensing technologies have rapidly progressed in recent years and been proven in a range of agricultural fields including weed science, yield prediction and crop monitoring. They provide researchers significant opportunities for additional phenotyping strategies, although are yet to be widely deployed in routine commercial breeding applications. Canopy temperature in particular presents breeders with an opportunity for phenotyping a genotype's response to stressed conditions (Jackson *et al*. 1981), with the value of canopy thermography already demonstrated for drought and heat stress (Amani *et al.* 2008). As the crown rot pathogen infects cereals, it disrupts the vascular system restricting the ability of the plant to transpire. Given that transpiration provides a canopy cooling effect, it is hypothesised that plants with differing resistance and tolerance to crown rot will display differential canopy temperature reactions.

Measuring canopy temperature

To assess the relationship between canopy temperature and crown rot resistance and tolerance, a series of bread wheat, durum wheat and barley trials were planted across the northern region in both 2021 and 2022. A total of 60 bread wheat, 12 durum and 24 barley varieties were included representing the phenotypic range of resistant to susceptible and intolerant to tolerant. Canopy temperature data was collected using a FLIR One Pro® thermal camera attached to a vehicle mounted rig at 3m above the canopy (Figure 1). Each paired plot was captured in a single image to reduce the impact of temporal variation. Thermal images were taken at multiple opportunities through the growing season, as dictated by weather and ground access conditions.

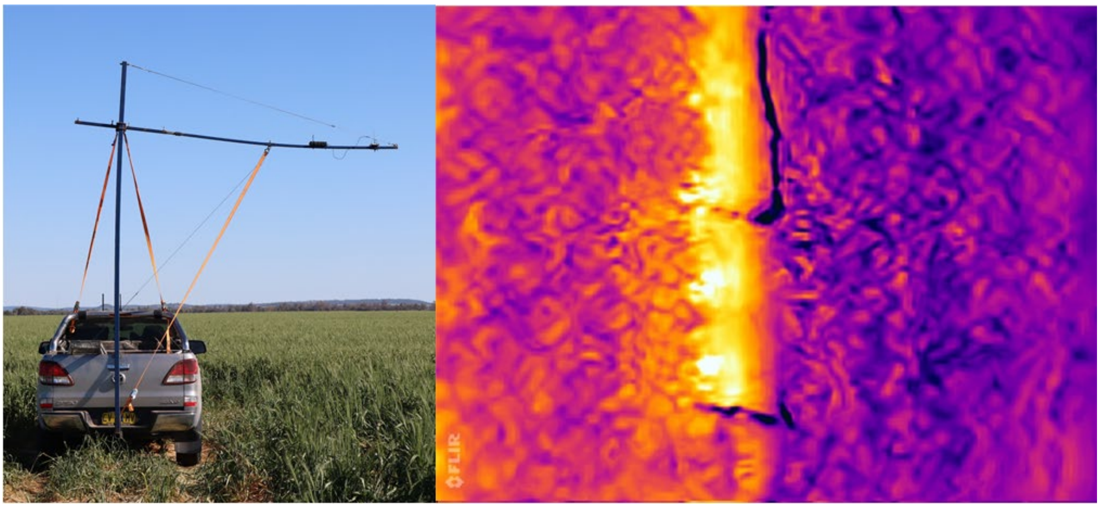

Figure 1. The canopy temperature phenotyping platform (left) used for high-throughput phenotyping of thermal imagery in a wheat breeding program and (right) an example of a thermal image of a paired plot of a single genotype, with (left of image) and without (right of image) crown rot inoculum.

Yield loss to crown rot in favourable seasons

Growing conditions in both 2021 and 2022 were very favourable, and not conducive to obvious crown rot symptom development. Indeed, across the 12 trials completed in these two seasons, only a handful of whiteheads were observed in a single trial. Conventional wisdom indicates that in such seasons, yield loss to crown rot is largely absent, and it is the build-up of large amounts of *Fusarium* inoculum through accumulation of large amounts of biomass that is of most concern to growers with respect to crown rot.

While data from these experiments confirms that yield loss was limited when compared to observations made in seasons more conducive to disease expression, the extent of yield loss was still of concern. An example of this was Walgett in 2022, where trials were planted on a near full profile and received ~260mm in-crop rainfall. Despite the mild conditions during grain-fill, average yield losses were around 11%, 13% and 14% for bread wheat, durum and barley, respectively, with intolerant varieties such as EGA Gregoryᶲ losing around 21% of yield to crown rot. This represents lost production of around 0.9 t/ha for this variety in a season when stripe rust, flooding and grain storage challenges were the main issues faced by growers. Even in more tolerant varieties such as Sunchaserᶲ and LRPB Lancerᶲ, yield losses were approximately 10%, representing lost production of 0.53 t/ha and 0.40 t/ha, respectively. While such losses are more palatable when offset by the high yields observed in 2022, they nevertheless represent a significant and likely hidden loss in production. Similar observations were made at North Star in 2022, where average yield losses of around 9% in bread wheat genotypes (rising to 17% in EGA Gregoryᶲ) were recorded.

Clearly, these results suggest that avoiding highly susceptible and intolerant varieties can significantly improve productivity, even in seasons conventionally not seen as favourable to crown rot expression. Indeed, improvements in varietal performance under crown rot in the last decade or so have made it easier to avoid highly intolerant or susceptible varieties.

Relationship between yield loss and canopy temperature

There has been a significant relationship between crown rot and canopy temperature in all the trials conducted over two years as part of this project, with plant canopies of inoculated plots consistently warmer than their uninoculated pairs. This observation is likely attributable to the disruption of the vascular system by the crown rot pathogen and the resulting restriction of transpiration. Differences were observed in the magnitude of the effect of inoculation on canopy temperature between both crop types and the stage of crop development, with a general trend towards greater differences between treatments increasing through crop development.

Significant differences between genotypes in the degree of increase in canopy temperature following crown rot inoculation were observed consistently, even in sites where limited disease expression was observed. Differences were more pronounced later in the crop's development and are consistent with our understanding of the putative mechanisms driving the canopy temperature response. During grainfill, the crops moisture requirement increases, subsequently increasing the demands put on the plant's vascular system. In plants where the vascular system has been disrupted through fungal proliferation by the crown rot pathogen, rates of transpiration are likely to be suppressed, leading to greater differences in canopy temperature between inoculated and uninoculated plots.

Importantly, these differences were associated with yield loss. Correlations between the increase in canopy temperature following inoculation and yield loss ranged between $R^2 = 0.42$ and $R^2 = 0.75$ (average $R^2=0.6$) for bread wheat and between $R^2 = 0.42$ and $R^2 = 0.75$ (average $R^2=0.59$) for durum. Unfortunately, correlations for barley were less reliable, averaging $R^2 = 0.38$. A number of factors have contributed to the less favourable finding for barley; the most notable of which is the impact of lodging on reliable canopy temperature data collection.

Despite the mild conditions experienced, thermography, and particularly measuring the temperature difference between inoculated and uninoculated plots, has still been able to discriminate between genotypes based on their crown rot tolerance levels. This is an important finding as it indicates that genetic progress can be achieved even in seasons where abiotic stress pressures are intermittent or indeed completely absent. This is critical for breeding programs where cohorts of germplasm may only be screened at certain intervals, particularly with segregating populations and early generation yield testing, and thus being able to make informed selections independent of seasonal variations is necessary.

What's next?

There remains significant further research in understanding the role of canopy temperature in phenotyping crown rot tolerance. The timing of data collection requires experimental work. This includes the impact on diurnal variations in transpiration, and the role that crown rot infection may play in effecting these patterns. Further to this, the value of night canopy temperature assessments should be investigated. Indeed, such observations have proven useful when phenotyping both heat and drought stresses and warrant investigation with respect to crown rot. These studies must also be conducted under higher levels of crown rot expression, where heat and moisture stresses stimulate high levels of disease pressure to determine whether the observed relationships hold under a greater range of conditions.

In addition to investigating canopy temperature, research is also seeking to identify further strategies to improve the efficiency and efficacy of crown rot phenotyping. Once approach is to use machine learning to identify whiteheads amongst healthy heads. Assessing whiteheads is a routine phenotyping methodology, widely used within commercial breeding programs due to its ability to readily identify intolerant lines. By incorporating machine learning approaches to whitehead detection, both the speed and accuracy of this phenotyping method would be improved.

Further, a more fundamental understanding of the relationship between resistance to crown rot and its impact on yield loss is being sought. Historically, much of the breeding and research efforts have focussed on resistance to crown rot, measured largely by the extent of stem browning. Relationships between this trait and tolerance, however, have not been fully examined. Data collected from these trials is being used to identify the relative impact of resistance on yield loss, so that breeders and researchers alike can more efficiently deploy their resources for maximum production gains.

References

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Acknowledgements

The research undertaken as part of this project is made possible by the significant contributions of growers through both trial cooperation and the support of the GRDC, the author would like to thank them for their continued support.

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Date published

August 2023

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