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Crop & Pasture Science

Supplementary Material

Links between soilborne pathogens, plant parasitic nematodes, farm management and biophysical constraints in a southern Australian rainfed cropping system

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Supplementary material

S1.

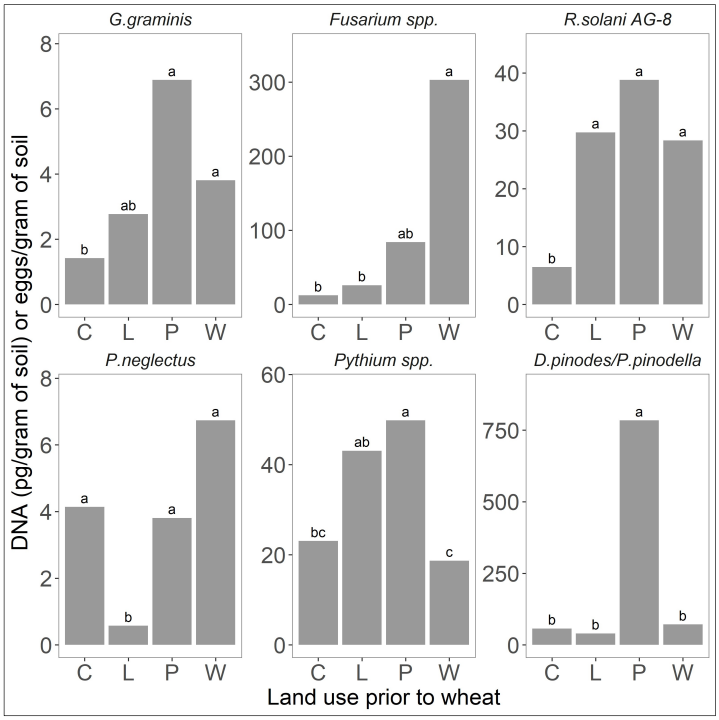

Figure S1. Amount of DNA in soil of *Fusarium* spp., *R. solani* (AG-8), *G. graminis* var. *tritici*, *Pythium Clade* F, *D. pinodes*/*P. pinodella*, or eggs, of *P. neglectus* preceding the sowing of wheat after different land uses; canola (C), lupin (L), pasture (P), wheat (W). Letters above bars represent significant differences ($P \leq 0.05$) between land uses for each pathogen.

S2.

Table S2.1. Generalised linear model output for paddock incidence of soil pathogens or plant parasitic nematode DNA above detection limit in spring (absent or present) using environmental and agronomic variables. P values and coefficients (estimate) presented. Grey background indicates a significant effect at $P \leq 0.05$.

	R. solani (AG-8)		*P. neglectus*		*Fusarium* spp.		*G. graminis* var. *tritici*	
Independent variate	*P* value	Coef.	*P* value	Coef.	*P* value	Coef.	*P* value	Coef.
Intercept	0.971	0.056	0.125	3.070	0.000	8.892	0.502	2.283
Summer rain (mm)	0.069	0.009						
Annual rain (mm)			0.003	-0.013			0.051	-0.016
Growing season rain (mm)			0.000	0.038			0.093	0.013
Jan-Mar rain (mm)	0.003	-0.019	0.014	0.014			0.002	0.024
Apr-Jun rain (mm)	0.003	-0.012	0.000	-0.041	0.000	-0.022		
Jul-Sep rain (mm)			0.000	-0.043	0.000	-0.015		
Growing season temperature (c)			0.010	0.510	0.069	0.434		
Jan-Mar temperature (c)	0.000	-0.310	0.000	-1.101	0.000	-1.448	0.004	-0.373
Apr-Jun temperature (c)	0.007	0.334					0.000	-1.358
Jul-Sep temperature (c)			0.000	0.688	0.000	1.206	0.000	1.779
Sow day			0.047	0.017			0.043	0.023
Number of herbicides applied	0.091	0.068	0.001	-0.145	0.033	-0.118		
Weed density in spring (p/m2)	0.112	0.001					0.031	0.001
Fertiliser N (kg/ha)			0.001	0.019				
Soil mineral N (mg/kg 0-10 cm)					0.008	-0.026		
Soil P (mg/kg 0-10 cm)			0.000	0.033	0.000	0.047		
Soil K (mg/kg 0-10 cm)							0.016	0.002
Organic carbon (%)	0.062	0.293					0.085	0.365
Electrical conductivity (dS/m 0-10cm)			0.042	3.251	0.000	8.271		
pH (CaCl2 0-10 cm)	0.008	0.479	0.004	0.588				
Soil texture *(1-5)					0.000	1.457		

Soil texture; 1= coarse texture (sand), 5 = fine texture (clay). Sow day = days since Jan 1st in each year, for volunteer pastures the 1st occurrence of 15mm of rain over two or less days after April 1 was considered sow date. Summer rain = rain between crops or pastures.

Table S2.2. Generalised linear model output for paddock incidence of pathogen root disease and plant parasitic nematode observed on roots in spring (absent or present) using environmental and agronomic variables. P values and coefficients (estimate) presented. Grey background indicates a significant effect at $P \leq 0.05$.

	R. solani (AG-8)		*P. neglectus*		*Fusarium spp.*		*G. graminis* var. *tritici.*	
Independent variate	*P* value	Coef.	*P* value	Coef.	*P* value	Coef.	*P* value	Coef.
Intercept	0.000	-11.589	0.000	-10.790	0.000	-7.658	0.000	-17.652
Summer rain (mm)							0.009	0.020
Annual rain (mm)			0.091	-0.003	0.102	0.006	0.103	0.013
Growing season rain (mm)					0.005	-0.021	0.000	-0.033
Jan-Mar rain (mm)			0.089	0.008			0.003	-0.040
Apr-Jun rain (mm)					0.156	0.011	0.000	0.050
Jul-Sep rain (mm)					0.035	0.016		
Growing season temperature (c)	0.001	0.269						
Jan-Mar temperature (c)			0.001	0.257	0.000	0.277		
Apr-Jun temperature (c)							0.000	2.198
Jul-Sep temperature (c)	0.002	-0.354	0.009	-0.331	0.001	-0.455	0.003	-2.035
Sow day	0.000	0.070	0.000	0.068	0.000	0.039	0.101	0.025
Number of herbicides applied	0.002	0.175	0.141	0.072	0.043	0.094	0.013	0.191
Weed density in spring (p/m2)	0.106	0.008						
Fertiliser N (kg/ha)			0.003	0.017	0.026	0.013		
Soil mineral N (mg/kg 0-10 cm)					0.081	-0.014		
Soil K (mg/kg 0-10 cm)			0.150	0.001				
Electrical conductivity (dS/m 0-10cm)			0.022	4.205				
Soil texture *(1-5)			0.021	-0.787				

Soil texture; 1= coarse texture (sand), 5 = fine texture (clay). Sow day = days since Jan 1st in each year, for volunteer pastures the 1st occurrence of 15mm of rain over two or less days after April 1 was considered sow date. Summer rain = rain between crops or pastures.

Table S2.3. Mean values of environmental and management independent variables used in binomial generalised linear models of soil pathogens or plant parasitic nematode DNA above detection limit in spring (absent or present) and pathogen root disease and plant parasitic nematode observed on roots in spring (absent or present).

	Region		
Independent variable	NAR	CAR	SAR
Summer rain (mm)	80	76	99
Annual rain (mm)	334	326	394
Growing season rain (mm)	256	240	281
Jan-Mar rain (mm)	49	45	50
Apr-Jun rain (mm)	100	86	110
Jul-Sep rain (mm)	135	124	138
Growing season temperature (c)	26.3	23.5	20.3
Jan-Mar temperature (c)	27.4	24.4	21.2
Apr-Jun temperature (c)	17.6	15.1	14.5
Jul-Sep temperature (c)	14.4	12.0	11.8
Sow day	134	139	141
Number of herbicides applied	6.3	5.9	6.6
Weed density in spring (p/m2)	41	108	288
Fertiliser N (kg/ha)	35	31	34
Soil mineral N (mg/kg 0-10 cm)	25	32	32
Soil P (mg/kg 0-10 cm)	30	38	46
Soil K (mg/kg 0-10 cm)	213	137	156
Organic carbon (%)	0.94	1.36	2.34
Electrical conductivity (dS/m 0-10cm)	0.12	0.13	0.15
pH ($CaCl_2$ 0-10 cm)	5.64	5.29	5.16
Soil texture *(1-5)	1.79	1.62	1.76

* Soil texture; 1= coarse texture (sand), 5 = fine texture (clay).

S4. Equation 1, interpretation of DNA incidence probability from logistical regression output

$$p = \frac{1}{1 + e^{-(int + b1x1 + b2x2 \ \cdots binfxinf)}} \qquad \text{Equation 1}$$

Where p = probability, e = natural log exponent (2.718), int = intercept, b = slope of independent variable and x = value of independent variable.

i.e. Using Tables 4 and S2.3 the predicted probability of *R. solani* (AG-8) occurring within northern region paddocks, based on regional means, is 0.365, or 37% as presented in Table S2.4.

$$p = \frac{1}{1 + e^{-(0.0560413 \ +0.009*80 \ \ -0.019*49 \ \ -0.012*100 \ \ -0.310*27.4 \ +0.334*17.6 \ +0.068*6.3 \ +0.001*41 \ \ +0.293*0.9 \ \ +0.479*5.6)}}$$

Table S2.4. Model predictions for each region of incidence of a paddock with one or more plants with root or crown damage and of a paddock having soil pathogens or plant parasitic nematode DNA above the detection limit, from optimised logistical general linear models.

Pathogen/nematode	Incidence of positive field visits			Incidence of DNA above detection		
	NAR	CAR	SAR	NAR	CAR	SAR
Fusarium spp.	3	1	2	7	13	73
G. graminis var. *tritici*	32	37	26	4	5	24
P. neglectus	60	68	96	34	54	78
R. solani AG-8	76	89	95	37	43	67

S3.

Table S3. The percentage of spring samples containing no diseased plants, 1-5% of plants with disease, 6–25% plants diseased, 26–50% plants diseased, 51–75% plants diseased and > 75% plants diseased.

	Percentage of plants with disease in each spring sample					
	All samples					
Pathogen	0%	1-5%	6-25%	25-50%	51-75%	>75%
Fusarium spp.	90	5	4	1	0	0
G. graminis var. *tritici*	61	21	17	1	1	0
P. neglectus	38	18	27	10	4	2
R. solani AG-8	28	13	33	17	6	2
	Wheat					
Fusarium spp.	87	7	5	1	0	0
G. graminis var. *tritici*	48	28	22	1	1	0
P. neglectus	19	25	37	12	5	3
R. solani AG-8	9	17	44	21	7	2
	Barley					
Fusarium spp.	82	8	6	2	2	0
G. graminis var. *tritici*	53	25	20	2	0	0
P. neglectus	22	20	25	20	10	4
R. solani AG-8	10	14	24	27	22	4
	Canola					
P. neglectus	98	1	1	0	0	0
R. solani AG-8	97	1	1	1	0	0
	Lupin					
P. neglectus	96	2	2	0	0	0
R. solani AG-8	60	5	20	13	0	2