Crop sequence to manage crown rot in cereals in south-eastern Australia

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Abstract

Crown rot is a fungal disease which affects all winter-growing cereals and is estimated to cost the Australian grains industry up to $56 million per annum. In south-eastern Australia, the main pathogens causing crown rot are *Fusarium pseudograminearum* (*Fp*) and *F. culmorum* (*Fc*). Management of this disease relies heavily on a non-host break but the relative effects of each crop/pasture type on *Fp* and *Fc* levels are not well understood. Quantitative DNA assays specific to *Fp* and *Fc* were used to monitor pathogen levels in plant material on and in soil. Effects of a range of cereals and non-cereals on *Fp* and *Fc* inoculum were assessed at two sites in Victoria and one in South Australia during the period 2003 to 2005. *Fp* and *Fc* responded to treatments in a similar manner. The relative effects of the different previous crop and pasture treatments were consistent at all sites, although some sites were more responsive than others to treatments. All commercial cereals increased levels of *Fp* and *Fc* - durum wheat increased levels most, followed by barley, oats and bread wheat. All non-cereals decreased levels of *Fp* and *Fc* - fallow was most effective, followed by peas and canola. There is potential to predict the effect of sequence options at a site if the background *Fp* and *Fc* levels and their variability are known.

Key Words

Disease, pathogen, inoculum, functional relationships, ribosomal DNA probe.

Introduction

Crown rot is a fungal disease which affects all winter growing cereals and is estimated to cost the Australian grains industry up to $56 million per annum (Brennan and Murray 1998). The main pathogens causing crown rot in Victoria (Vic) and South Australia (SA) are *Fusarium pseudograminearum* (*Fp*) and *Fusarium culmorum* (*Fc*) (Backhouse *et al.* 2004).

Both *Fp* and *Fc* can survive saprophytically on infected plant residues for at least 3-4 years. Neither pathogen grows through soil and infection normally occurs by direct contact between infected plant residues and uninfected plants. Crop residue retention, direct seeding and an increase in cereal (particularly durum wheat) in cropping sequences all contribute to increased incidence and severity of crown rot (Duveiller *et al.* 2007).

Since varietal resistance, seed treatment and fungicidal sprays are not available for crown rot management, farmers rely principally on crop sequences (Lamprecht *et al.* 2006) and other cultural techniques to minimise the impact of crown rot on cereal production. Non-cereal breaks such as canola, chickpeas and legume pasture are known to contribute to reduced crown rot expression in subsequent cereal crops (Sturz and Bernier 1989, Kirkegaard *et al.* 2004, Lamprecht *et al.* 2006). For good crown rot management, it is important that the relative effects of each crop/pasture type on *Fp* and *Fc* are understood and quantified under the conditions and farming systems of south-eastern Australia.

The purpose of this study was to compare the effects of a range of cereals and non-cereals on levels of *Fp* and *Fc* in Vic and SA to determine if crop sequence can be used to manage crown rot.

Materials and methods

Treatments (Table 1) were applied in paddocks either naturally infected with high levels of *Fusarium* spp. (Birchip, Vic and Cambrai, SA) or artificially infected in the previous year by sowing durum wheat seed artificially infected with either *Fc* or *Fp* (Longerenong, Vic). Treatments were applied using a randomised block design with 4 (Longerenong) or 6 (Cambrai and Birchip) replicates. Sites were managed according to local agronomic recommendations. Field experiments were direct drilled (except for one treatment at Longerenong) and plant residues were retained. Herbicides were applied as needed (no residual herbicides were used) and weeds were effectively controlled.

During March or April of the year following treatment, samples were collected to quantify *Fusarium* spp. levels. From each plot, forty cores were taken to a depth of 100 mm using a 15 mm diameter Accucore^{TM} soil sampler (Spurr Soil Probes, Brighton North, South Australia). All cores were taken over crop rows and included plant residues on the soil surface as well as the soil and the plant residues in the soil. Samples were sent to the Root Disease Testing Service (South Australian Research and Development Institute, Adelaide, South Australia) where PCR assays using ribosomal DNA probe sequences specific to *Fp* and *Fc* were applied to total DNA extracted from the samples (Ophel-Keller *et al.* 2008). Results were converted via a quantitative DNA standard and are expressed as picograms of *Fp* and *Fc* present per gram of sample.

Table 1. Crop, variety and non-crop treatments used at each site to determine their effects on levels of *Fusarium* spp. MS - moderately susceptible (bread wheat); S - susceptible (bread wheat); VS - very susceptible (durum wheat). H, host; NH, non-host. *na* –treatment not applied at this site. Note – results for vetch, medic, triticale and cultivated peas are not presented as they were sown at one site only.

Treatment	Description	Cambrai	Birchip	Longerenong
Barley	H	Schooner	SloopVic	SloopVic
Oats	H	Mortlock	*na*	Marloo
Wheat MS	H, mod. susc.	Kukri	*na*	*na*
Wheat S	H, susceptible	Frame	Yitpi	Yitpi
Wheat VS	H, very susc.	Tamaroi	Tamaroi	Tamaroi
Fallow	No host	Chemical	Mechanical	Mechanical
Canola	NH (oilseed)	Outback	Saphire	Saphire
Field peas	NH (legume)	Parafield	Kaspa	Kaspa

Log_{10} transformed DNA levels of *Fp* and *Fc* after treatment from individual sites were subjected to analysis of variance by GenStat Version 8.2. Multiple comparisons were conducted using Fisher's protected l.s.d. test. A meta-analysis was performed for *Fp* data from all sites by the use of estimating equations following the method of Morton *et al.* (2007) to combine the information from several experiments. This model assumes the treatment effects on the log scale have a linear relationship. The meta-analysis was performed for *Fp* only, as there was most information for this species and because at

Birchip, *Fp* and *Fc* (present naturally in the paddock) behaved in a similar manner in response to treatments as shown by a strong linear correlation (R^2 = 0.776) between the species.

Results and discussion

In the year after treatment, highest levels of *Fusarium* spp. occurred after cereals and lower levels occurred after no host or non-hosts (Table 2). Apart from this difference between cereals and non-cereals, no other treatment differences were evident.

Table 2. Effect of cereal and non-cereal treatments on levels of *Fusarium* spp. (Log_{10} pg fungal DNA/g of sample) the season after treatments were applied. *Fp*, *F. pseudograminearum*; *Fc*, *F. culmorum*; *na* –treatment not applied at this site. MS - moderately susceptible (bread wheat); S - susceptible (bread wheat); VS - very susceptible (durum wheat). Means in the same column followed by the same letter are not significantly different (P=0.05). Note – results for vetch, medic, triticale and cultivated peas are not presented as they were sown at one site only.

Treatment	Cambrai	Birchip		Longerenong	
	Fp	*Fp*	*Fc*	*Fp*	*Fc*
Fallow	2.19 *a*	2.36 *a*	1.29 *a*	2.29 *a*	2.38 *ab*
Canola	2.29 *ab*	2.78 *ab*	1.33 *a*	2.91 *cd*	2.51 a*b*
Peas	2.57 *abcd*	2.32 *a*	1.24 *a*	2.61 *bc*	2.42 *ab*
Wheat MS	2.78 *cdef*	*na*	*na*	3.11 *d*	2.57 *bc*
Wheat S	2.94 *def*	3.23 *bcd*	1.53 *a*	3.02 *cd*	2.56 a*bc*
Wheat VS	3.09 *ef*	3.62 *d*	1.94 *bc*	3.54 *e*	2.85 *d*
Barley	3.18 *f*	3.48 *cd*	2.20 *c*	2.88 *cd*	2.36 *ab*
Oats	3.24 *f*	*na*	*na*	3.01 *d*	2.79 *cd*
LSD (*P*=0.05)	0.45	0.54	0.45	0.39	0.26

This is inconsistent with previous studies, where durum wheat has been a critical trigger for crown rot problems (Duveiller *et al.* 2007) and some non-cereals (e.g. canola) reduced levels of *Fp* significantly more than others (Kirkegaard *et al.* 2004). The highly variable distribution of *Fusarium* spp. (Heap and McKay 2004) may be contributing to this inability to differentiate statistically between specific treatments at individual sites. For this reason and also to assess the consistency of response to treatments across sites, meta-analysis of data from all sites was undertaken to further explore the practical implications for industry of results from this research.

Meta-analysis of F. pseudograminearum *data from all sites*

There was a good relationship between actual (measured) and fitted (predicted) values of *Fp* levels (Table 3) which indicates that treatment effects on a Log_{10} scale have a linear relationship. This validated the underlying assumption of the meta-analysis model.

Table 3. Comparison of fitted (predicted) and actual (measured) *F. pseudograminearum* levels (Log10 pg fungal DNA/g of sample) the season after treatments were applied. The fitted value for each treatment at a site is a weighted average determined by the variability of the trial in relation to the other trials. Differences of ≤0.1 between fitted and observed values are within the error from normal "noise" seen in field results. *na* –treatment not applied at this site. MS - moderately susceptible (bread wheat); S - susceptible (bread wheat); VS - very susceptible (durum wheat). Note – results for vetch, medic, triticale and cultivated peas are not presented as they were sown at one site only.

Treatment	Cambrai		Birchip		Longerenong	
	Actual	Fitted	Actual	Fitted	Actual	Fitted
Fallow	2.19	2.31	2.37	2.33	2.29	2.44
Peas	2.58	2.45	2.33	2.53	2.61	2.58
Canola	2.29	2.57	2.78	2.69	2.92	2.68
Wheat MS	2.79	2.87	*na*	3.10	3.11	2.95
Wheat S	2.94	2.95	3.23	3.21	3.02	3.03
Oats	3.24	3.04	*na*	3.33	3.01	3.11
Barley	3.19	3.11	3.48	3.43	2.88	3.18
Wheat VS	3.10	3.23	3.62	3.59	3.54	3.28

Fallow reduced levels of *Fp* to approximately a third, while peas and canola approximately halved *Fp* levels (Table 4). Durum wheat more than trebled levels of *Fp* (Table 4), with other cereal types increasing levels much less. These findings support those already reported in the literature for durum wheat (Duveiller *et al.* 2007).

Table 4. Effects of treatments on levels of *F. pseudograminearum*, assessed using a standardised measure of treatment effects (ξ) estimated over all the sites. Converting ξ to a multiplicative scale allows calculation of the magnitude of changes in fungal DNA levels. MS - moderately susceptible (bread wheat); S - susceptible (bread wheat); VS - very susceptible (durum wheat). Note – results for vetch, medic, triticale and cultivated peas are not presented as they were sown at one site only.

Treatment	Treatment effects	
	ξ (Log_{10} scale)	Multiplicative scale
Fallow	-0.42	0.38
Peas	-0.27	0.53
Canola	-0.16	0.69
Wheat MS	0.14	1.39
Wheat S	0.23	1.68
Oats	0.31	2.01
Barley	0.39	2.44
Wheat VS	0.50	3.18

Although it is implicit in these results that treatments will behave similarly in relation to one another at all sites, the magnitude of the overall response to treatments varied between sites. Birchip was the most responsive site to treatments, having a responsiveness rating of 1.36 compared with ratings of 0.9 and 1.0 for the other sites. Responsiveness may be related to high starting levels of *Fp* (Birchip had the highest starting levels of *Fp*), site characteristics (e.g. soil type), environment (e.g. rainfall) or a combination of factors.

Predicting responses of sites to treatments

The good relationship between actual and fitted values of *Fp* levels (Table 4) gives an assurance that predictions for those treatments not tested at all sites are well estimated by the fitted values. This gives rise to the possibility of predicting the effect of crop sequences on levels of *Fp*. Being able to predict the effects of different non-cereals on changes in *Fp* levels would have particular practical value in assessing the length of non-cereal break needed prior to sowing highly susceptible crops such as durum wheat. The reliability of predicting changes in *Fp* levels needs to be validated in the field before it is considered for commercial use. Validation will need to include assessment of the effects of site responsiveness and seasonal conditions.

Conclusions

Non-cereals decrease *Fp* levels (fallow more than peas and canola) and cereals increase *Fp* levels (durum wheat more than barley and oats more than bread wheat). Relative to one another, cereal and non-cereal treatments behave similarly across sites and seasons. The magnitude of reduction or increase in *Fusarium* spp. levels will depend on the responsiveness of the site. Once the responsiveness of a site is known it may be possible to predict the changes in *Fp* levels over the next cropping season under different cereal and non-cereal options. The reliability of the predictive process needs to be validated in the field to assess its commercial usefulness.

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