

Investigations on *Rhizoctonia solani* in cropping soils and vegetable crops

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Abstract

Soil tests were conducted in 2006 and 2007, on soils from 40 paddocks that had been used intensively for vegetable crop production for the presence and levels of important *Rhizoctonia solani* sub-groups. AG2.1 was the most common *R. solani* sub-group in the soil samples from 40 paddocks, being detected in 83% of paddocks. The other *R. solani* sub-groups, AG3, AG4 and AG2.2 were detected in 35%, 25% and 8% of the paddocks, respectively. AG8, which can seriously reduce yield in cereal crops was not detected in any of the soil samples. The effects of each sub-group on various vegetable crops are currently being examined in further studies in order to get a better understanding of their impact on various vegetable crops. Green beans, which are generally highly susceptible to stem, hypocotyl and root rot by *Rhizoctonia* and various soilborne pathogens, were mainly used as indicator plants in this study on root pathogens and their impact on crop establishment and growth.

In bioassay tests of soils from 24 paddocks to bait root pathogens with green beans, almost all the soils had root pathogens. *Rhizoctonia* was found in association with bean root rot in 63% of the soil samples. In 42% of the soil samples, only the *Rhizoctonia* pathogen could be observed on the root rots. However, in paddocks which had been used more intensively for bean production, root rot by other pathogens, namely *Thielaviopsis basicola* and *Aphanomyces euteiches*, were more damaging and severe than those caused by *Rhizoctonia*. Under relatively cold and wet conditions, seedling establishment from the untreated green bean seeds was very poor, with seedling emergence and survival at less than 46% in 42% of the soil samples.

Introduction

Increasingly, *R. solani* has been recognized as consisting of a collection of fungal isolates that look similar in taxonomy but are different genetically (Anderson 1982). A concept of using anastomosis group (AG) to describe each unique *R. solani* type based on hyphal anastomosis (a fusion of hyphae together to establish their relatedness) has now gained wide acceptance among plant pathologists (Anderson 1982, Ogoshi 1987). More recently, molecular methods based on DNA analysis, developed to assist in identifying the separate AG sub-groups of *R. solani*, have facilitated research in identification, pathogenicity, host specificity and economic impact of the different sub-groups.

Even though *R. solani* has often been associated with root rot and yield decline in vegetable crops, there have been little or no studies to establish or confirm their presence and impact on crop productivity. Therefore, preliminary studies were conducted in this section to test and identify the type and levels of *R. solani* present in paddocks that had been intensively used for vegetable crop production. Although up to 12 AG groups have been described, many are non-pathogens or are crop specific. The SARDI DNA tests used in this study were aimed at determining the presence of AG2.1, AG2.2, AG3, AG4 and AG8, the sub-groups that are identified as being associated with important potato and cereal crop diseases.

In addition to soil tests for *Rhizoctonia* sub-groups, additional quantitative and qualitative data were collated with bioassay tests to bait root pathogens and assess their impact on seedling growth of a vegetable crop, as well as to conduct field examinations to observe crop growth and determine the causes of poor crop growth. Green beans were used as a benchmark vegetable crop in this study, because of their high susceptibility to a wide range of root pathogens.

Materials & Methods

Soil sampling

Soil samples were collected from 40 paddocks in Tasmania, Victoria and Queensland. Each sample consisted of an aggregate of 20 soil core samples taken to a depth of 15 cm in a 'W' formation across each paddock, which were then bulked together before use for soil tests or bioassays. Soil tests based on DNA analysis for *R. solani* sub-groups and their levels were conducted at the SARDI laboratory for DNA analysis. The SARDI DNA tests were developed to determine the presence and levels of AG2.1, AG2.2, AG3, AG4 and AG8, which represent the most studied sub-groups that are associated with important crop diseases. Where possible, DNA tests for other pathogens or pests, such as *Spongospora subterranea* (powdery scab), *Streptomyces scabies* (common scab), *Verticillium dahliae* (*Verticillium* wilt) and *Pratylenchus* nematode species, were also conducted for growers' interest.

The locations of the paddocks were marked using a global positioning system (GPS). Most of the paddocks were selected because they have been used for intensive vegetable and potato production, and yield decline have been experienced in these soils. Many of the paddocks were sown with green beans in the 2006/07 season. Roots of green bean plants are generally highly susceptible to stem, hypocotyl and root rot by various soilborne pathogens, including *Rhizoctonia*, and hence are ideal for studies on root pathogens and their impact on crop establishment, growth and yield.

Bioassay tests

Bioassay tests were conducted in a pot trial using green beans, with 24 soil samples collected initially in October 2006 (Sample No. 1-24) to bait *R. solani* and other root pathogens. Twenty green bean seeds were sown in each pot, and there was only one pot per soil sample. At 19, 27 and 43 days after sowing (19DAS, 27DAS and 43DAS), seedling emergence and survival were recorded as a percentage of the total number of seeds initially sown. At 43DAS, surviving plants were also assessed for fresh shoot weights and roots were rated for root rot severity. Thin sections of roots were examined for root pathogens. Roots of surviving plants were assessed for root rot severity as described below.

Root rot severity ratings:

- 0 = no hypocotyl discolouration & no root rot
- 1 = some superficial hypocotyl rot, light root pruning, with good root branching
- 2 = superficial hypocotyl rot and moderate root pruning
- 3 = severe hypocotyl rot and moderate root pruning
- 4 = severe hypocotyl rot and severe root pruning
- 5 = severe stunted or dying plant with very small roots

Root rot severity index = $\frac{[(1 \times \text{no. plants in rating 1}) + \dots + (5 \times \text{no. plants in rating 5})]}{\text{no. surviving plants}} \times 100$

Field observations

Paddocks where the soil samples were collected (above) were also monitored after sowing with beans, carrots, onions and potatoes. Roots of plants were examined for root rot and *R. solani*, as well as for the presence of other root pathogens. Qualitative descriptions on the establishment and growth of the commercial crops were also recorded.

Results

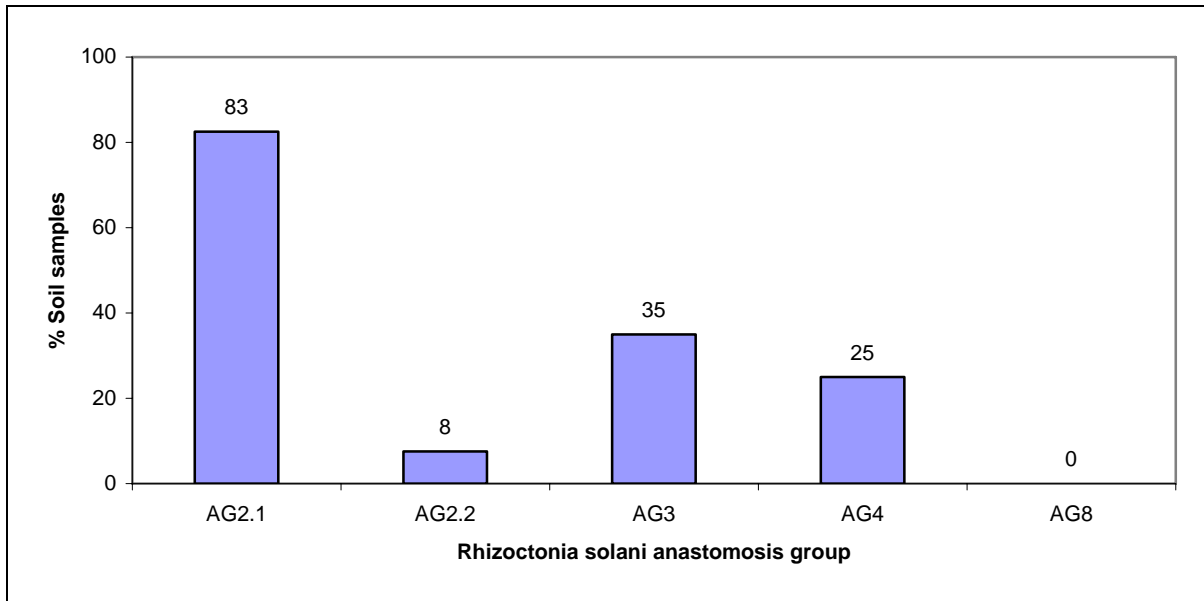
R. solani sub-groups and levels in soils

Table 1.1 - Soil tests for *R. solani* AG groups and common soilborne pathogens in 40 intensively cropped paddocks

Sample No.	Sample Code	Grower	Cropping practice	Soil type	Location	DNA / g soil										
						AG2.1	AG2.2	AG3	AG4	AG8	<i>Spongospora subterranea</i>	<i>Streptomyces scabies</i>	<i>V. dahliae</i>	<i>P. neglectus</i>	<i>P. thornei</i>	<i>P. penetrans</i>
1	AA63283	NB	vegetable, pasture, potato	Red Ferrosol	Sassafras	258	0	9	27	0	798	0	na	na	na	na
2	AA63284	NB	vegetable, pasture, potato	Red Ferrosol	Sassafras	2227	0	8	0	0	5860	0	na	na	na	na
3	AA63285	AM	vegetable, pasture, potato	Red Ferrosol	Sassafras	174	0	0	281	0	9670	0	na	na	na	na
4	AA63286	AM	vegetable, pasture, potato	Red Ferrosol	Sassafras	144	0	103	0	0	26038	0	na	na	na	na
5	AA63287	DP	vegetable, pasture, potato	Red Ferrosol	Sassafras	612	0	0	60	0	42702	0	na			
6	AA63288	GR	vegetable, pasture, potato	Red Ferrosol	Sassafras	49	0	0	0	0	36692	0	na	na	na	na
7	AA63289	MR	vegetable, pasture, potato	Red Ferrosol	Thirlstane	102	0	718	14276	0	80	0	na	na	na	na
8	AA63290	JP	vegetable, pasture, potato	Red Ferrosol	East Sassafras	1	0	0	45	0	6209	0	na	na	na	na
9	AA63291	JP	vegetable, pasture, potato	Red Ferrosol	East Sassafras	7	0	5	24	0	15748	0	na	na	na	na
10	AA63292	JP	vegetable, pasture, potato	Red Ferrosol	East Sassafras	0	0	165	0	0	21005	0	na	na	na	na
11	AA63282	LB	vegetable, pasture, potato	Red Ferrosol	Forth	14	0	2	33	0	3189	0	na	na	na	na
12	AA63276	DB	vegetable, pasture, potato	Red Ferrosol	Upper Burnie	525	0	66	0	0	31195	14	13	0	0	1
13	AA63277	BC	vegetable, pasture, potato	Red Ferrosol	Flowerdale	33	0	0	0	0	84	83	0	0	0	0
14	AA63278	WE	vegetable, pasture, potato	Brown sandy clay loam	Flowerdale	88	5	0	0	0	27259	0	13	0	0	0
15	AA63279	BH	vegetable, pasture, potato	Red Ferrosol	Sisters Creek	16	0	6	0	0	14482	0	0	0	0	0
16	AA63280	BH	vegetable, pasture, potato	Red Ferrosol	Sisters Hills	7364	0	0	0	0	17283	0	0	0	0	0
17	AA63281	CD	vegetable, pasture, potato	Red Ferrosol	Sisters Hills	183	0	0	0	0	11009	288	1	0	0	55
18	AA63293	CD	vegetable, pasture, potato	Red Ferrosol	Sisters Hills	1	0	0	0	0	75619	32	0	0	0	0
19	AA63294	JC	vegetable, pasture, potato	Red Ferrosol	Sisters Hills	54	0	8	0	0	70389	0	0	0	0	0

Table 1.1 - Soil tests for *R. solani* AG groups and common soilborne pathogens in 40 intensively cropped paddocks (Cont.)

Sample No.	Sample Code	Grower	Cropping practice	Soil type	Location	DNA / g soil										
						AG2.1	AG2.2	AG3	AG4	AG8	<i>Spongospora subterranea</i>	<i>Streptomyces scabies</i>	<i>V. dahliae</i>	<i>P. neglectus</i>	<i>P. thornei</i>	<i>P. penetrans</i>
20	AA63295	JC	vegetable, pasture, potato	Red Ferrosol	Montumana	404	0	36	0	0	53593	0	1	0	0	0
21	AA63465	JC	vegetable, pasture, potato	Red Ferrosol	Sisters Hills	952	0	20	30	0	4059	0	0	1	0	0
22	AA63466	BH	vegetable, pasture, potato	Red Ferrosol	Boat Harbour	679	0	0	0	0	28055	0	24	0	0	0
23	AA63467	BH	new ground, one potato crop*	Grey sandy loam	Wynyard	24	427	0	0	0	19	0	0	0	0	0
24	AA63468	JB	vegetable, pasture, potato	Red Ferrosol	Sassafras	2	0	0	0		1626	0	na	na	na	na
25	AA63469	RB	pasture, vegetable, cereals, potato between long break	Red Ferrosol	Forthside	0	0	0	181		3	0	na	na	na	na
26	AA63470	NW	pasture, vegetable, potato between long breaks	Red Ferrosol	Table Cape	0	0	0	0		90	0	na	na	na	na
27	AA63471	OT	vegetable, pasture, potato	Red Ferrosol	Wesley Vale	0	0	0	0		26370	62	na	na	na	na
28	AA63472	GR	vegetable	Sandy loam	Heatherton, Vic	0	0	0	0		0	67	na	na	na	na
29	AA63473	HF-C	vegetable	Sandy clay loam	Cambridge	2	0	0	0		0	42	na	na	na	na
30	AA63474	HF-C	vegetable	Sandy clay loam	Cambridge	26	0	0	653		0	63	na	na	na	na
31	AA63475	HF-R	vegetable	Clay loam	Richmond	100	0	0	0		11	0	na	na	na	na
32	AA63476	HF-R	vegetable	Clay loam	Richmond	8	0	0	0		0	0	na	na	na	na
33	AA63477	QL	vegetable	Clay loam	Glenore Grove, Qld	0	0	0	0		0	0	na	na	na	na
34	AA63478	DS	vegetable	Black clay	Gatton, Qld	0	0	0	0		0	0	na	na	na	na
35	AA63479	AR	vegetable, pasture, potato	Red Ferrosol	Natone	124	0	37	0	0	90716	0	na	na	na	na
36	AA63480	AR	vegetable, pasture, potato	Red Ferrosol	Natone	7	1	0	0	0	102794	0	na	na	na	na
37	AA63481	AR	vegetable, pasture, potato	Red Ferrosol	Natone	30	0	0	0	0	54659	115	na	na	na	na
38	AA63482	AR	vegetable, pasture, potato	Red Ferrosol	Natone	2	0	0	0	0	78386	0	na	na	na	na
39	AA63483	AR	vegetable, pasture, potato	Red Ferrosol	Natone	458	0	0	0	0	30612	0	na	na	na	na
40	AA63484	AR	vegetable, pasture, potato	Red Ferrosol	Natone	987	0	4	0	0	41776	37	na	na	na	na

Figure 1.1 - The frequency of *Rhizoctonia solani* anastomosis groups in 40 soil samples**Bioassay tests of soils from 24 paddocks****Table 1.2 - *R. solani* sub-groups in soil tests, and seedling emergence and survival in the bioassay tests with the same soils**

Sample No.	Sample Code	Soil type	AG2.1	AG2.2	AG3	AG4	AG8	% Seedling emergence (19DAS)	% survival (27DAS)	% survival (43DAS)
1	AA63283	Red Ferrosol	258	0	9	27	0	85	85	75
2	AA63284	Red Ferrosol	2227	0	8	0	0	50	50	45
3	AA63285	Red Ferrosol	174	0	0	281	0	65	65	65
4	AA63286	Red Ferrosol	144	0	103	0	0	65	65	65
5	AA63287	Red Ferrosol	612	0	0	60	0	60	70	55
6	AA63288	Red Ferrosol	49	0	0	0	0	70	70	70
7	AA63289	Red Ferrosol	102	0	718	14276	0	40	40	40
8	AA63290	Red Ferrosol	1	0	0	45	0	30	30	30
9	AA63291	Red Ferrosol	7	0	5	24	0	45	55	55
10	AA63292	Red Ferrosol	0	0	165	0	0	50	55	55
11	AA63282	Red Ferrosol	14	0	2	33	0	50	50	50
12	AA63276	Red Ferrosol	525	0	66	0	0	30	35	35
13	AA63277	Red Ferrosol	33	0	0	0	0	60	60	60
14	AA63278	Brown sandy clay loam	88	5	0	0	0	30	30	30
15	AA63279	Red Ferrosol	16	0	6	0	0	40	50	50
16	AA63280	Red Ferrosol	7364	0	0	0	0	95	95	95
17	AA63281	Red Ferrosol	183	0	0	0	0	65	65	60
18	AA63293	Red Ferrosol	1	0	0	0	0	50	50	50
19	AA63294	Red Ferrosol	54	0	8	0	0	75	80	80
20	AA63295	Red Ferrosol	404	0	36	0	0	30	30	30
21	AA63465	Red Ferrosol	952	0	20	30	0	80	80	80
22	AA63466	Red Ferrosol	679	0	0	0	0	40	40	40
23	AA63467	Grey sandy loam	24	427	0	0	0	10	10	10
24	AA63468	Red Ferrosol	2	0	0	0	-	25	25	25

Figure 1.2 - Seedling emergence in the bioassay tests on 24 soil sample at 19 days after sowing

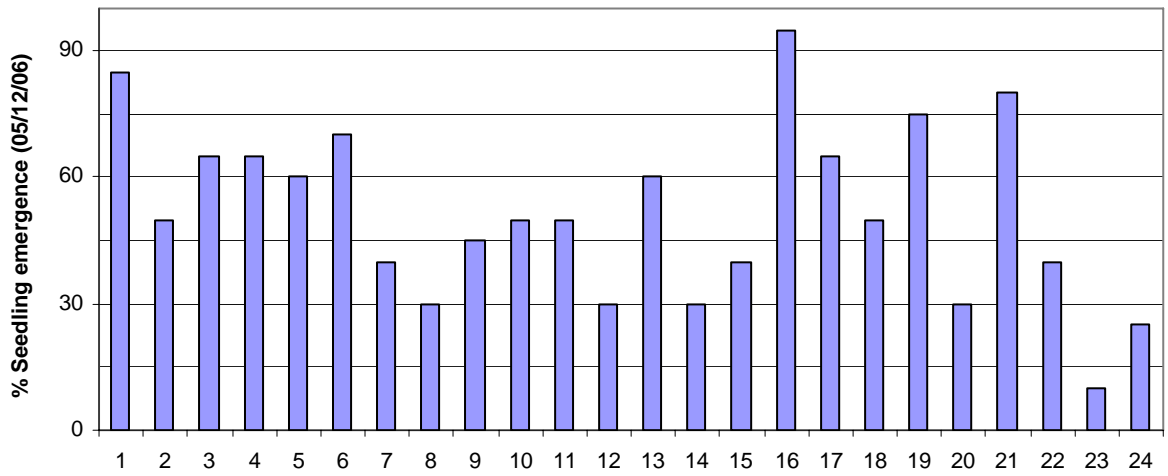


Figure 1.3 - Seedling emergence range at 19 days after sowing

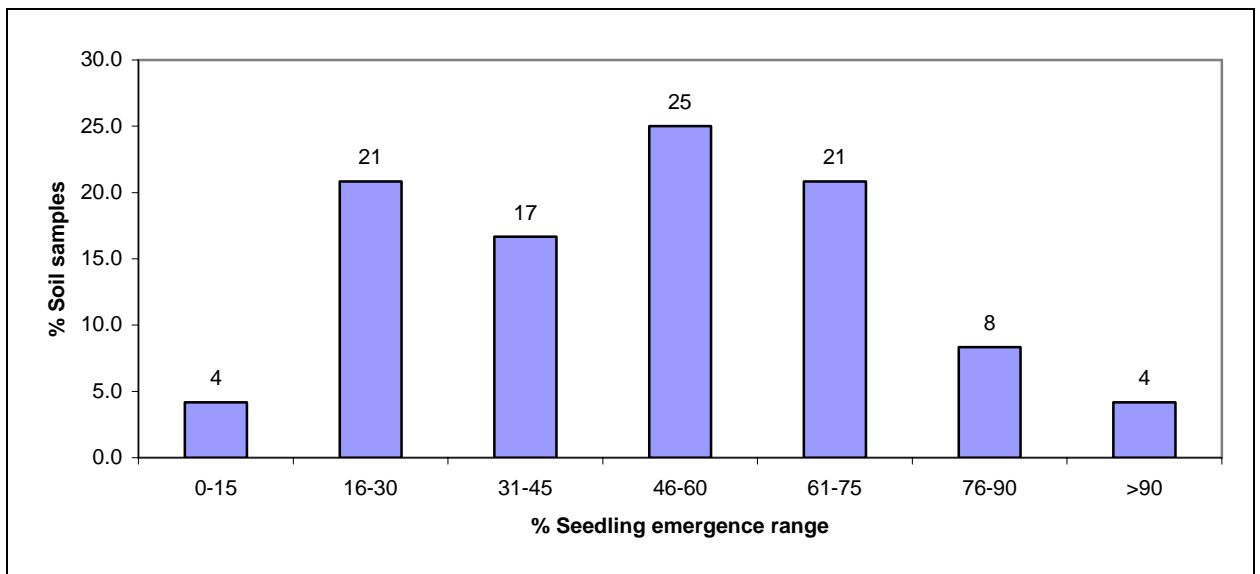


Table 1.3 - *R. solani* sub-groups in soil tests, and seedling emergence and survival in the bioassay tests with the same soils

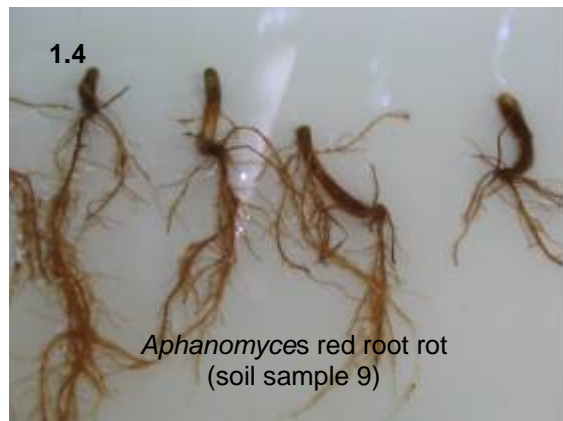
Paddock & Soil Sample No.	Sample Code	Fresh shoot weight (g/all plants)	Average fresh shoot weight/plant	Disease severity rating (1-5)	Root rot	Major pathogens associated with root rot
1	AA63283	52.52	3.50	3.9	black rot	<i>Thielaviopsis</i>
2	AA63284	31.23	3.47	3.6	brown rot	<i>Rhizoctonia, Pythium</i>
3	AA63285	53.64	4.13	3.8	black rot	<i>Thielaviopsis</i>
4	AA63286	56.39	4.34	3.5	brown rot	<i>Rhizoctonia, Pythium</i>
5	AA63287	63.62	5.78	3.8	black rot	<i>Thielaviopsis, Rhizoctonia</i>
6	AA63288	49.80	3.56	3.9	brown rot	<i>Rhizoctonia</i>
7	AA63289	48.70	6.09	3.9	black rot	<i>Thielaviopsis</i>
8	AA63290	38.93	6.49	4.0	black rot	<i>Thielaviopsis</i> (main disease), <i>Aphanomyces</i>
9	AA63291	40.53	3.68	4.1	red brown rot	<i>Aphanomyces</i>
10	AA63292	21.09	1.92	3.8	black & red brown rot	<i>Thielaviopsis</i> (main disease), <i>Aphanomyces, Rhizoctonia</i>
11	AA63282	10.56	2.11	2.2	brown rot	<i>Rhizoctonia</i>
12	AA63276	33.53	4.79	2.0	light brown rot	<i>Aphanomyces</i>
13	AA63277	16.96	2.83	1.8	light brown rot	unknown
14	AA63278	19.72	6.57	2.0	light brown rot	<i>Rhizoctonia</i>
15	AA63279	15.86	3.17	3.6	light brown rot	<i>Rhizoctonia</i>
16	AA63280	87.84	4.62	3.4	light brown rot	<i>Rhizoctonia</i>
17	AA63281	47.10	3.93	3.3	light brown rot	<i>Rhizoctonia</i>
18	AA63293	19.66	3.93	2.2	light brown rot	<i>Rhizoctonia</i>
19	AA63294	51.72	3.23	3.2	light brown rot	<i>Rhizoctonia</i>
20	AA63295	11.22	3.74	1.3	light brown rot	<i>Rhizoctonia</i>
21	AA63465	16.74	2.09	4.0	light brown rot	<i>Thielaviopsis, Rhizoctonia</i>
22	AA63466	11.34	2.83	4.0	light brown rot	<i>Rhizoctonia</i>
23	AA63467	4.76	2.38	1.0	no obvious rot	no obvious pathogens, only poor emergence
24	AA63468	29.11	5.82	3.8	black rot	<i>Thielaviopsis, Pythium</i>

Photographs of bean roots from bioassay tests

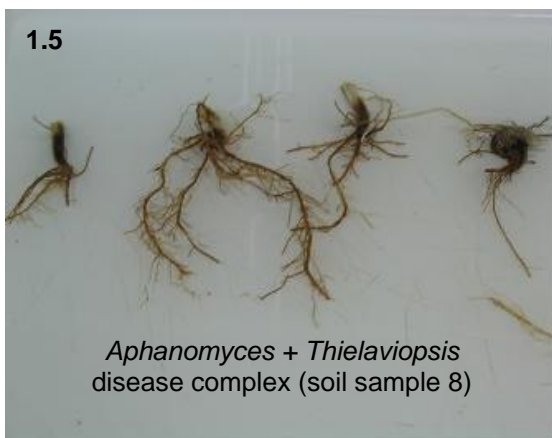
Light brown to brown rot due to *Rhizoctonia* infections on beans (Photographs 1.1-1.2)



Black rot due to *Thielaviopsis* (Photograph 1.3) and red brown rot due to *Aphanomyces* (Photograph 1.4) on beans



Severe bean root rots due to disease complexes by *Thielaviopsis* + *Aphanomyces* (Photograph 1.5) and *Thielaviopsis* + *Rhizoctonia* (Photograph 1.6)



Field sampling and observations of crops in the paddocks

Table 1.4 - Field observations in 2007

Paddock No.	Location	Current crop	Field observations
1	Sassafras	green bean	Sparse to bare patches in the bean crop. Smaller plants were affected by black root rot due to <i>Thielaviopsis</i> . Roots break off easily when pulled, due to the root rot.
2	Sassafras	green bean	Crop terminated early due to very high weed pressure and shortage of water.
3	Sassafras	n/a	No crop sown, under pasture.
4	Sassafras	n/a	No crop sown, under pasture.
5	Sassafras	green bean	Very high levels of undecomposed grass residue due to dry soil conditions. Uneven plant sizes. Relatively small plants at harvest due to a lack of water. Root rots due to <i>Thielaviopsis</i> and <i>Rhizoctonia</i> .
6	Sassafras	green bean	Poor crop establishment with large, sparse to bare patches in the bean crop compounded by poor soil conditions. Relatively small plants at harvest suffering from early crop senescence. Severe rot on lower tap roots.
7	Thirlstane	green bean	Black rot more severe, with stunted plants in the area close to the fence line, where less water was applied in irrigations. Black and brown root rots due to <i>Thielaviopsis</i> and <i>Rhizoctonia</i> .
8	East Sassafras	n/a	No crop sown, under pasture.
9	East Sassafras	green bean	Reduced plant density and poor growth. Reddish brown rot due to <i>Aphanomyces</i> noted on seedlings, but at close to harvest, secondary <i>Penicillium</i> rot was noted on many rotten roots.
10	East Sassafras	green bean	High levels of undecomposed cereal crop residue. Uneven plants with sparse patches due to root rot complex by <i>Aphanomyces</i> and <i>Thielaviopsis</i> . Basal stem rot caused by a white sterile fungus that originated from rotting cereal crop residue.
11	Forth	n/a	No vegetable crop sown.
12	Upper Burnie	n/a	No crop sown, fallow.
13	Flowerdale	green bean	High levels of undecomposed grass residue. Relatively even crop establishment with some sporadic small and stunted plants. Stunted plants had abnormal swollen hypocotyl end with no tap root.
14	Flowerdale	green bean	High levels of undecomposed grass residue. Relatively even crop establishment. Some stunted plants had abnormal swollen hypocotyl ends with no tap root. <i>Rhizoctonia</i> observed on some roots with brown rot.
15	Sisters Creek	potato	Even potato crop. Powdery scab was common on potato tubers.
16	Sisters Hills	green bean	Uneven plant sizes, small stunted plants had swollen hypocotyl ends with no tap root and few lateral roots. Some light brown root discolouration of healthy plants due to <i>Rhizoctonia</i> .
17	Sisters Hills	green bean	Very uneven plant sizes with many small plants. Small, stunted plants had swollen hypocotyl ends with no tap root and few lateral roots. Some light brown root discolouration of medium sized plants due to <i>Rhizoctonia</i> .
18	Sisters Hills	onion	Uneven plant size and hence uneven bulbs. Plants had relatively shallow root systems with a depth of approximately 15 cm. This may be due to the drought conditions and shallow irrigation. <i>Rhizoctonia</i> hyphae were observed on the surface of some onion roots, but there were no lesions or discolouration.
19	Sisters Hills	green bean	Good crop establishment with relatively even plant sizes; a few small plants with stunted and swollen hypocotyl ends with no tap roots. Some light brown root discolouration of medium size plants due to <i>Rhizoctonia</i> .
20	Montumana	green bean	Uneven plant sizes, many small plants with swollen hypocotyl ends and no tap root. A few small plants have brown hypocotyl rot due to <i>Rhizoctonia</i> .
21	Sisters Hills	n/a	No crop sown, under pasture.
22	Boat Harbour	n/a	Crop not sown, fallow after carrots.
23	Wynyard	green bean	Uneven crop establishment, patches of poor emergence, most roots had red brown hypocotyl and root discolouration. No obvious root pathogens could be found in association with the above discolouration. Poor sandy loam soil with very low organic matter.
24	Sassafras	pasture	Under pasture. The previous bean crop sown in 2006 had severe root rot causing the crop to wilt and senesce early due to a root disease complex by <i>Thielaviopsis</i> and <i>Pythium</i> .

Photographs of bean crops and samples from the paddocks in field observations

Uneven crop establishment and severe root rot of stunted seedlings (Photographs 1.7-1.8)



Early crop senescence due to root rot and constrictions of lower tap roots (Photographs 1.9-1.10)



Typical stunted plants due to abnormal root growth observed in paddock nos. 16-22 (Photographs 1.11-1.12)



Discussions

Soil tests for *R. solani* sub-groups

AG2.1 was the most common *R. solani* sub-group in the soil samples from 40 paddocks, being detected in 83% of paddocks. In inoculated soil, studies have shown that *R. solani* AG2.1 infections of peas, beans and pumpkin reduced root biomass and caused constrictions of lower stems and roots, thus affecting the overall plant growth and productivity (Pung & Cross 2007).

The other *R. solani* sub-groups, AG3, AG4 and AG2.2 were detected in 35%, 25% and 8% of the paddocks, respectively. AG8 was not detected in any of the soil samples. The effects of these sub-groups on various vegetable crops are currently being examined in further studies, in order to gain a better understanding of their impact on vegetable crop production. *R. solani* AG3 is the principal cause of *Rhizoctonia* black scurf on potato tubers, and appears to be specific to potatoes (Carling & Leiner 1986, Campion et al 2003). Many of the paddocks surveyed were also typically used for potato production. Black scurf on potato tubers due to black sclerotia formed on the surface of tubers by *R. solani* is the most obvious symptom of *Rhizoctonia* disease on potato crops. Most of the other AG groups are believed to have a broad host range and the levels of damage cause by them may be dependent on field and crop conditions. In France, AG2.1 isolates did not cause black scurf on potato tubers, but at very high levels, it can cause deformities and corky lesions on tubers (Campion et al 2003).

Bioassay tests

In the bioassay tests with green beans, soils in the pots were kept relatively wet and cool during the trial, with two irrigations per day. The bean seedling emergence and survival at 19 days after sowing (19DAS) was highly variable, ranging from 10% to 95% (Table 1.2, Figure 1.2). Figure 1.3 shows the percentage of soil samples at various levels of seedling survival. The seedling emergence and survival were more than 60% in only approximately one third of the soil samples, and less than 46% in approximately 42% of the soil samples. These figures indicate that seedling establishment from the untreated green bean seeds was very poor.

There was no linear correlation between the populations of *R. solani* AG2.1 and the seedling survival at 43DAS ($R^2 = 0.1952$) (Table 1.2). There were also no obvious correlations between the other AG groups and seedling survival. Apart from *R. solani*, there were also other pathogens such as *Thielaviopsis*, *Aphanomyces* and *Pythium* that can impact on seed germination and seedling survival. The causes of poor seedling establishment and growth can be complex and each paddock, location or farm may have its own unique sets of contributing factors.

The examination of roots from the bioassay tests at 43DAS indicated that *R. solani* was common in most of the soil samples. It was found in association with bean root rot in 63% of the soil samples. In 42% of the soil samples, only the *R. solani* pathogen was observed on the root rots. Root rot caused by *Rhizoctonia* was generally light brown to brown in colour (Photographs 1.1-1.2). There were also other root pathogens, particularly *Thielaviopsis basicola* and *Aphanomyces euteiches*, which caused severe black root rot and red brown root rot (Photographs 1.3-1.4). Roots with more than one pathogen, typically had worse root rot compared to those affected only by a single pathogen (Photographs 1.5-1.6).

It is noteworthy that the two devastating bean root pathogens, *Thielaviopsis* and *Aphanomyces*, were frequently found in the Sassafras and Thirlstane areas in paddock nos. 1-10 and 24, which have been more intensively used for bean production, compared to those located west of Wynyard in paddock nos. 12-23.

The worst seedling emergence and survival, with 10% seedlings, was recorded in sample no. 23, taken from a sandy loam soil from Wynyard. Although this soil had the highest level of *R. solani* AG2.2, no *Rhizoctonia* hyphal growth or other root pathogens could be found on hypocotyls and roots of the surviving seedlings. This is surprising, as *R. solani* AG2.2 has been described as a serious pathogen to beans, causing lesions on hypocotyls and roots (Hagedorn & Hanson 2005). It is possible that this pathogen only caused poor seedling emergence in this soil type. Other unknown non-pathological causes related to the type of soil in the paddock are also believed to be contributing factors to the poor seedling emergence, as uneven crop establishment is commonly found in other paddocks with the same soil type. The second worst seedling emergence and survival, at 25%, was recorded in sample no. 24, a soil from Sassafras. There was little or no *R. solani* detected in the soil test for this sample, and no *R. solani* growth could be found in association to root rots. Instead, *T. basicola* and *Pythium*, observed in root rot tissues, were the major pathogens.

The outcomes of the bioassay tests indicate that root rot could be caused by a range of root pathogens, which may also interact with one another to cause a root disease complex, which can result in a more severe root rot than that cause by a single pathogen. Soil tests developed to detect soilborne pathogens may have to be crop specific and be able to cover the range of important and damaging pathogens for that crop, in order to be useful for commercial use.

The impact of the root pathogens and root rot severity on seedling growth could not be properly measured in the bioassay study, because plant growth was affected by plant competition in the limited space available in each pot (Table 1.3).

Field observations

Most of the paddocks were selected because they had been used for intensive vegetable and potato production, and yield decline had been experienced on these soils. Most of the bean crops in the paddocks appeared to have better seedling establishment compared to the bioassay tests. The differences in emergence between the bioassay tests and the field crops may be due to the relatively warm and dry field soil conditions in Tasmania in 2006/07. Furthermore, all of the bean seeds used in the bioassay study were untreated, whereas seeds in commercial crops had been treated with commercial fungicide seed treatments (Apron and Thiram, Maxim, Dynasty or Captan). Crop establishment in the paddocks would have been substantially enhanced by the fungicide seed treatments.

Fungal pathogens found in association with root rots and discolouration of bean plants in the paddocks were consistent with those observed in bean seedling roots in the bioassay tests (Table 1.3). Black and red brown root rots due to *Thielaviopsis* and *Aphanomyces* were common in the Sassafras area, while light brown root rot caused by *Rhizoctonia* was common in the Sisters Creek area.

In addition to root rot, sparse plant densities and stunted seedlings with swollen and tapered roots were consistently observed in paddock nos. 16-22 in areas west of Wynyard (Photographs 1.11-1.12). No pathogens or crop management practices and field factors could be identified in association with the symptoms. The symptoms were later traced to abnormalities associated with the seed batch used. The same root symptoms were observed on seedlings grown from the same seed batch sown in pasteurised soil in pots.

Conclusions

In soil tests, the most common type of *R. solani* sub-group was AG2.1, which was detected in 83% of soils collected from 40 paddocks that had been intensively used for vegetable and potato productions. The effects of each sub-group on various vegetable crops are being examined in further studies, in order to get a better understanding of their impact on crop production.

The bioassay tests indicated that root rot could be caused by a range of root pathogens, which may also interact with one another to cause a root disease complex, and which often resulted in a more severe root rot than that caused by a single pathogen. Soil tests developed to detect soilborne pathogens need to cover all the major pathogens in order to be useful for commercial use.

In the bioassay tests, *Rhizoctonia* was found in association with bean root rot in 63% of the soil samples. In 42% of the soil samples, only the *Rhizoctonia* pathogen was observed on the root rots. However, bean root damage caused by other pathogens, such as *Thielaviopsis* and *Aphanomyces*, was more severe than that caused by *Rhizoctonia*.

In the bioassay tests, under relatively cold and wet conditions, seedling establishment from the untreated green bean seeds was very poor. The seedling emergence and survival was less than 46% in approximately 42% of the soil samples.

In the field observations, poor crop establishment and growth was associated to root rots, root pathogens, more intensive use of paddocks for bean production and poor soil conditions, as well as poor seed quality.

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