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Published by NSW Department of Primary Industries,
a part of the Department of Regional New South Wales.

Effects of early and late waterlogging on phytophthora root rot and chickpea resistance

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Key findings

- Waterlogging had a greater effect on chickpea yield when compared with phytophthora root rot (PRR) disease.
- Commercial chickpea varieties, such as PBA HatTrick(D), were more affected by waterlogging during the late vegetative growth stage (83% yield loss) than the early vegetative growth stage (26% yield loss).
- Late waterlogging plus PRR infection resulted in rapid plant death and up to 98% yield loss.
- Waterlogging reduces the plant's ability to overcome PRR infection, even in varieties with higher resistance PRR.

Keywords waterlogging, chickpea, phytophthora, yield loss, PRR

Introduction

Under high soil moisture conditions, PRR is explosive where inoculum is present. Under waterlogging conditions where water level is above field capacity the disease is exacerbated even further. PRR and waterlogging are difficult to differentiate in chickpea during a wet season, as symptoms are quite similar.

PRR symptoms include:

- reduced or stopped growth rate
- leaf chlorosis
- foliage desiccation
- premature senescence
- wilting
- lateral root decay
- reddish-brown stem canker
- yield loss.

Symptoms of waterlogging are identical except that there is rapid onset in warmer conditions and the absence of stem canker and unique root lesions (Moore 2015).

This study aimed to describe the effect of soil waterlogging on PRR disease, including chickpea varieties with moderate levels of resistance to PRR. This information can be used to understand the risks associated with both waterlogging and PRR; describing when integrated disease management (IDM) practices might be successful.

Site details

Location	Shade house – Tamworth Agriculture Institute, Tamworth, NSW. Shade house temperatures described in results section.

Soil media	1:1:1, loam, sand, Greenlife® garden blend, pH_{Ca} 7.6 in 100 L bins as deep pots.
Experiment design	• Four replicates in a factorial split plot design • Waterlogging (n = 3) × *Phytophthora medicaginis* (pm) inoculation (n = 2) as the main plot treatment level • Chickpea genotypes (n = 8) the subplot treatment level.
Sowing date	29 June 2020.
Fertiliser	After 8 weeks all plants were fertilised fortnightly with 30 mL Yates® Thrive soluble all-purpose fertiliser.
Plant population	Target 30 plants/m^2.
Harvest date	19 October 2020.

Treatments

Varieties (4)

Four chickpea genotypes:

- Moderately resistant: 04067 (wild chickpea backcross breeding line)
- Moderately susceptible: Yorker$^{\Phi}$ and PBA HatTrick$^{\Phi}$
- Susceptible: Rupali$^{\Phi}$.

Disease and waterlogging

Six treatments:

1. a nil control (no PRR or waterlogging)
2. PRR infection
3. early waterlogging
4. late waterlogging
5. PRR infection with early waterlogging
6. PRR infection with late waterlogging.

Measures

Measures were analysed using a generalised linear mixed model with 5–95% confidence intervals, measures included: Grain weight (g/plant) and root health score (1=good; 9=bad) were taken from above the seed.

Results

Waterlogging had the greatest effect on grain weight (F = 305, P<0.001), when compared with genotype (F = 33, P<0.001) and PRR (F = 10.2, P<0.05), respectively (Figure 1). Reductions in grain weight were seen to be associated with plant stunting and early senescence following early waterlogging; and plant death resulting from late waterlogging. None of the 4 genotypes was able to fully recover seed weight following early or late waterlogging.

PBA HatTrick$^{\Phi}$ yield of was reduced by 26% and 83% following early and late waterlogging respectively. Late waterlogging had a more detrimental effect than early waterlogging (Figure 1) due to a significantly greater root disease incidence under waterlogging conditions (Figure 2). PRR in combination with waterlogging further reduced grain weight in some genotypes (Figure 1) and increased root disease (Figure 2), with 74% and 98% losses observed in PBA HatTrick$^{\Phi}$ after early and late vegetative waterlogging, respectively.

The PRR treatment (without waterlogging) displayed no foliar symptoms or seed weight reduction compared with the non-waterlogged uninoculated control (Figure 2). With greater soil moisture, which was difficult to maintain in the light soil media in this study, higher levels of root disease due to PRR is expected especially in susceptible varieties. Under field capacity, PRR-caused root damage was more severe in the very susceptible genotype Rupali$^{\Phi}$ (Figure 2), and although this was not significantly different from the uninoculated Rupali$^{\Phi}$, it still supports using varieties with better PRR resistance where Pm inoculum is present.

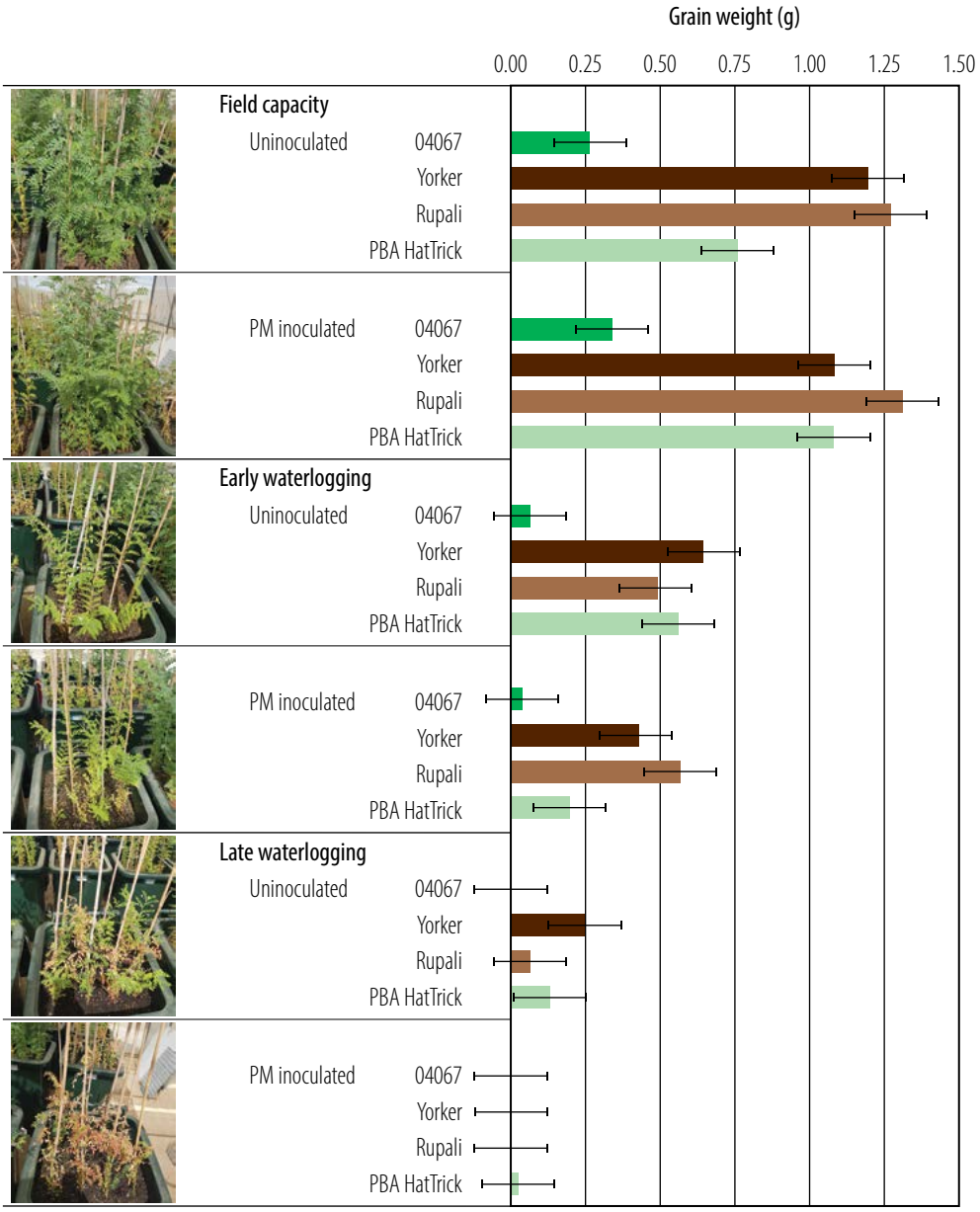

Figure 1 Mean grain weight and 5–95% confidence intervals for treatments: Field capacity or early and late vegetative waterlogging, uninoculated or *Phytophthora medicaginis* (Pm) inoculated; for 4 chickpea genotypes. *P* value for the 3-way interaction is <0.05.

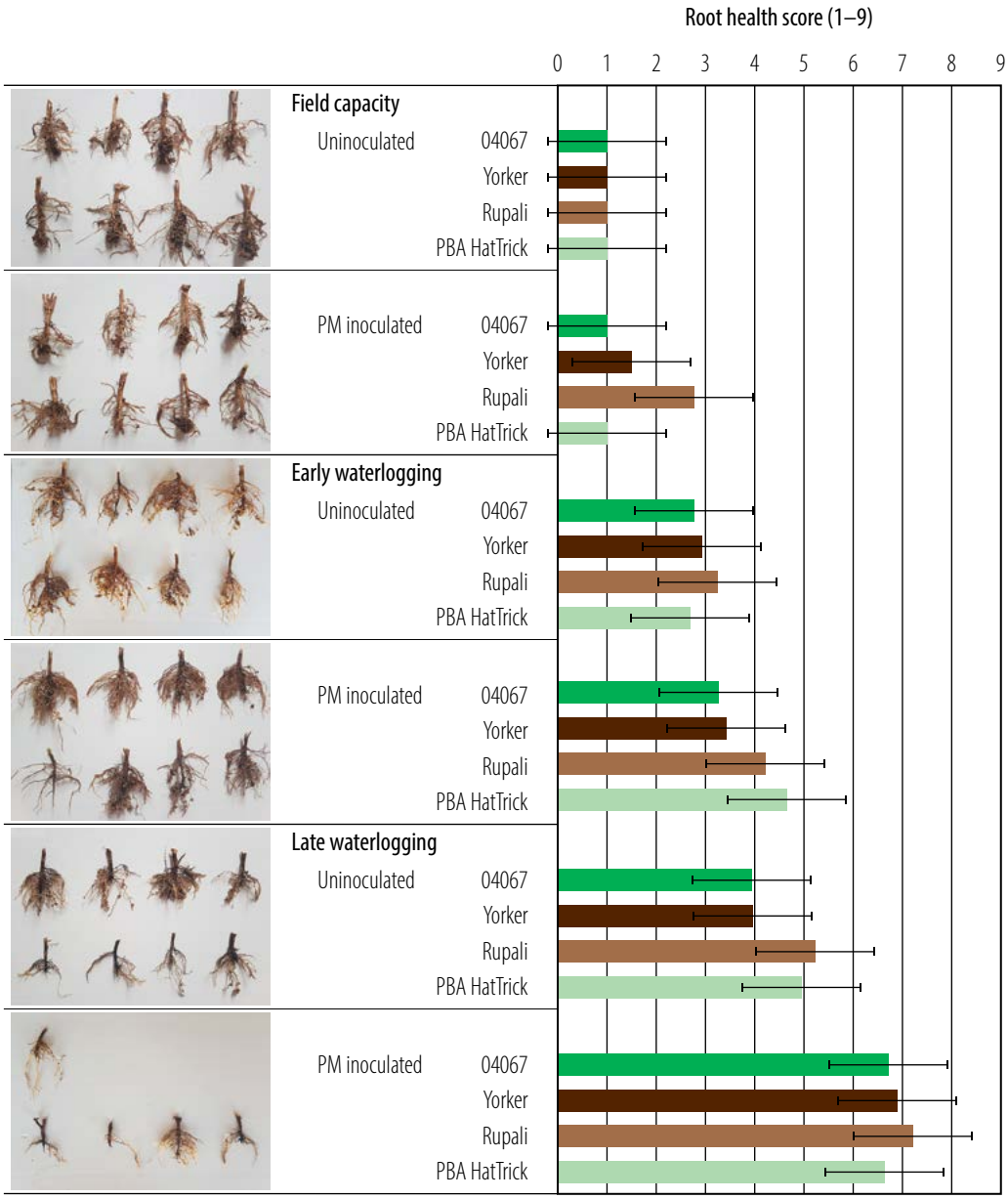

Figure 2 Mean root health score and 5–95% confidence intervals for treatments: Field capacity or early and late vegetative waterlogging, uninoculated or *Phytophthora medicaginis* (Pm) inoculated; for 4 chickpea genotypes. *P* value for the 3-way interaction is <0.001.

Final redox measures (mV), a measure of waterlogging severity, were not significantly different between early and late waterlogging treatments. However, the soil temperature and ambient temperatures were 12.1 °C and 7.8 °C warmer during the late waterlogging treatment than during the early waterlogging treatment, respectively (Figure 3). Higher temperatures increase the rate of plant transpiration and respiration, which in turn puts the plants under greater stress when waterlogged, particularly during the late vegetative and flowering stages (Cowie and Voesenek L 1996).

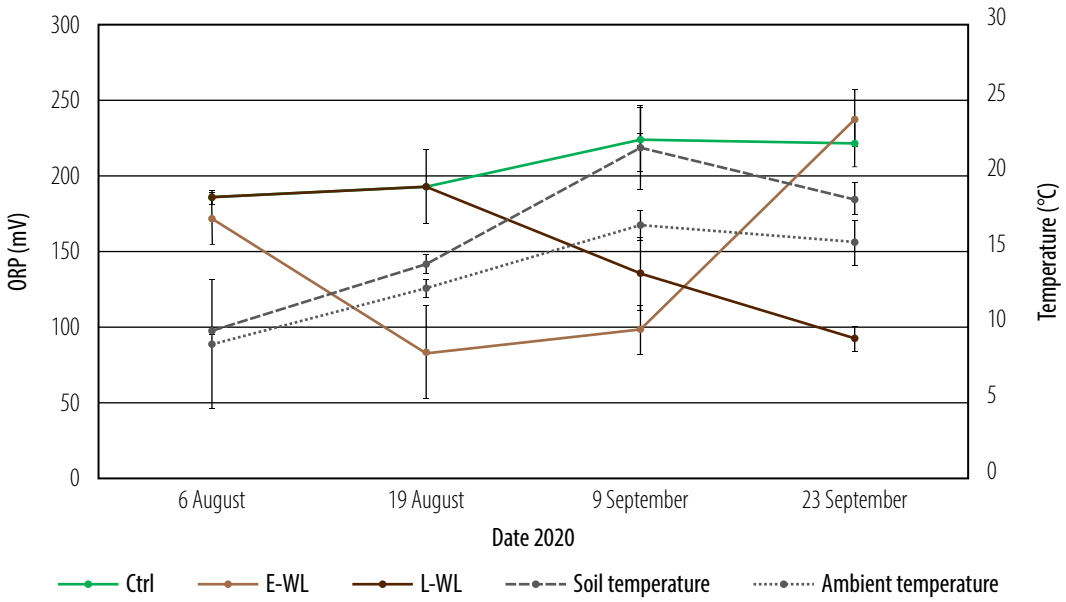

Figure 3 Soil redox (oxidation reduction potential, ORP) an indicator of oxygen availability, ambient and soil temperatures during early and late waterlogging treatments. E-WL: Early waterlogging, L-WL: late waterlogging, Ctrl: control.

Conclusions

This study shows that waterlogging alone can cause major disease and yield losses, with waterlogging timing also having a significant effect. The findings show that the likelihood of plant survival and recovery from waterlogging (in the absence of PRR inoculum) is higher when waterlogging occurs during early growth stages. These findings are supported by waterlogging results of chickpea and other crop species, where waterlogging causes both root damage and physiological constraints (water and nutrient uptake) that reduces the plants ability to overcome stress (Colmer and Voesenek 2009, Palta et al. 2010). Therefore, in a scenario where both waterlogging and PRR inoculum is present, chickpea will have greater yield reductions.

The ability to predict PRR and waterlogging-induced yield losses could be used to reduce late season in-crop inputs, as there is currently no economic in-crop control. The findings support currently recommended practice to avoid paddocks with:

- a known presence of PRR
- a history of chickpea, lucerne or medic weeds
- low-lying areas particularly when above average rainfall is forecast
- growing chickpea varieties with higher levels of PRR resistance.

Moreover, using conservative agronomy and soil improvement practices could be used to reduce waterlogging as IDM for PRR, as waterlogging alone results in plant stunting, yield loss and a reduced resistance to PRR in chickpea.

For more further detail please follow the link https://www.mdpi.com/2073-4395/12/1/89 (Dron et al. 2022).

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Acknowledgements This research was supported by investment from the Grains Research and Development Corporation (GRDC) and New South Wales Department of Primary Industries, Grains Agronomy and Pathology Partnership (project BLG302). Kevin Moore and Sean Bithell developed the disease assessment and oospore production methods used in this study.

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