

Summer Root Rot in Parsley: A Scoping Study

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Purpose of Report

This project aims to address a recent industry concern over the development of summer root rot in parsley. Previous work on parsley root rot conducted by the Victorian DPI has identified a number of causal agents and has reviewed potential management options. The most significant root rots of parsley in Victoria were encountered during winter, and summer root rots were considered to potentially not warrant management. Recently however, severe summer root rots of parsley have been reported with crop losses of up to 100%.

This project aims to review relevant literature on root rot of parsley and meet with growers affected by the recent outbreaks in order to determine an approach to address the issue.

Acknowledgments

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Media summary

Root rot disease complexes of Parsley crops have been previously investigated in Australia, particularly in Victorian and Queensland production systems through a series of projects during the last decade. A range of factors appear to affect the extent to which the rots develop including environmental conditions, production systems and cultural practices, the range of microorganisms associated with the root system, plant variety and management options. A 2005 national study of parsley crops identified fungi associated with parsley roots including *Rhizoctonia*, *Sclerotinia*, *Mycocentrospora*, *Cylindrocarpon*, *Microdochium*, *Pythium* and *Phytophthora*, however it appeared that *Pythium* species and *Phytophthora* species are closely associated with winter sown parsley crops, while *Fusarium* is likely associated with summer parsley crops.

The aim of this project was to better understand the immediate issues associated with recent outbreaks of summer root rot in parsley crops and to recommend further activities to address this issue. In conducting this project, prior literature on the topic was reviewed and concisely summarised, in addition to consulting with growers, a seed company representative and a local vegetable agronomist. Collection of plant and soil samples for pathology testing was also carried out. Results demonstrated a range of grower observations and practices currently employed to manage parsley root rots and found that *Fusarium* was a common pathogen identified in infected samples across geographically diverse Victorian growing regions. Recommendations for future work for management of parsley root rots include; consideration of chemical alternatives, irrigation scheduling and moisture monitoring techniques, bio control agents, nutrient management, variety selection, integrity of irrigation water sources, impact of herbicide applications on plant health and previous cropping cycles and field history

These recommendations may be considered for future investment in management of parsley root rots by the Australian vegetable industry.

Technical summary

Root rot disease complexes of Parsley crops have been previously investigated in Australia, particularly in Victorian and Queensland production systems through a series of projects during the last decade. A range of factors appear to affect the extent to which the rots develop including environmental conditions, production systems and cultural practices, the range of microorganisms associated with the root system, plant variety and management options. A 2005 national study of parsley crops identified fungi associated with parsley roots including *Rhizoctonia*, *Sclerotinia*, *Mycocentrospora*, *Cylindrocarpon*, *Microdochium*, *Pythium* and *Phytophthora*, however it appeared that *Pythium* species and *Phytophthora* species are closely associated with winter sown parsley crops, while *Fusarium* is likely associated with summer parsley crops.

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These recommendations may be considered for future investment in management of parsley root rots by the Australian vegetable industry. Some of the key considerations from this project are presented below;

Previous investigations into root rots in parsley crops have largely focused on winter root rots caused by *Pythium* spp. and *Phytophthora* spp. and not summer root rots.

Incidences of summer root rots are extremely variable, growers do not know when they will lose a crop to summer root rot.

Crop losses of up to 90% or greater can occur when a crop succumbs to summer root rot.

Summer root rots generally occur after a period of increased irrigation applications or a significant rainfall event.

Fusarium was identified as the only common root rot pathogen identified in all three plant and soil samples, which underwent plant pathology assessment.

Much can be done to further investigate both the cause of summer root rots of parsley as well as how previous research can be re-visited in order to develop some sustainable practices to manage the disease.

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Introduction

National production of parsley is approximately equally distributed between Victoria, Queensland and New South Wales, with 1, 160 tonnes produced from 233ha with an estimated value of \$8.3 million/year (ABS, 2001). Production is either 'in-ground' or in hydroponic systems, with multiple harvests per year depending on the production system. Disease issues in parsley production include leaf and root diseases as a result of fungal, oomycete, bacterial, viral and nematode origins.

Root rot disease complexes have been previously investigated in Australia, particularly in Victorian and Queensland production systems through projects VG04025, VG06046 and VG08026. A range of factors appear to affect the extent to which the rots develop including environmental conditions, production systems and cultural practices, the range of microorganisms associated with the root system, plant variety and management options. A 2005 national study of parsley crops identified fungi associated with parsley roots of species including *Rhizoctonia*, *Sclerotinia*, *Mycocentrospora*, *Cylindrocarpon*, *Microdochium*, *Pythium* and *Phytophthora* (Minchinton, 2006), however it appears that *Pythium* species and *Phytophthora* species are closely associated with winter sown parsley crops, while *Fusarium* is likely associated with summer parsley crops.

The aim of this project is to better understand the immediate issues associated with the current summer root rot of parsley outbreak and to recommend further activities to address this issue.

Material and Methods

Literature related to parsley root rot in Australia, with a particular focus on what aspects of disease management have been considered and addressed well and what knowledge gaps still exist has been reviewed and concisely summarised. Associated with this review of prior R, D & E, is understanding the key issues faced by a selection of growers who have been impacted by parsley root rot, in particular the summer root rot disease. Soil samples will have been collected to confirm the associated pathogen(s) involved in this disease.

Following this, a report has been compiled to summarise the above information to provide recommendations on the best approach via R, D & E activities that may address the issues faced by the parsley producers to overcome the constraints of parsley root rot disease. These recommendations may be used to guide future investment in this area by the Vegetable Industry.

Results and Discussion

A Review of the Literature

Pathogen Identification

Pythium spp. was originally identified as the causal agent of root rot in parsley by Minchinton (2005), after this time, further work was conducted across New South Wales, Queensland & Victoria which lead to the more specific identification of several strains of *Pythium* spp. as well as several other pathogens that were found to cause root rot of parsley. Table one provides a summary of these findings.

These findings, combined with international findings, such as those published by Hine & Aragaki (1963), McCracken (1984), Hershman et al (1986), Davis et al (1994) and Nawrocki et al (2002)

identify many pathogenic and non-pathogenic strains of *Pythium* as well as pathogenic strains of *Fusarium* and *Phytophthora*.

Based on this information, it is difficult to suggest what could be done further to investigate causal agents of root rot in parsley. However, further reading reveals there is much work to be done in terms of identifying the exact cause of summer root rot in parsley. Minchinton (2007) describes this type of rot as being caused by *Fusarium* whilst both *Pythium* and *Phytophthora* cause winter root rot.

Table One Pathogen and strains as identified by various Australian research projects.

Location	Study	Pathogen	Causing	Comments
VIC	VG01045 (2005)	Pythium spp.	Damping off	
NSW	VG04025 (2006)	Pythium spp. Phytophthora spp. Fusarium spp.	Mild root rot	Limited pathogenicity
QLD	VG04025 (2006)	Pythium spp Pythium ultimum Phytophthora cryptogea Fusarium Solani	Severe root rot	Difficult to infect healthy plants during lab experiments
VIC	VG04025 (2006)	Pythium ultimum Pythium sulcatum Pythium intermedium Phytophthora megasperma Phytophthora inundata	Root rot	

Management Techniques

Most literature that has been developed surrounding parsley root rot (both summer and winter types) provides several broad and generalised management techniques to help reduce the spread of, or occurrence of root rot. Generally, these techniques include:

Sterilising equipment between sites of infection and other, non-infected areas

Maintaining a 'balanced' nutrition program

Avoid water logging areas for an extended period

Avoid irrigating prior to forecast heavy rain

Implement crop rotation systems to lessen the severity of infections (McCracken, 1984)

Adjusting irrigation timings to lessen the occurrence of wet/dry extremes

Rapidly incorporating crop debris to encourage breakdown

When using fungicides for control, rotating chemical groups to ensure continued effectiveness.

It is suggested that further investigation be made into the exact composition of a 'balanced nutrition' program as well as research into irrigation timing, and moisture monitoring technologies that may assist in avoiding conditions that favour increased pathogenic activity.

Chemical controls

Recent research by Minchinton (2005) has shown that winter root rot of parsley can be successfully controlled by applications of Ridomil Gold 25WG[®] or by using applications of both Ridomil[®] & SprayPhos[®] in crop. However, other research, such as that conducted by Minchinton (2007) shows that these types of fungicide applications may not be as effective in every situation. With so many variabilities within trials over the years, further research needs to be conducted into fungicides and reasons for, or lack of, effectiveness.

The table overleaf summarises past and present registrations of chemicals within Victoria that can be, or have been, used to provide control of parsley root rots under research conditions. One particular product, Previcur[®], was to be trialed by Minchinton et al (2005) during earlier experimentation and was not used because of the absence of an MRL. Trialing chemicals such as these, and those that have had registrations lapse, should be investigated in order to provide some new insights into control options for parsley root rots.

Table Two, Agricultural chemicals either currently or previously permitted for use on parsley or herb crops and their targets as per Agricultural Pesticides and Veterinary Medicines Association permits search (APVMA, 2013).

Active ingredient	Chemical group	Current permit	Targets
Phosphoric/Phosphorus acid	33	Yes	Phytophthora sp.
Fenhexamid	17	No	Botrytis cinerea
Procymidone	2	No	Sclerotinia sp., Botrytis sp. & Alternaria solani.
Azoxystrobin	11	No	Rhizoctonia sp.,

			Phytophthora sp., Botrytis sp., Alternaria sp. & Sclerotinia sp.
Propiconazole	3	No	Not applicable to these plant samples.
Tebuconazole	3	No	Sclerotinia sp.
Quinoxyfen	13	No	Powdery mildew (Grapes)
Chlorothalonil	M5	Yes	Botrytis sp. & Alternaria sp.
Mancozeb	M3	Yes	Fusarium sp., Rhizoctonia sp., Alternaria. & Botrytis sp.
Propamocarb	28	No – not previously permitted.	Pythium sp.
Metalaxyl-m	4	Yes	Phytophthora sp. & Pythium sp.

Research has as also briefly touched on the use of biological substances in order to provide some effective control against pathogenic strains of Pythium and Phytophthora. One such product, Polyversum[®], was trialed by Minchinton et al (2007) but was deemed ineffective, citing soil temperature issues within Victoria as a possible reason for failure. In a later study (Minchinton et al 2013) a local isolate of Pythium oligandrum and a commercially available formulation based on Bacillus subtilis were also trialed, however these did not control disease in the trials.

Many other products, containing non-pathogenic strains of Pythium spp. are available commercially within the United States - contact should be made with these companies for trialing within Australia.

Consultation with Growers

Grower 1

Plant & soil sample 1

Cropping program occurs throughout the Clyde and greater peninsula region producing a wide range of bunching vegetables.

- Previously root rot issues in parsley crops have been attributed to Rhizoctonia sp., Fusarium sp., Pythium sp. & Phytophthora sp. as per laboratory analysis.
- Root rot issues occur in parsley crops year round however the symptoms may vary.
- Brown & white lesions on parsley crowns & roots have been visually identified on affected plants.
- Diazinon improved control initially.
- Rusts affect Parsley crops once plant gets susceptible. Occurs after big rain or wind storm causing plant damage.
- Ridomil Gold 25G was being used at planting and after establishment. This product is no longer used as it was not resulting in any disease control.
- Phosphorus/phosphoric acid is not being used in any crops.
- The production system used both bore water (under 1000EC) and recycled water (must be below 600EC).

- Recycled water contains a naturally high nutrient loading.
- A range of soil amendments/nutrients are used for parsley production including Campbell's Rustica Plus, Campbell's Gold Plus, foul manure (not used at the moment), lime, gypsum.
- Previous work has generally been conducted through winter due to funding timing; trials should have included summer work.
- Coriander, carrots not affected do not appear to be affected by root rot disorders.
- Producing parsley crops in soil which has not previously grown parsley crops but has been heavily vegetable cropped still produces infected parsley crops.
- New parsley varieties appear to have much finer root systems.
- The best parsley is produced during dry periods when irrigation water can be managed.
- The use of herbicides on this property varies with the cropping type under production.
- DNA sequences of parsley root rot pathogens were close to being profiled during previous research however funding ceased and this process ceased.
- BQ mulch is being trialed to control parsley root rots.
- Losses vary from 30-40% losses to total crop losses.
- Italian/continental parsley currently showing only minor signs of infection.
- Worms were seen present in this soil when collecting plant and soil samples.



Figure 1: Grower 1 – Image of parsley roots and crowns.



Figure 2: Grower 1 – Image of parsley roots.

Grower 2

- Production occurs in the Clyde region on Sandy Clay Loams.
- This grower has been producing bunching lines for approximately 40 years.
- Both recycled and runoff water sources are used in the production process.
- Chicken manure is used in the cropping program.
- Significant crop losses regularly occur affecting different varieties at different times of the year.
- Previous trials conducted with Dr Liz Mitchington occurred where a new crop was sown directly over the top of a severely diseased crop and no infection was recorded in the trial crop!
- Until the parsley problem arose the crop was a major component of cropping program, now dropping due to disease issues.
- Customers need continuity of supply.
- When serious summer root rot issues occur in parsley crops supply may be lost for 3-4 months.
- Root rots may affect young crops and/or crops which have been established for a number of months.
- This grower experienced most significant root rot issues during the drought years approximately 5 years ago, crops grown in lighter soils appeared to be worst impacted.
- The timing of root rot diseases in parsley crops on heavy and lighter soils generally occurs during different periods, soil type appears to impact on crops at different times of the summer.
- Previous work conducted on parsley root rots did not resolve the issue, Ridomil Gold 25G and Phosphonic/phosphorus acid have been used in the cropping program with limited results. Ridomil Gold 25G appears to be effective for a limited time, when the crops should harvest over a 9-10 month period longer term control is required.
- Once parsley root rot diseases are established there is no controlling the disease.
- Parsley transplants have been used in the past however they don't take off well.
- Parsley crops don't like moisture extremes.
- Initially root rot was a summer issue, then crop losses occurred year round/cooler season however now issues are more common through the summer cropping period.
- This grower is very uncertain as to when root rots in Parsley crops will occur – “you never know when you will lose a crop”.

- Need an outcome/best practice guidelines - simple, easy steps to control issue.

Grower 3

Plant & soil sample 2

- Production occurs in the Devon Meadows region where bunching lines are grown.
- Recycled water makes up almost 100% of the irrigation water used, bore water is no longer in use.
- Chicken manure is used in the cropping program.
- Root rots in parsley crops cause very significant losses throughout spring, & summer into autumn.
- Root rots are more of an issue in summer but only when must irrigate consistently & not allow ground to dry out during periods of high temperatures.
- Summer root rots are a very irregular infection, infection levels can change within the same bed or from bed to bed.
- Every crop is treated with Ridomil Gold 25G at sowing – it is questionable as to the efficacy of this practice.
- Using Phosphonic/phosphorus acid in crop weekly & using in with pre-emergent Ridomil Gold 25G applications appears to assist with disease management however significant crop losses do still occur.
- This grower asked the question “is it possible an insect is attacking roots and allowing fungi into root.
- Parsley appears to grow better after an onion crop.
- Some varieties appear to be more resistant than others.
- This grower finds it very difficult to cover crop with the high cost of land, taking land out of production can be expensive in the short term.
- Damping off is less of a problem during dry weather.



Figure 3: Grower 3 – Image of parsley roots.



Figure 4: Grower 3 – Image of parsley crop.

Grower 4

- Cropping occurs in the Clyde region using both recycled and runoff irrigation water.
- Has been producing largely bunching lines (grows only small areas of spring onions) and leeks on the same property for approx. 10 years.
- This grower had not seen any of the research findings compiled by Dr. Liz Mitchington et al and therefore did not follow any of the recommendations.
- Summer and winter root rots in parsley crops caused significant crops losses during 2010 and 2011.
- Summer root rot is most prevalent when large rainfall events occur.
- Very few problems with root rot in parsley crops this summer even in varieties which were previously susceptible to infection.
- One visual observation made occurred was quoted as when parsley plants are cut too short in winter plants are opened up to infection.
- This grower attempts to minimise free moisture on tops of beds and encourage soils to breathe.

- Again, this grower produces a little bit of everything, must have diversity for customers.

Grower 5

- Growing bunching lines on a number of properties throughout the Devon Meadows growing region.
- This grower was seeing some significant losses to root rot in the past but now losses are limited.
- The production focus has moved from a mix of curly and Italian/continental varieties to majority Italian/continental parsley crops with minimal curly parsley as Italian/continental varieties are more tolerant to root rot issues and customers will accept it. “We just tell our customers we don’t have curly parsley at the moment”.
- Parsley is not a major component of this growers cropping program.

Grower 6

- Has been cropping the same area of soil for approximately 15 years in the Clyde region
- Production is focused on bunching lines and leeks.
- Irrigation water is collected from rainfall which falls on the property.
- Chicken manure is used in the cropping program.
- Has experienced significant losses to parsley root rot in the past. During both summer and winter production periods.
- Some significant parsley crop losses observed – 24/6/13.
- Last summer experienced significant root rot problems.
- This grower made the comment “It is a gamble when you sow parsley crops, never know if they will survive or not”.
- Seedlings may rot off 3-4 weeks after emergence or throughout the cropping cycle.
- Transplants were used in the past and appeared to suffer more significant root rot issues than direct sown crops.
- Another comment was made “I never had a problem with root rot in parsley crops when seed was treated”.
- Uses some Phosphonic/phosphoric acid in the spray program and occasionally uses Ridomil in this program but has never used Ridomil Gold 25G granules in production program.
- Currently not worth growing parsley, no money in it and considering cutting back however he must grow parsley as customers demand this line.
- Some varieties may be more tolerant than others, Madori may be more tolerant.

Grower 7

- New grower on new soil. Farm has only been in operation for 4 years.
- Constant cropping program focusing on bunching lines.
- Very little if any incidence of summer or winter root rot issues in parsley crops.

Grower 8

Plant & soil sample 3

- Properties are located outside the Clyde/Devon Meadows growing region, west of Melbourne.
- Soil type – sandy clay loam.
- Cropping history consists of lettuce and baby leaf crops. Properties have been used consistently for 30-40 years with limited break crops.
- Irrigation water is sourced from either bores or local reservoirs and delivered via an open channel system.

- Has only been growing parsley crops (both curly and Italian/continental varieties) for approximately 12 months.
- Crops are direct sown and hand harvested for processors.
- Two crops of both curly and Italian/continental were significantly affected by summer root rot this season resulting in losses of approximately 50%. Curly parsley was more significantly affected than Italian/flat leaved varieties.
- Summer root rot only entered crops following 10 days of maximum temperatures reaching in excess of 30°C (3rd March to 12th March 2013) where considerable amounts of irrigation were applied.
- Ridomil (foliar applied) & Phosphonic have both been used in an effort to control summer root rot but with limited or no affect.
- This summer is the first incidence of root rot experienced in parsley crops on this property.



Figure 5: Grower 8 – Image of parsley crop.



Figure 6: Grower 8 – Image of rot affected parsley.

Industry Agronomist

Root rot issues are more prominent with growers who have a long term history of vegetable production at the same location.

- Growers on “new ground” experience very little if any root rot issues – there are limited numbers of growers cropping on “new ground”.
- Root rot of parsley crops have not been as significant during last 12 months.
- Ridomil Gold 25G has been used over the top of beds following 1st cuts.
- Seed resellers keep running out of parsley seed, there is considerable demand for this line.
- Summer root rots are incredibly variable, you just don’t know when they will impact on crops.
- Bacterial issues have been an issue in the past but during the last few years even their prevalence has reduced.
- This agronomist does not see any significant resistance from one variety to the next, some growers prefer one variety and other growers prefer a different variety.
- Chemical management practices appear to provide some control.
- The issue of parsley root rots has largely not been resolved, previous work has not fully resolved the issue.

Seed industry representative

- Most growers are/have experiencing issues with root rots in parsley crops. Generally growers just put up with the issue.
- Most parsley seed has previously been untreated (no fungicides applied to seed prior to sowing).
- This company is investigating fungicide dressings on seed. Currently only Thiram is available as a seed treatment on many vegetable/herb crops.
- The small scale of the herb market inhibits further investigation of other chemical products available for use. Agricultural chemical companies do not see the value of investigating large sums of money for limited returns on investment.
- Seed treatments are possible from an application point of view.

- Some varieties appear to be more tolerant of root rots than other varieties.
- Breeding varieties for resistance to any plant pathogens is very limited in herb crops as they are openly pollinated and can easily be copied or reproduced by competitors. Seed is relatively expensive and there is very little value in investing in these crops from a return on investment point of view.
- Crop yields are generally high vs. the amount of seed used. Grower's expenses are largely incurred in the growing/cultivating of parsley crops.
- Seed companies do conduct trials of breeders selections however there is not a large breeding focus in this area.
- The variety 'Madori' is strong against root rot, but not resistant.

Results of laboratory analysis

Table Three. Summary of results of clinical examination carried out by Len Teseriero, Plant Pathologist, Department of Primary Industries NSW.

Plant and Soil sample number	Clinical examination comments	Microscope examination comments	Fungal isolation	Selective culture for <i>Phytophthora</i> spp.	Selective culture for <i>Pythium</i> spp.	Bacterial isolation	Media seed baiting bio-assay
0001	Most plants look OK. A couple have rotten crown & vascular browning of tap root. Some root tips brown. Few plants with leaf blight of centre leaves & water soaked lesions on petioles.	Slide made of vascular crown tissue – bacteria observed. Slide made from petiole – bacteria observed.	Rhizoctonia & Fusarium isolated.	Not detected.	Detected (several species).	No significant growth (from petiole).	Positive for Rhizoctonia spp. – seedlings damping off after 2 weeks and all dead after 3 weeks.
0002	Leaf tip & petiole necrosis of some leaves. Plants stunted & slightly chlorotic. Tap root rotten & brown root tips.	Slide made of roots & crown vascular tissue – bacteria observed but no fungi.	Fusarium & Plectosphaerell a isolated.	Not detected.	Detected (several species).	No significant growth (from vascular tissue of tap root).	No pathogens detected - seedlings healthy after 3 weeks.
0003	Larger plants – tap root rotten, brown root tips & necrosis of crown in some plants. Some leaf tip & petiole necrosis. Reddening of vascular tissue of tap root.	Slide made of leaf petiole & vascular tissue of tap root – bacteria observed.	Fusarium & Alternaria isolated.	Not detected.	Not detected.	No significant growth (from petiole & vascular tissue of tap root).	No pathogens detected - seedlings healthy after 3 weeks.

Pathology Conclusion

A mixture of root rot fungal pathogens which were recovered, along with several secondary soft-rotting bacterial species (*Erwinia* spp.) appear to have invaded the crown and petiole roots.

The following are the fungal pathogens isolated from each of the samples.

- Sample 0001
 - Three species of *Pythium*, *Rhizoctonia* and *Fusarium*
- Sample 0002
 - Two species of *Pythium*, *Fusarium* and *Plectosphaerella*
- Sample 0003
 - *Alternaria* and *Fusarium*

Parsley seed was planted into the three soil samples submitted. After three weeks of growth, the fungus *Rhizoctonia* was observed causing a damping off of all the parsley seedlings from sample 0001. Soils from samples 0002 & 0003 both produced healthy parsley seedlings.

Discrepancies and Similarities

Previous investigations into parsley root rot have primarily focused on *Pythium* spp. and *Phytophthora* spp. Samples of plant and soil collected concluded *Pythium* spp. were present in two of the three plant and soil samples, however with one sample testing negative for *Pythium* spp. and all three samples testing negative for *Phytophthora* spp. these plant pathogens cannot be attributed solely to the current parsley summer root rot issues.

Fusarium species were isolated in all three plant and soil samples collected along with single detections of *Rhizoctonia*, *Plectosphaerella* and *Alternaria*. It can be assumed that much of the recent summer root rot issues are attributed to *Fusarium* spp at the sites examined during this study.

Crops inspected on properties where field assessments were made were all noted to be impacting severely on older crops between three and six months of age, no young crops were showing any signs of fungal root rots. Samples for laboratory analysis were collected from these three to six month old crops.

Crops inspected growing in the Clyde/Devon Meadows region and showing signs of summer root rot were also noted to be growing in a very stunted manner with re-growth very slow and poor yields are assumed. Crops growing in the Bacchus Marsh region were actively growing but also suffering severe summer root rot. Re-cut, re-growth and yields from these crops was visually assessed as being significantly quicker and taller.

One crop inspected did show a significant difference in crop tolerance to summer root rot from one side of a sprinkler row to another. Crops growing on the eastern side of the paddock inspected showed on average 80-90% plant losses to summer root rot whilst crops growing on the western side of the same sprinkler row showed 70-90% plant losses to summer root rot.



Figure 7: Grower 1 - significant summer root in crop to the left of sprinkler row and some crop to the right of sprinkler row with very little if any summer root rot.

Technology Transfer

Due to the nature of this project, there have been no formal technology transfer activities. Technology transfer will be facilitated by delivery of the recommendations and findings from this final report to the vegetable industry.

Recommendations - Suggestions for Future Direction

- The investigation of Fusarium introduction to parsley crops and the control of this typically very difficult to manage pathogen should be the main focus of future research. Fusarium was the only common pathogen present in all 3 plant and soil sample assessments and has not been investigated as extensively in past projects.
- Agricultural chemicals require further investigation, both those which can be applied to seed prior to sowing as a seed coating and those for use on the seedbed or growing crop. Currently those seed companies investigating the possibilities of root rot control in parsley crops via seed dressings are trying a number of products with little understanding of the actual diseases they are targeting, chemical effect on the seed to be sown and any relevant withholding periods. Previous work completed has focused on chemical control for Pythium spp. and Phytophthora spp. As Fusarium spp. have been noted in all three samples assessed in this study, control should focus on this disease. As noted in Table two, a number of fungicides have previously been permitted for use in parsley crop production – why have a number of these permits lapsed? Were they at all effective in controlling summer root rots?
- Further research into irrigation scheduling and moisture monitoring techniques – as well as the role these play in disease prevention. Summer root rots appear to occur either during/shortly following periods of extreme temperature spikes where irrigation practices result in higher than normal irrigation applications or during/shortly following significant summer rain events.
- Investigate biological controls which may be available to assist with disease suppression, plant inoculation and parsley stress management. Biological controls/inoculants are becoming increasingly prevalent within the Australian horticultural/agricultural market place as some large international chemical companies realign their businesses to include such products and researchers continue to unravel and discover soil microbe species.
- Nutrient management could be one focus area for new research, especially the use of chicken manure based fertilisers and the effect these have on plant health, soil nutrient balances, impact on soil salinity and sodicity and soil porosity.
- Variety selection trials could be easily conducted by sourcing both flat leafed and curly leafed parsley varieties from all seed companies, sowing them side by side and attempting to encourage root rot issues in this trial by irrigation scheduling and not applying recommended fungicides.
- Irrigation water sources should be sampled to determine if root pathogens noted, as present in the plant and soil samples tested, are endemic in irrigation waters applied to crops. Are these pathogens introduced to stressed crops at the time of irrigation?
- Herbicide impact on seedling tolerance/susceptibility to root rot disorders should be investigated. Plants with root systems already compromised by herbicide applications may be more prone to root rots. Currently seven herbicides are available to parsley producers for varying purposes including essential oils and leaf production.

■ With the observation of variable summer root rot incidence in the same crop grown on different sides of a sprinkler row, crop rotations and previous cropping practices should be investigated. Are previous cropping selections impacting the occurrence/severity of summer root rots in following parsley crops? Further to this, what is the impact of “new ground” versus “old ground”? Is continual cropping of horticultural/agricultural soils having a direct impact on incidence of summer root rots?

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