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Project Code	
Project Type	

FINAL REPORT 2016

PROJECT CODE : SARDI 215

PROJECT TITLE Impact of seeding time and *Pratylenchus neglectus* on Rhizoctonia fungicide yield responses

PROJECT DURATION

Project Start date	1 July 2015				
Project End date	30 June 2016				
SAGIT Funding Request	2013/14	$	2014/15	$	2015/16

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PROJECT REPORT

Executive Summary

This project investigated the effect of time of sowing and *Pratylenchus neglectus* levels on the yield responses associated with liquid streaming the fungicide Uniform® above and below the seed to control rhizoctonia root rot caused by *Rhizoctonia solani* AG8 in wheat and barley. Patching caused by *Rhizoctonia* was severe in both crops at all 3 times of sowing assessed, probably due to below average soil temperatures post sowing and below average growing season rainfall.

- In barley, the fungicide treatment produced a significant yield response of 0.3 t/ha and this was not affected by time of sowing and *P. neglectus* levels.
- In wheat, there was a significant interaction between the fungicide and *P. neglectus* which resulted in a 0.2 t/ha yield increase in the low *P. neglectus* treatment and no yield response in the higher *P. neglectus* treatment. A similar response was previously observed at Lameroo (2014).
- Fungicide treatment increased root growth of wheat on row by >50% and barley by 40% for all 3 times of sowing.
- Fungicide application decreased *Rhizoctonia* levels by >30% in both crops mid-season and 40% by November, reducing inoculum carried into the next season.
- Time of sowing had the greatest effect on wheat and barley yields, with early sowing producing the highest yields, 2.01 t/ha for wheat and 2.4 t/ha for barley.

These results show that fungicides applied to control *Rhizoctonia* are more likely to produce yield responses in barley than wheat. This work needs to be repeated in different seasons to better understand the factors that determine the magnitude of yield responses to fungicides applied to control rhizoctonia root rot.

Project Objectives

Determine if time of sowing and moderate *Pratylenchus neglectus* numbers affect the yield responses in wheat and barley associated with application of fungicide to control rhizoctonia root rot caused by *Rhizoctonia solani* AG8.

Provide recommendations to growers on likely impact of *Pratylenchus neglectus* and time of sowing on yield responses associated with application of fungicides to control rhizoctonia root rot.

Overall Performance

This is the first project designed to investigate factors that cause yield responses to vary when fungicides are applied to control rhizoctonia root rot. Results from this trial show that:

- Yield responses are greater in barley than wheat.
- Time of sowing (TOS) did not have a significant effect on the magnitude of fungicide yield responses, but had large effect on wheat and barley yields.
- Significant *P. neglectus* levels can eliminate the fungicide yield responses in wheat.
- The fungicide treatment increased wheat and barley root growth on the rows at each TOS, however there was no benefit to root growth between rows.
- NDVI data collected by a drone can be used to measure variation in plant growth within plots. Plots with uniform growth produced the highest yields and analysis of the data suggests potential yields for wheat and barley could have been 0.4 t/ha and 0.6 t/ha respectively, above that achieved by the fungicide treatments at the first sowing time.

Problems encountered include:

- Use of Fusion triticale to produce the low nematode population created a significant crown rot risk which was avoided by burning the stubble and sowing between the rows.
- Use of Estoc wheat to create the high *P. neglectus* populations may have left some residual moisture that could have reduced the impact of the high nematode treatment in 2015.
- Amount of patching caused by *Rhizoctonia* was greater than in previous seasons, this made it impractical to collect dry matter cuts, so drones were used to collect NDVI and canopy temperature data.

Dr Alan McKay, SARDI, was the Principal Investigator and oversaw the overall management of the project.
Dr Katherine Linsell, SARDI, organised the trial management and the majority of the data collection.
Dr Ramesh Raja Segaran, University of Adelaide Unmanned Research Aircraft Facility, collected and extracted NDVI, thermal data and videos of the trial site.
Dr Victor Sadras provided advice on APSIM to estimate potential yield.
Dr Ray Correll, Rho Environmetrics, performed statistical analysis of the collected data.

Key Performance Indicators (KPI)

KPI	*Achieved (Y/N)*	*If not achieved, please state reason.*
Each plot assessed to determine levels of *Rhizoctonia* and *P. neglectus* prior to seeding. Each plot was soil sampled on the row of the previous crop prior to sowing in May. *P. neglectus, Rhizoctonia* and crown rot inoculum levels were assessed by the SARDI PreDicta B.	Y	
Trial sown by New Crop Agronomy group, seeding times 1, 2 and 3 to coincide with start, mid and end of district practice. Soil cores taken for moisture.	Y	

A factorial trial design was used, with each treatment combination replicated 5 times; the 3 TOS (6th May, 22nd May and 11th June) and fungicide treatments were blocked. Other treatments included Scope barley and Grenade CL Plus wheat, two *P. neglectus* densities (1.5 range 0-4, and 10 range 2-20 nematodes/g soil), and plus/minus Uniform® fungicide dual banded at 200 ml/ha above the seed and 200 ml/ha below the seed. A weather station recorded daily rainfall figures, hourly soil temperature and moisture readings at 5cm, 10cm and 30cm deep for each TOS. Four soil cores were taken randomly across the trial at each TOS and divided into 4 portions 0-10, 10-30, 30-50 and 50-65 for gravimetric soil moisture content measurement.		
In crop assessment (i) NDVI, greenness and canopy temperature at least 2 times between stem elongation and flowering, (ii) biomass cuts at stem elongation, flowering and maturity, (iii) visual score of crown root health in spring, DNA assessments of root growth, *Rhizoctonia, P. neglectus* on and between rows at 2 depths to assess treatment responses. (i) Dr Segaran (UofA) was contracted to capture NDVI, canopy temperature and visual images of each plot in August and October using drones. (iii) Potential interactions with crown rot were examined using pre-sowing and post-harvest *Fusarium* DNA concentrations as covariates in the analysis. *Rhizoctonia, P. neglectus*, wheat and barley DNA concentrations in soil were measured in August and October; wheat and barley DNA results are a measure of root growth.	Y	(ii) Biomass cuts were not collected due to the severe bare patching and small plot lengths. (iii) Visual assessment of crown root health was not performed in spring because the soil was too hard. Also rather than soil sample on and between the rows at 2 depths at one time, it was decided to sample 0-10cm on and between the rows in August and October, and on row post-harvest in November; *Fusarium* spp. associated with crown rot were also assessed post-harvest.
Trial harvested. Residual water assessed in selected plots. Trial was harvested on 26th Nov.	Y	Residual water could not be assessed due to 51 mm of rain received post crop maturity on 4th and 5th Nov.
Progress report submitted.	Y	
Data analysed and final report submitted	Y	

Technical Information

This trial was conducted at Wilkawatt in 2015 to study the effect that time of sowing (TOS) and *Pratylenchus neglectus* levels have on yield responses in wheat and barley associated with liquid streaming Uniform® (200 ml/ha on to the furrow surface, and 200 ml/ha at the base of the furrow) to control rhizoctonia root rot.

Seasonal conditions

The growing season had 114 mm rainfall, dry spring (26 mm rainfall) and cold soil temperatures which dropped to 10°C four times in May (Figures 1 and 2). The cold start probably contributed to development of rhizoctonia patches in all three sowing times in both wheat and barley (Figure 3).

Assessments

Each plot was soil sampled on the row of the previous crop prior to sowing in May, on and between the rows in August and October, and on row post-harvest (November). Each sample was a composite of 21 cores, 12mm x 100mm. PreDicta B was used to measure *Rhizoctonia* and *P. neglectus* levels at each sampling time. Wheat and barley DNA concentrations were measured to monitor root growth during the growing season. The site was harvested on 23rd November, this was delayed due to heavy rainfall post crop maturity on 4th and 5th November. Grain quality was also assessed for each plot. A weather station collected hourly soil temperature and moisture readings and daily rainfall. Drones were used to capture canopy temperature, NDVI and visual images of each plot in August and October.

Data were analysed by Dr Ray Correll of RHO Environmetrics. The main analyses were performed using the spatial REML options. A first order autoregressive model was used to model the residuals. Analyses involving root DNA were undertaken using a within-species randomised split-plot analysis with columns treated as main plots. A second set of models used the Papadakis technique to model field variation. The latter was used to analyse wheat and barley effects individually.

Initial pathogen levels

The trial site was established in 2014. Fusion triticale and Estoc wheat was sown to create in paired plots of low and high numbers of *P. neglectus*.

In 2015, each plot was sampled on 6th May, time of sowing 1, to assess initial levels of *Rhizoctonia solani* AG8, *P. neglectus*, *Fusarium pseudograminearum* and *F. culmorum* (Table 1). The low *P. neglectus* population averaged 1.5 nematodes/g soil and the high population 10.5 nematodes/g soil, these were significantly different ($p<0.001$), though the "high" population was lower than expected. *Rhizoctonia* levels were not different between the two nematode densities and averaged 190 pg DNA/g soil (high risk). *Fusarium pseudograminearum* and *F. culmorum* levels were significantly greater in the low *P. neglectus* treatment. Incorporating the *Fusarium* levels as covariates in the analysis did not change the treatment effects, probably because the stubble had been burnt and the trial was sown between the rows of the 2014 crop.

Yield effects

- Time of sowing had the greatest effect on wheat and barley yields. Wheat and barley sown on 6th May (TOS 1) produced 2.01 t/ha at and 2.4 t/ha, respectively and yield declined to 1.40 and 1.20 t/ha respectively when sowing was delayed until 11th June (TOS 2; Figure 4).
- The fungicide treatment produced 0.3 t/ha yield response in barley ($p=0.022$) and the interaction with time of sowing was not significant, even though there was a 0.6 t/ha yield response at TOS 2 (Figure 5, Tables 2 and 3).
- The fungicide treatment increased wheat yields by 0.2 t/ha in the low *P. neglectus* treatment, but did not increase yield in the high nematode treatment (Table 4). A similar effect was observed at Lameroo in 2014.
- The fungicide treatment had no overall effect on grain quality, though it did increase grain weight in barley (Table 5).
- Sowing time did affect grain quality; 1000 grain weight declined and % protein and % screenings increased when seeding time was delayed and the effects were greater in barley (Table 6).
- There was a significant ($p<0.001$) correlation between drone biomass assessment (NDVI) in August and yield ($r^2= 0.885$) compared to October ($r^2= 0.197$), which indicates yield was determined by August.
- There was also a significant negative correlation between uneven growth (within plot NDVI coefficient of variation) in August and October, and yield, $r^2= -0.564$ and $r^2= -0.423$, respectively (Figure 6). Both measures show the importance of minimising uneven growth to reduce yield loss. Figure 3 indicates that if patching had been eliminated, wheat and barley yields would have

been about 0.4 t/ha and 0.6 t/ha greater than was achieved by the respective fungicide treatment at TOS 1.

- The fungicide treatment reduced plot variation in barley, but not in wheat.
- APSIM modelling predicted wheat and barley yields should have been marginally greater than the actual wheat and barley yields achieved in the fungicide treated plots at sowing time 1, but APSIM predictions were lower than the achieved yields at TOS 2 and 3 (Table 7). These results indicate the APSIM settings were too conservative.

Root growth effects

- The crops sown at TOS 2 (22 May) had the highest on-row root DNA concentrations, but the crops sown at TOS 1 had the highest between row root DNA concentrations (Table 8).
- Fungicide treatment increased root growth on row of wheat by >50% and barley by 40% at each time of sowing, and the effects persisted into October (Table 9).
- Fungicide treatment did not affect root growth between rows, indicating the fungicide did not move to the root tips (Table 9).

Rhizoctonia effects

- *Rhizoctonia* levels were highest on row in crops sown at TOS 2 (Table 10).
- *Rhizoctonia* multiplication was 20 to 30% greater on barley than wheat throughout the growing season and the effects persisted post-harvest (Table 10).
- Fungicide treatment reduced *Rhizoctonia* levels by 30 to 40% on row at each assessment time including post-harvest; *Rhizoctonia* levels between rows were mostly not affected (Table 11).
- TOS did not affect post-harvest *Rhizoctonia* levels for wheat, but levels were lower for barley at TOS 3 (Table 11).
- *Rhizoctonia* DNA levels on row in August accounted for 90% of the fungicide effect on barley yield and 45% of the effect on wheat yield. This indicates *Rhizoctonia* was responsible for the yield responses (Table 11).

Pratylenchus effects

- *P. neglectus* multiplication was greater in crops sown early, and greater on Grenade wheat (MSS) than Scope barley (MRMS) (Table 12).
- Fungicide treatment had no effect on *P. neglectus* multiplication (Table 13).
- The different crops used to create the paired low and high *P. neglectus* levels may have affected residual soil moisture levels as the NDVI results were reduced and patchiness was greater in the low nematode treatment (Table 14).
- *P. neglectus* levels were negatively correlated with yield of wheat in the low nematode treatment and in the low and moderate nematode treatment for barley (Table 15).

Conclusions Reached &/or Discoveries Made

The key findings include:

- Confirmation that fungicide applied to control rhizoctonia root rot in barley is more likely to produce significant yield responses than if applied to wheat.
- The fungicide treatment increased barley yield by 0.3 t/ha, even though rainfall was below average. Also the magnitude of the yield response was not affected by time of sowing, though this needs to be confirmed at other sites.
- The fungicide yield responses in barley are less likely to be reduced by *P. neglectus* than in wheat.
- Significant levels of *P. neglectus* can negate potential yield gains when fungicides are applied to control rhizoctonia root rot in wheat.
- *Rhizoctonia* multiplication was greater in barley than wheat and post-harvest levels were not greatly affected by sowing time.

- *Pratylenchus neglectus* multiplication was greater in crops sown early and greater on wheat than barley.
- Variation of NDVI data collected within plot is a useful measure of uneven growth.
- Time of sowing had a greater impact on yield in both wheat and barley than rhizoctonia root rot.

Intellectual Property

The intellectual property generated by this project is mostly data on the effects of the interactions between *Rhizoctonia* and *P. neglectus* affecting the yield responses in wheat and barley associated with application of fungicides applied to control rhizoctonia root rot.

The value of this IP is likely to be in facilitating development of more robust recommendations to growers on when to use fungicides to minimise yield losses caused by *Rhizoctonia*.

Application / Communication of Results

<u>Main findings of the project in a dot point form suitable for use in communications to farmers</u>
A field trial was conducted at Wilkawatt SA in 2015 to investigate how time of sowing and different *Pratylenchus neglectus* levels affect the yield responses associated with application of the fungicide Uniform® as a dual liquid stream to control *Rhizoctonia* in wheat and barley.

- In barley, the fungicide treatment produced a significant 0.3 t/ha yield increase, and this was not affected by the time of sowing or nematode level.
- In wheat, the fungicide treatment increased yield by 0.2 t/ha in the low nematode treatment, but in the high nematode treatment the fungicide treatment did not increase yield even though root growth was increased by 50%. A similar affect was observed at Lameroo in 2014.
- Fungicide application decreased *Rhizoctonia* levels on row by >30% in both crops mid-season and 40% post-harvest.
- Fungicide treatment increased root growth on row of wheat by >50% and barley by 40% at each time of sowing, but not between the rows.
- Time of sowing had the greatest effect on yield, at TOS 1 wheat produced 2.01 t/ha and barley 2.4 t/ha, at TOS 3 wheat yield declined by 0.64 t/ha and barley by 1.26 t/ha.
- *Rhizoctonia* multiplication was greater on barley than wheat.
- Post-harvest *Rhizoctonia* levels were not affected by TOS on wheat but was reduced significantly following barley at TOS 3.
- *P. neglectus* multiplication was greater on wheat than barley and greater in treatments sown early.
- Increasing levels of *P. neglectus* were associated with reduced wheat and barley yields.

<u>A statement of potential industry impact</u>
The information produced by this project will assist growers to get a better return of funds invested in fungicides to control rhizoctonia root rot. This project also provides an important first step into understanding which soilborne pathogens interact to affect crop yield. The fungicide treatment used was Uniform® dual banded at 200ml/ha above and 200 ml/ha below the seed.

This experiment needs to be repeated in at least one other season, preferably one with above average rainfall, to check that the effects of sowing time and interactions with *P. neglectus* are consistent.

<u>Publications and extension articles delivered as part of the project</u>

AgCommunicators Bridget Penna visited the site on three occasions to capture video and images for an article for distribution in local newsletters and regional newspapers. AgCommunicators released a YouTube clip using the aerial video captured by the drone (University Adelaide) in August.

Results were presented at the

- Southern Mallee Ag Bureau Meeting in August 2015.
- PreDictaB agronomist root disease courses in November 2015 (Adelaide, Perth, Gunnedah, Wagga Wagga and Bendigo).
- GRDC research updates in Adelaide and Ballarat in February 2016.
- Independent Consultants meeting at Waite in February 2016.
- GRDC Technical Workshops – Identifying Cereal Root Disease at Horsham, Pinaroo and Lock in March 2016.

Suggested path to market for the results including barriers to adoption

It is recommended that the results of this work be extended to growers via consultants, media articles. A provisional economic decision support model is under development in collaboration with Amir Abadi (Centre for Crop Disease Management, Curtin University). This could be a useful tool to assist growers understand the economic risks and benefits associated with using products like Uniform® to manage yield losses caused by rhizoctonia root rot.

POSSIBLE FUTURE WORK

Rhizoctonia root rot can cause significant yield losses in wheat and barley and new fungicides can provide significant protection of the root systems, especially when applied by liquid streaming. However in below average rainfall years, there is a significant risk that growers will not get a return on investment in fungicide. These conditions are most likely to occur in the low to medium rainfall districts where rhizoctonia root rot is most prevalent.

The interaction between *Rhizoctonia* and *P. neglectus* that diminishes the fungicide responses in wheat, shows this is a potentially important new area of research.

Recommendations:

- Better experimental methods and trial designs may need to be developed to reduce/manage the natural variability in soilborne pathogens to enable the effects of pathogen complexes on crop yield to be investigated.
- The interaction between *Rhizoctonia* and *P. neglectus* that reduces fungicide yield responses in wheat, need to be examined in a broader range of seasons.
- Other interactions that should be considered include rhizoctonia and crown rot, and *Pratylenchus* and crown rot.

AUTHORISATION	
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Signature:	
Date:	31 August 2016

Appendix

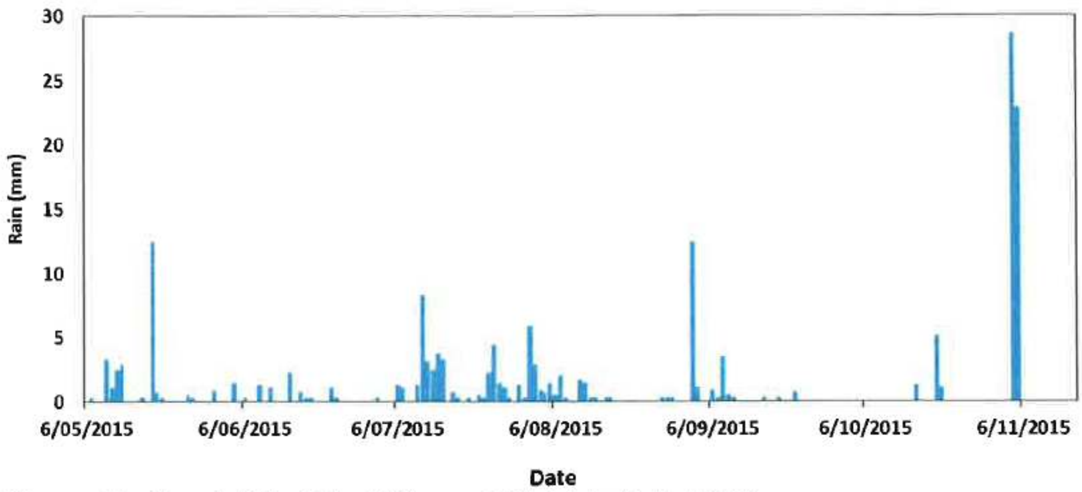

Figure 1 Daily rainfall at the Wilkawatt SA trial site in 2015

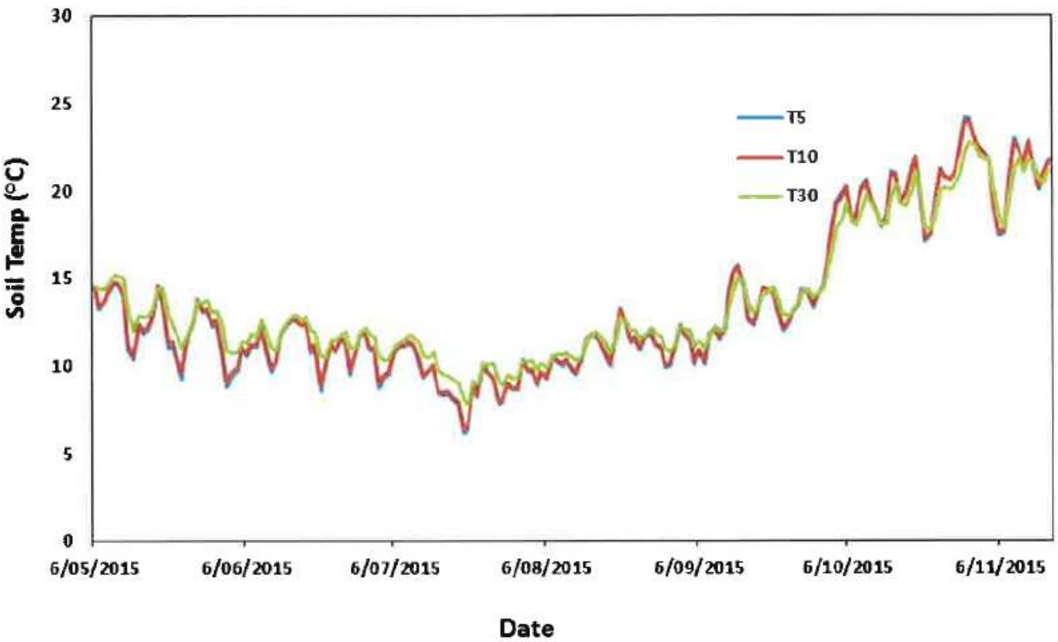

Figure 2 Soil Temperature at 5cm (T5), 10cm (T10) and 30cm (T30) at Wilkawatt SA in 2015

Table 1 Initial soilborne pathogen levels in the low and high *Pratylenchus* treatments.

Pathogen	Units	*P. neglectus* population		SED*	p value
		Low	High		
Rhizoctonia solani AG8	pg DNA/g soil	207	173	33	0.310
Pratylenchus neglectus	nematodes/g soil	1.5	10.5	0.7	<0.001
Fusarium pseudograminearum	pg DNA/g soil	119	45	91	0.344
Fusarium culmorum	pg DNA/g soil	652	161	243	0.047

*SED: Standard error of difference

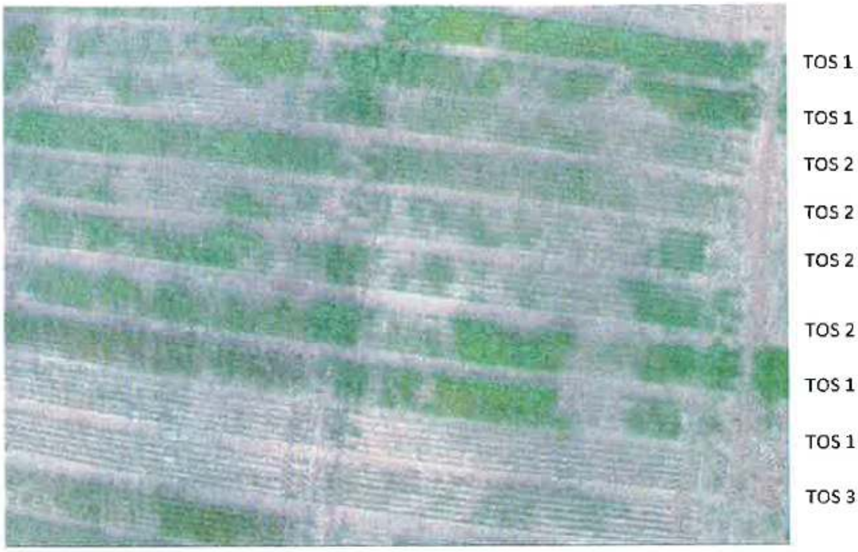

Figure 3 Rhizoctonia bare patches at the TOS 1 (6/5/15), TOS 2 (22/5/15) and TOS 3 (11/6/15) at Wilkawatt in 2015

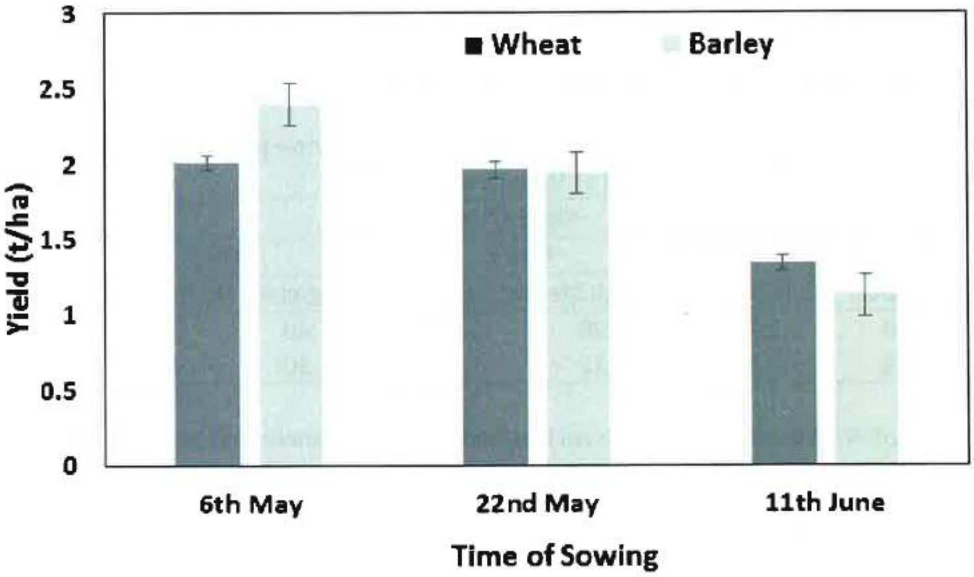

Figure 4. Effect of time of sowing on yield of Grenade CL Plus wheat and Scope barley, sown early (TOS 1, 6th May), mid (TOS 2, 22nd May) and late (TOS 3, 11th June) at Wilkawatt, 2015 (bars are standard error of difference)

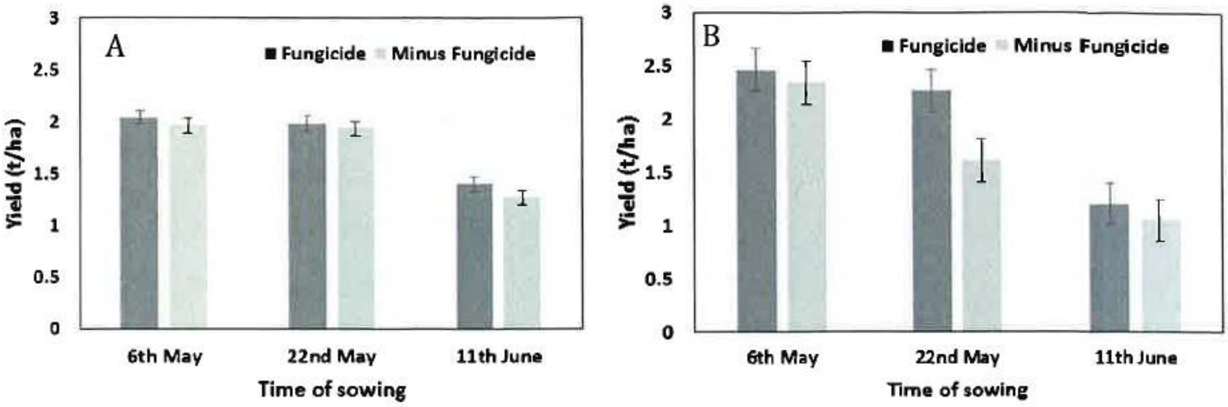

Figure 5 Fungicide yield responses in **A** Grenade CL Plus wheat **B** Scope barley sown early (TOS 1, 6th May), mid (TOS 2, 22nd May) and late (TOS 3, 11th June) at Wilkawatt 2015 (bars are standard error of difference)

Table 2 Fungicide yield responses in Grenade CL Plus wheat and Scope barley at Wilkawatt, 2015 averaged across the three TOS

Measure	Crop	Yield t/ha			SED	*p* value
		Fungicide	No Fungicide	Response		
Yield	Wheat	1.81	1.73	0.08	0.07	0.076
	Barley	1.97	1.67	0.30	0.04	0.022

Table 3 Fungicide yield responses in Grenade CL Plus wheat Scope barley at TOS 1 (6th May), TOS 2 (22nd May) and TOS 3 (11th June) at Wilkawatt 2015

Crop	Yield t/ha						SED	p value interaction
	TOS 1		TOS 2		TOS 3			
	Fungicide	No Fungicide	Fungicide	No Fungicide	Fungicide	No Fungicide		
Wheat	2.04	1.97	1.98	1.94	1.40	1.27	0.07	0.672
Barley	2.46	2.34	2.27	1.62	1.20	1.05	0.20	0.128

Table 4 Effect of *Pratylenchus neglectus* on fungicide yield responses in Grenade CL Plus wheat and Scope barley at Wilkawatt 2015

Measure	Crop	Yield t/ha				SED	p value
		Moderate *P. neglectus*		Low *P. neglectus*			
		Fungicide	No Fungicide	Fungicide	No Fungicide		
Yield	Wheat	1.81	1.85	1.80	1.61	0.06	0.022
	Barley	2.06	1.72	1.89	1.62	0.15	0.689

Table 5 Effect of fungicide treatment on grain quality in Grenade CL Plus wheat and Scope barley at Wilkawatt 2015

Measure	Crop	Minus Fungicide	Plus Fungicide	Row SED	Column SED
1000 grain weight (g)	Wheat	37.81	37.68	0.41	0.24
	Barley	39.58	40.16		

Table 6 Effect of time of sowing on grain quality in Grenade CL Plus wheat and Scope barley at TOS 1, TOS 2 and TOS 3 at Wilkawatt 2015

Measure	Crop	TOS 1	TOS 2	TOS 3	Row SED	Column SED
1000 grain weight	Wheat	38.63	37.02	37.58	0.5	0.29
	Barley	40.65	39.71	39.24		
% screenings	Wheat	3.46	3.85	3.14	1.61	0.93
	Barley	3.94	7.5	13.07		
Total protein	Wheat	0.206	0.204	0.161	0.013	0.008
	Barley	0.241	0.23	0.167		

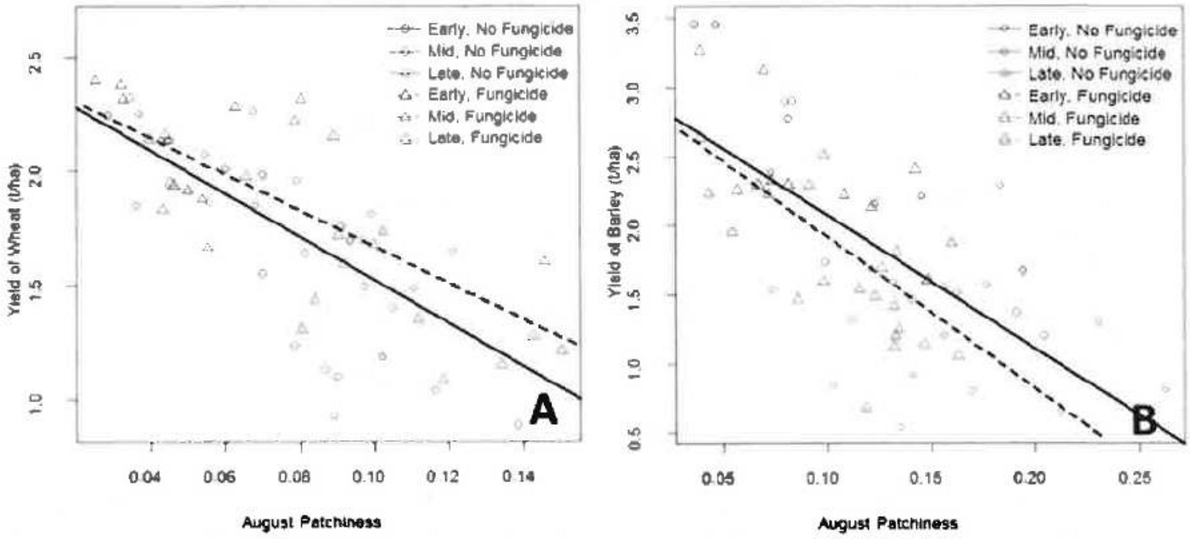

Figure 6 Relationship between patchiness (NDVI variation within plot) measured in August and yield of **A** Grenade CL Plus wheat and **B** Scope barley at Wilkawatt 2015

Table 7 Yield of the Grenade CL Plus wheat and Scope barley fungicide treatments and yield predicted by APSIM at Wilkawatt 2015

Measure	Crop	Yield t/ha		
		TOS 1	TOS 2	TOS 3
Yield	Wheat	2.04	1.98	1.399
	Barley	2.46	2.27	1.20
APSIM	Wheat	2.16	1.55	1.24
Yield	Barley	2.62	1.92	1.34

Table 8 Effect of crop type and sowing date on amount of root DNA present at Wilkawatt 2015

Measure	Crop	Root DNA (pg DNA / g soil)			SED	*p* value	p dev
		TOS 1	TOS 2	TOS 3			
August on row	Wheat	79,057	130,754	75,982	8,811	0.786	<.001
	Barley	86,603	107,798	67,923	10,153	0.05	0.003
October on row	Wheat	112,073	143,586	113,443	10,836	0.97	0.007
	Barley	98,558	129,304	105,791	13,408	0.631	0.023
August between row	Wheat	34,910	30,293	8,557	3,232	<.001	0.006
	Barley	45,053	27,034	12,715	5,356	<.001	0.672
October between row	Wheat	51,069	38,972	41,038	4,015	0.02	0.051
	Barley	47,551	37,234	48,957	6,733	0.842	0.073

Table 9 Grenade CL Plus wheat and Scope barley root growth, as measured by DNA concentration in soil, with and without fungicide treatment in August and October at Wilkawatt 2015

Measure	Measure	Crop	Root DNA (pg DNA / g soil)		SED	*p* value
			No Fungicide	Fungicide		
On Row Root Growth	August	Wheat	71,600	118,928	7,386	<.001
		Barley	73,131	101751	8,100	0.002
	October	Wheat	95,753	150,315	10,080	<.001
		Barley	92,800	129,636	10,260	0.002
Between Row Root Growth	August	Wheat	24,013	25,161	3,117	0.716
		Barley	28,837	27,697	4,525	0.804
	October	Wheat	44,036	43,350	3,466	0.845
		Barley	43,131	46,030	5,375	0.596

Table 10 Time of sowing (TOS) effect on *Rhizoctonia solani* AG8 soil levels in August, October and November on and between rows at Wilkawatt 2015

Measure	Crop	*R. solani* AG8 pg DNA / g soil				*p* value	p dev
		TOS 1	TOS 2	TOS 3	SED		
On row							
August	Wheat	787	753	349	81.0	<.001	0.019
October	Wheat	799	930	730	91.0	0.432	0.041
November (post-harvest)	Wheat	386	450	454	65.0	0.512	0.312
Between row							
August	Wheat	357	549	216	56.4	0.025	<.001
October	Wheat	524	601	540	102.0	0.884	0.444
On row							
August	Barley	1032	1215	399	142.0	<.001	0.001
October	Barley	1048	1257	869	129.0	0.165	0.012
November (post-harvest)	Barley	641	610	393	103.0	0.026	0.302
Between row							
August	Barley	605	853	287	75.5	<.001	<.001
October	Barley	551	843	721	105.0	0.122	0.034

Table 11 Effect of fungicide treatment on *Rhizoctonia solani* AG8 on row measured in August, October and November (post-harvest) at Wilkawatt 2015

Measure	Crop	***R. solani* AG8 pg DNA / g soil**		SED	*p* value
		No Fungicide	**Fungicide**		
August		741.0	519.0	68.0	0.003
October	Wheat	968.0	672.0	73.0	<.001
November		548.0	312.0	53.0	<.001
August		1044.0	720.0	119.0	0.021
October	Barley	1338.0	779.0	104.0	<.001
November		659.0	437.0	84.0	0.016

Table 12 Effect of time of sowing on *P. neglectus* multiplication in Grenade CL Plus wheat and Scope barley at Wilkawatt 2015

Sampling time	Crop	**Final *P. neglectus* /g soil**						SED	*p* value
		High initial *P. neglectus*			**Low initial *P. neglectus***				
		TOS 1	**TOS 2**	**TOS 3**	**TOS 1**	**TOS 2**	**TOS 3**		
August	Wheat	11.37	6.62	4.56	1.85	1.06	0.84	1.02	0.001
	Barley	3.66	3.21	2.34	4.93	3.93	2.72	0.66	0.59
October	Wheat	26.02	12.99	14.51	6.52	2.78	4.69	2.4	0.008
	Barley	10.94	8.41	8.53	3.49	2.41	3.03	0.92	0.373
Post-harvest	Wheat	20.1	19.08	12.9	5.66	4.76	2.61	1.63	0.028
	Barley	10.37	8.93	5.59	3.28	2.73	2.21	0.89	0.028

Table 13 Effect of fungicide treatment on *Pratylenchus neglectus* levels on row measured in November (post-harvest) at Wilkawatt 2015

Crop	**Final *P. neglectus* /g soil**				SED	*p* value
	High initial *P. neglectus*		**Low initial *P. neglectus***			
	Fungicide	**No Fungicide**	**Fungicide**	**No Fungicide**		
Wheat	19.08	15.64	4.16	4.53	1.47	0.115
Barley	9.56	7.03	3.03	2.45	0.72	0.090

Table 14 Biomass measures of Grenade CL Plus wheat and Scope barley with and without fungicide at the low and high *Pratylenchus neglectus* treatments in August at Wilkawatt 2015

Measure	Crop	High initial *P. neglectus*	Low initial *P. neglectus*	SED	*p* value
NDVI	Wheat	0.58	0.57	0.01	0.113
	Barley	0.63	0.6	0.01	0.022
Patchiness (NDVI Variation)	Wheat	0.08	0.08	0.01	0.877
	Barley	0.11	0.13	0.01	0.006

Table 15 Effect of pre-sowing levels of *Pratylenchus neglectus* on yield of Grenade CL Plus wheat and Scope barley at Wilkawatt 2015

P. neglectus density	Crop	Regression co-efficient	Estimate of impact on yield (kg grain/(*P. neglectus*/g soil)	SED	t value	Pr(>|t|)
Low	Wheat	Intercept	2.23	0.17	13.21	
		Slope	-0.19	0.09	-2.23	0.034
Low	Barley	Intercept	2.46	0.36	6.90	
		Slope	-0.38	0.19	-2.08	0.047
High	Wheat	Intercept	1.74	0.22	7.90	
		Slope	0.01	0.02	0.60	0.557
High	Barley	Intercept	2.70	0.35	7.82	
		Slope	-0.10	0.03	-3.42	0.002