Improving Phytophthora root rot resistance in chickpeas through breeding for waterlogging tolerance - implications for diagnosing root health and PREDICTA®B testing

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Key words

Chickpea, waterlogging, resistance breeding, Phytophthora root rot, diagnostics, PREDICTA®B

GRDC code

BLG302 - PhD Project: Improving Phytophthora root rot resistance though waterlogging tolerance in chickpea.

Take home messages

- Waterlogging will increase crop damage from Phytophthora root rot (PRR) including a reduction in rooting depth
- Sowing chickpea varieties with higher levels of PRR resistance (PBA HatTrick(b) & PBA Seamer(b)) will increase likelihood of survival in the presence of disease and in combination with waterlogging
- Observing chickpea root systems is the best determinant of plant health
- When using PREDICTA®B as an in-crop diagnostic tool, sampling for PRR in chickpea should be conducted approximately 8 days after a waterlogging event when increased levels of *Phytophthora medicaganis* DNA are present in the soil and root tissue.

Background

A link between Phytophthora root rot (PRR) resistance and waterlogging tolerance has been discovered previously in soybean. In chickpea this link has not yet been investigated. In 2010, 2012 and 2016, high in-crop rainfall occurred throughout the season in the PRR affected northern growing region and resulted in observed partial and complete chickpea crop losses. These losses were attributed to a number of issues including: waterlogging, salinity, lodging, Ascochyta blight, Botrytis grey mould and PRR. In undulating paddocks with free draining soil, where regular foliar fungicides could be strategically applied, crops suffered only minor yield penalties. Data collected from PRR yield loss trials (DAN00176, DAQ00186) demonstrated that in the 2016 season, when inoculated treatments were saturated for extended periods, yield loss reached up to 90% of the control in the moderately resistant Australian chickpea cultivar PBA HatTrick(b) (Table 1). This extent of loss was considerably higher than drier seasons with losses of 33% and 68% in 2014 and 2015, respectively (Table 1). However, it remains unclear as to whether increased yield losses in 2016 can be fully attributed to PRR or occurred in combination with waterlogging. Observations under early and cooler waterlogging events, as seen in 2010, saw extended chickpea survival in the absence of PRR. However, in 2016 extensive damage was recorded which may be related to higher temperatures, later physiological growth stage at the time of waterlogging and/or the presence of the PRR pathogen.

Table 1. Annual rainfall and Phytophthora root rot yield loss trial data from the 2014, 2015 and 2016 seasons for PRR moderately resistant variety PBA HatTrick♭*.

Season	Total in-crop rainfall (mm)	PBA HatTrick♭ yield (t/ha) in absence of PRR infection	PBA HatTrick♭ % yield loss due to PRR infection
2014	137	2.94	33
2015	194	2.50	68
2016	450	4.02	90

*GRDC updates paper - 'Phytophthora in chickpea varieties 2016 and 2017 trials –resistance and yield loss' (Bithell et al., 2018).

The life cycle of most oomycetes, including *Phytophthora medicaginis* which causes PRR in chickpea, consist of two phases each driven by the physical surroundings. The most prolific pathway (outer circle) is induced under high soil moisture (above field capacity) where dormant thick-walled oospore structures produce sac like sporangia containing large numbers of water motile zoospores which are released to infect plants. Zoospores can orientate and move towards the host plant infecting root tissue. The second and direct pathway (inner part of circle) is characterised by the production of a single germ tube from oospores or chlamydospores which also occurs under moist soil conditions. Oospores and chlamydospores are thick walled dormant structures able to survive long periods in adverse soil conditions (highest recorded 10 years). Under waterlogging conditions it is assumed that an influx of zoospores leads to severe PRR disease development. However, germination of Phytophthora spores requires oxygen which is greatly reduced or absent under waterlogging conditions. Oxygen levels are dependent on duration, temperature and soil characteristics. If the waterlogging event is short and water is fast draining, oxygen is not depleted and adequate levels of oxygen remain where Phytophthora species are able to survive and infect host root tissue.

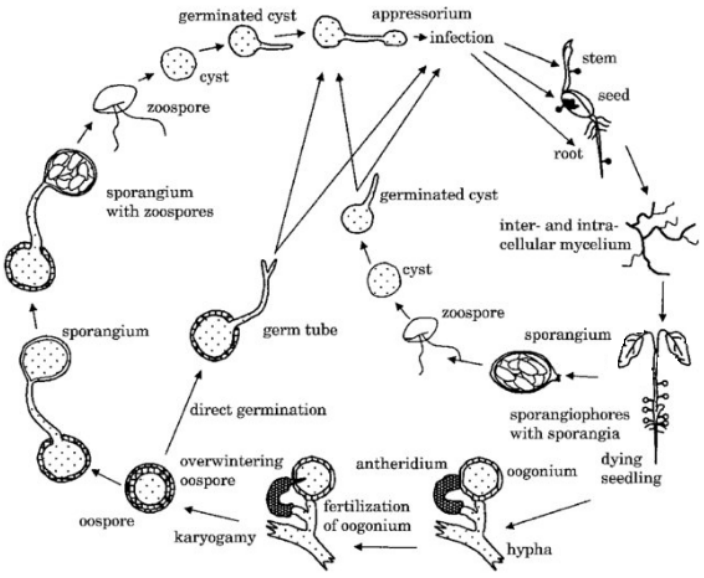

Figure 1. Life cycle of a typical root infecting oomycete *Pythium* and *Phytophthora* species (Van West, Appiah, & Gow, 2003).

Ongoing breeding and pathology efforts aim to understand and improve PRR resistance within Australian chickpea varieties. The specific aim of this PhD project (BLG203) is to investigate the possibility to improve or select for PRR resistance based on variation in waterlogging tolerance; with short term benefits of understanding the interaction between PRR and waterlogging and improved sampling time for in-field molecular diagnostics.

Sources of PRR resistance in commercial chickpea varieties are scarce with the search for novel sources of resistance for incorporation into adapted northern region backgrounds continuing. Older varieties (Kyabra(b), Jimbour, Moti(b) and Yorker) vary with low to moderate levels of PRR resistance. More recent varieties (PBA HatTrick(b)& PBA Seamer(b)) are characterised by their moderate resistance to PRR, but have been shown across seasons to still suffer up to 20-70% yield loss from PRR. Wild chickpea has been found to have novel PRR resistance, however it is notoriously poorly adapted, having a prostrate growth habit with low yield and seed quality issues; making genetic lag a major challenge when breeding for PRR resistance. Extensive backcrossing into domestic chickpea material has been required to improve yield, seed quality and adaption whilst maintaining the high level of PRR resistance.

The following results discuss the response of two varieties and one breeding line; the domestic PRR susceptible variety Rupali, and moderately PRR resistant Yorker as well as the wild chickpea interspecific back cross genotype 04067-81-2-1-1 with high PRR resistance. Varieties PBA HatTrick(b) and PBA Seamer(b) commonly grown in the Northern region would perform similarly to Yorker with slightly less resistance; and Kyabra(b) is similar to Rupali in terms of PRR resistance.

Disease symptoms and root characteristics of chickpea in response to waterlogging, PRR and both in combination

In a glasshouse experiment, foliar chlorosis was not observed in PRR resistant 04067-81-2-1-1 and moderately resistant Yorker seedlings in aerated PRR, waterlogging only or waterlogging + PRR treatments (Figure 2, left). However, under aerated PRR and waterlogging + PRR treatments the same entries suffered significant root disease symptoms including lateral root loss and primary root canker (Figure 2, right). The PRR susceptible entry Rupali had significantly increased chlorosis and root disease over 04067-81-2-1-1 and Yorker in both the aerated PRR and waterlogged + PRR treatments (Figure 2). The waterlogging treatment in the absence of PRR did not produce root necrosis or foliar chlorosis in any entry, being similar to the un-inoculated aerated control treatment (Figure 2).

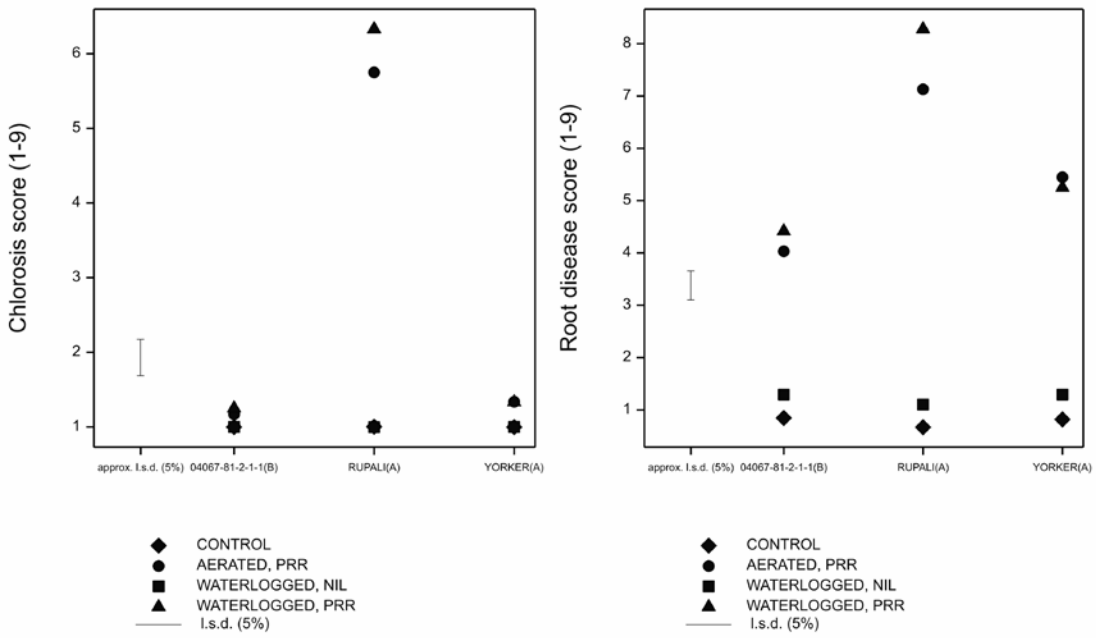

Figure 2. Foliar chlorosis (left) and root disease score (right) for chickpea entries under control conditions, aerated and PRR infected, waterlogged only and waterlogged with PRR infection. Chlorosis and root disease scale 1 =no symptoms, 9 = completely chlorotic foliage or total root loss. Root disease score rated the severity of necrosis in root tissue.

04067-82-1-1 has been noted to have an inherently smaller root system compared to cultivated chickpea Yorker and Rupali; and had significantly reduced root volume when infected with PRR under both aerated and waterlogging treatments conditions (Figure 3, left). Yorker had no significant change in root volume across treatments compared with the control treatment, despite having a higher root disease score. Waterlogging alone did not significantly affect the root volume of 04067-82-1-1, Yorker and Rupali (Figure 3, left). Interestingly under the waterlogging only treatment Yorker trended towards having higher root volume than the control treatment. Whilst root length volume remains largely affected by genotype and PRR infection, primary root length was greatly influenced by both waterlogging and PRR treatments (Figure 3, right). Primary root growth appears to be halted in the presence of both PRR and waterlogging. The moderately PRR resistant Yorker and PRR susceptible Rupali however continued to suffer further root length reductions with the combination of waterlogging and PRR infection over the PRR resistant genotype 04067-81-2-1-1 (Figure 3, right).

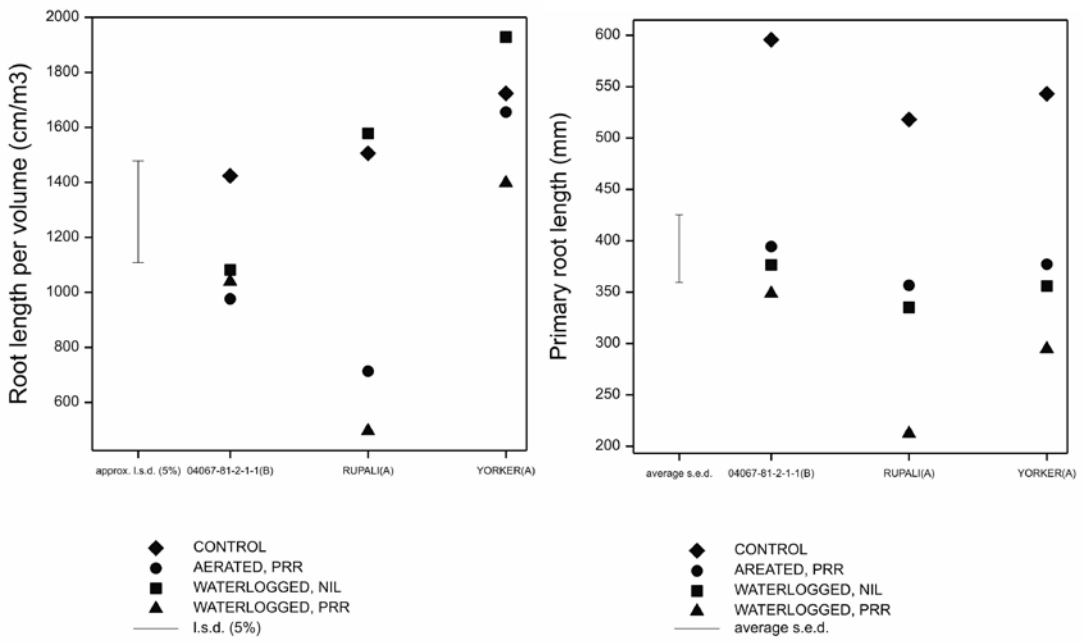

Figure 3. Root length volume (left) and primary root length (right) for chickpea entries under control conditions, aerated and infected with PRR, waterlogged only and waterlogged with PRR infection.

What does it mean for growers?

Both waterlogging and PRR can cause advanced root lesions and/or reductions in growth prior to the appearance of chlorosis in leaf tissue, except when a PRR susceptible variety is infected with PRR. The environmental conditions, timing and duration of waterlogging will determine whether plant death or yield losses are attributed to PRR or waterlogging. When diagnosing visually it is important to dig up the roots soon after water receding to identify the presence of brown root lesions which indicate PRR infection. Waterlogged plants will not have initial root lesions and have lateral roots remaining which provide greater resistance when attempting to pull them from the soil compared to PRR infected plants.

Plants may survive waterlogging if it occurs early in the season and plant biomass is low enough for the reduced root volume to maintain plant metabolism. Following flooding, if chickpea plants survive, in the presence of *Phytophthora medicaginis* root lesions will appear after 8-10 days as Phytophthora germinates and infects upon the re-introduction of oxygen to the favourable moist environment. Potting mix and hydroponic experiments (data not shown) as anticipated, showed that under long term waterlogging (11 days) and a lack of oxygen, zoospores were greatly reduced or absent in solution and PREDICTA®B results demonstrated a reduction in the number of Phytophthora DNA copies detected compared to non-waterlogged treatments. These results indicate that when looking to diagnose PRR during a flood season, soil sampling 8 days after waterlogging with the inclusion of suspect chickpea root tissue may provide the best chance to identify the presence or absence of PRR using PREDICTA®B for paddock history purposes.

Losses from PRR infection in chickpeas are increased when they occur in combination with waterlogging; not necessarily because the pathogen is able to proliferate in the favourable conditions, but due to lack of oxygen during waterlogging when root growth is restricted. This limits the chickpea plants ability to compensate for root damage caused by PRR. Initial findings indicate that increased levels of resistance to PRR did reduce damage to chickpea roots under the combination of PRR and waterlogging. Root characteristics under waterlogging did change between the domestic and wild chickpea resistance sources. Understanding the impact of these root traits and usefulness for waterlogging tolerance and/or PRR resistance is ongoing, with a wider search to discover new sources of waterlogging tolerance and PRR resistance.

References

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