Stop the Rot – Managing Onion White Rot in Spring Onions

Final Report
Horticulture Australia Limited Project VG01096
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Villalta et al
Department of Primary Industries, Victoria

Horticulture Australia Project VG01096 – 'Stop the rot – managing onion white rot in spring onions'

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Purpose of project
The purpose of this project was to evaluate chemical and biological treatments for the control of the disease onion white rot on bunching onion crops. This was to provide vegetable growers with more control options and an integrated strategy for the sustainable control of this soil-borne disease and to better inform them of the most appropriate and effective use of chemical and biological treatments for disease management on their farms.

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1. Media Summary

The disease onion white rot is a serious problem in bunching *Allium* crops, which include spring onions and shallots, sometimes causing crop losses of up to 50% in eastern Australia. Before this project began vegetable growers used the fungicide procymidone to manage white rot, but complained that they were not getting good control. As a result of this research, growers now have a range of new options to control onion white rot.

By changing the timing and method of application (banding *vs* broadcast) of procymidone, control of white rot was 75% more effective than that obtained by growers. However, procymidone did not persist long enough in soil to effectively suppress late-season infections at high disease sites and recently procymidone was suspended from use in vegetable crops pending a review by the Australian Pesticides and Veterinary Medicines Authority. This project developed four new fungicide treatments that proved to be more effective and reliable than procymidone, and efficacy and residue data from this research will be used to support minor use permits for these products.

To compliment the conventional fungicide treatments two other methods of control were tested and developed. Treatment of soil with DADS (onion oil) tricked the fungus into germinating causing it to die out before spring onion crops were sown reducing the fungal population by up to 90%. This resulted in a 85% reduction in disease in the following spring onion crop at high disease sites. Because the amount of fungus in the soil was reduced the biological treatment *Trichoderma atroviride* C52, applied in the furrow with seed, was more effective reducing disease in soil treated with DADS than in untreated soil. DADS integrated with fungicide treatments resulted in almost complete disease control. Combining *T. atroviride* C52 treatments with post-planting sprays of fungicide was more effective reducing disease than using the biological treatment alone at high disease sites. Efficacy and application data from this research will be used to support registration of DADS and the biocontrol in Australia.

This project has successfully developed new treatments which can be used alone or as part of an integrated package by vegetable growers to control onion white rot of bunching onions in their farms. The project also provided valuable information that will assist vegetable growers to make informed decisions about the use of the biological control *Trichoderma* for managing onion white rot and soil health.

2. Technical Summary

Onion white rot is the most serious soilborne disease of bunching onion crops in eastern Australia. In this region, a survey found that this disease occur in approximately 194 hectares of land used for growing bunching onion crops in vegetable farms in Victoria, NSW, Tasmania and Queensland. Most of the land affected is located in the south and south-east of Melbourne, Victoria. The survey also found that this disease was responsible for crop losses of 5-50%, or higher, due to the high levels of sclerotia of *Sclerotium cepivorum* in soils (range 5-232/kg soil) and insufficient chemical protection provided by procymidone treatments. Petri dish experiments indicated that the lack of effective control with procymidone could not be attributed to the development of procymidone resistance in populations of *S. cepivorum*. However, survey data suggested that inadequate application of procymidone treatments was probably one the reasons for ineffective disease control with procymidone.

This project therefore conducted a series of field trials to evaluate new methods of applying procymidone treatments and identify alternative treatments to procymidone for control of white rot of bunching onions. Field trails also evaluated biological controls (*Trichoderma*) and a commercial formulation of the soil treatment diallyl disulphide or DADS (Alli-Up™, germination stimulant of sclerotia) for integrated control of white rot. Trials were conducted within commercial crops of spring onions grown in sandy loam/clay soils naturally infested with sclerotia of *S. cepivorum*. Petri dish experiments determined the range of soil temperatures favourable for disease development. This information and soil temperature data collected in the field were used to optimise the time of application of control measures in field trials.

Field trials demonstrated that the effectiveness of procymidone treatments for white rot control can be improved by improving its application. Results from two trials on fields where procymidone was ‘ineffective’ controlling white rot showed that two procymidone treatments reduced the incidence of plants with white rot by 75-76% of the untreated control, (20-40% plants diseased). Procymidone treatments were more effective in reducing disease incidence, compared to grower’ practices, because sprays were strategically placed (banded) across the furrow with seed and plant-rows where protection against infection is needed. Although these and other trials showed that the effectiveness of procymidone treatments for disease control was improved by better application of treatments, its persistence in soil and plant was insufficient to provide the effective protection required throughout the growing season.

Field trials identified a number of fungicide treatments that can be used as alternatives to procymidone. Filan™ (boscalid) treatments were consistently more effective than procymidone treatments in controlling white rot and increasing yields at all field sites. At three field sites, for example, two applications of Filan™ reduced the incidence of plants with white rot by 90-99% of the untreated controls (15-30% of plants diseased). One spray with Folicur™ (tebuconazole) applied after sowing was as effective as Filan™ in controlling disease at three field sites. Two sprays with either Filan™, Amistar™ (azoxystrobin) or Bayfidan™ (triadimenol), applied to young plants approximately four and six weeks after sowing were more effective than procymidone treatments in controlling white rot. Commercial trials (treatments applied with boom sprayer) confirmed the excellent efficacies of Filan™ and Folicur™ for white rot control of spring onions.

Field trials showed that *Trichoderma* treatments alone were less effective than fungicide treatments in controlling white rot at high disease sites. At two field sites, for example, Filan™ treatments reduced the incidence of disease by 90-98% of untreated controls (28-29% diseased plants). *Trichoderma* C52 applied on formulated prills in the furrow with seed at sowing (Trichopel Ali 52™, 50kg prills/ha) gave a reduction in disease in the order of 50% of that of untreated plants at one of the two high-disease field sites. At both field sites, the biocontrol applied at sowing combined with one post-planting spray of Filan™ gave reductions in disease in the order of 58-75% of that of untreated controls. At a low-disease field site (11% plants diseased), *Trichoderma* treatments were as effective as two procymidone sprays in controlling disease.

Overall, results showed that *Trichoderma* C52 levels in sandy soils were below the required levels for effective biocontrol. Despite that, the results indicated that *Trichoderma* C52 was able to provide some degree of protection against early season infection when its levels were highest in the region of roots.

Field trials demonstrated that two applications of DADS were more effective than single applications in reducing the number of viable sclerotia in soil (90% reduction) and disease incidence. The two rates of DADS tested (5 and 10L/ha) were equally effective in reducing disease incidence. In two trials, for example, two applications of DADS applied at 5 L/ha caused reductions in the incidence of disease of 85-87% (20-34% plants diseased). Combining two applications of DADS with either 1 or 2 sprays of Filan™ resulted in almost completed disease control. At one field site, DADS integrated with Trichopel Ali 52™ gave levels of disease control comparable to those provided by DADS combined with fungicide treatments.

Controlled studies identified soils, chemicals and soil amendments that are compatible with *Trichoderma*. *Trichoderma* C52 grew to levels desirable for biocontrol (>10^5 cfu/g soil) in clay and black loam soils but required incorporation of pellets containing humic acids (Agrolig™) to grow to similar levels in sandy soils. *Trichoderma* growth was inhibited by nitrogen released from nitrogenous materials such as fertilizer (urea) and fresh chicken manure but it was compatible with low-nitrogen soil amendments (eg spent mushroom compost) and field rates of key fungicides used for white rot control (eg procymidone, boscalid). DADS was also detrimental (fungistatic) to *Trichoderma* growth in close contact. The information collected will be used to optimise the application of *Trichoderma* into soils and develop an integrated strategy for managing white rot and soil quality in vegetable farms.

Onion white rot on bunching onions and its control with the fungicide procymidone

Summary

Onion white rot is the most serious soilborne disease of bunching onion crops (eg shallots, spring onions, shives) in eastern Australia. In this region, a survey (fax, phone and visits to farms) estimated that this disease was present in at least 195 hectares of land used for growing bunching onions in commercial vegetable farms in Victoria, NSW, Tasmania and Queensland. Most of the land affected is located in the south and south-east of Melbourne, Victoria. The disease was not reported in vegetable farms in South and Western Australia. In farms in New South Wales, Tasmania and the Lockyer Valley, growers reported that white rot occurs in small areas or 'hot spots' within fields. The survey data does not include the hundreds of hectares of land infested with white rot that are used for growing bulb onions in Tasmania, Victoria and Queensland. The survey data revealed that onion white rot was responsible for crop losses of 5-50%, or higher, due to the high levels of sclerotia of *S. cepivorum* in soils (range measured 5-232/kg soil) and insufficient chemical protection provided by procymidone treatments.

Results from *in vitro* experiments showed that mycelial growth from thirteen isolates of *S. cepivorum*, collected from fields where procymidone was 'ineffective' controlling white rot, was significantly inhibited by the two lowest concentrations of procymidone tested (1 and 5 ppm/mL). These results indicated that the lack of effective disease control with procymidone was not due to the development of procymidone resistance in the populations of *S. cepivorum* tested. Survey data, however, suggested that inadequate application of procymidone treatments by growers was probable one the reasons for ineffective disease control with procymidone in commercial farms. Petri dish experiments verified the range of soil temperatures favourable for disease development. This information and soil temperature data collected in the field were used to optimise the time of application of procymidone treatments in field trials. Results from two trials on fields where procymidone was 'ineffective' controlling white rot showed that two appropriately timed and applied sprays of procymidone reduced the incidence of plants with white rot by 75-76% of the untreated control (20-40% plants diseased). Procymidone treatments were more effective in reducing disease incidence, compared to grower's practices, because sprays were strategically placed (banded) across the furrow with seed and plant-rows where protection against infection is needed. However, these and other trials showed that procymidone treatments did not persist long enough in soil and plant to provide the effective protection required throughout the season at high disease field sites.

Introduction

Sclerotium cepivorum Berk., causes the disease white rot on several *Allium* species. White rot of onion (*Allium cepa* L.) and bunching onions (*Allium fistoloson* L.) is a serious threat to the bulb onion and bunching onion industries worldwide and in Australia. White rot is now present in major onion-growing districts in the country. The disease severely reduced onion production in south-western Victoria, once Australia's major onion-producing area in the 60-80's. Prior to this study, there was no information available on the prevalence of white rot in major bunching onion growing districts in the country. In Victoria, vegetable growers reported that this disease has progressively increased over the years due to the frequent use of monocultures of spring onion crops in short rotations with other non-host crops (e.g. radish, endive, parsley). This has probably resulted in drastic increases of pathogen (sclerotia) populations, leading to high disease levels and therefore considerable yield losses.

Spring onion growers in Victoria have reported that in the past seed and soil treatments with the fungicide procymidone provided adequate control of white rot but, in recent years, procymidone treatments (soil surface and foliar sprays) have not provided consistently adequate control of white rot.

The decline of fungicide effectiveness has been attributed to resistance in the pathogen. Field isolates with resistance to dicarboximide fungicides (e.g. iprodione, vinclozolin, and procymidone) have been reported in S. minor populations from peanut in Virginia, USA (Detweiler et al., 1983). Resistance to dicarboximates was not found in field isolates of S. cepivorum collected from a district with reported fungicide loss of effectiveness in New Zealand (A. Stewart, unpublished). However, it has been shown that S. minor and S. cepivorum have the capacity to develop resistance to dicarboximates in vitro (Entwistle 1983, Hubbard et al., 1997). Recent field and laboratory work in New Zealand indicated that the decline in the effectiveness of dicarboximide and triazole systemic fungicides used for white rot control could be attributed to enhanced microbial degradation of the chemicals in the soil and soil characteristics (Slade et al., 1992, Tyson et al., 1999).

Possible explanations for the inadequate control of white rot (bunching onions) with procymidone are (i) resistant strains of *S. cepivorum* have developed with continued fungicide use, (ii) fungicide applications are not being timed and applied properly and (iii) continue use of fungicide has increased the population of soil microbial populations that rapidly degrade the fungicide. Therefore this research conducted

- a survey to determine the distribution of onion white rot and levels of crop losses in bunching onion-producing districts of Australia.
- *in vitro* tests to determine the range of temperatures conducive to germination of sclerotia of *S. cepivorum* and mycelial growth.
- field monitoring of soil temperatures to define the periods of disease risk and therefore improve the time of application of control measures.
- collected isolates of *S. cepivorum* from fields where disease control with procymidone was reported as inconsistent and inadequate and conducted *in vitro* tests to determine their sensitivity to procymidone.
- two field trials to determine if better application of fungicides treatments at the right time could improve the efficacy of procymidone for white rot control on spring onions grown with three different compost amendments.

Materials and Methods

Survey

~~*Sites details*~~

~~Survey data was collected by fax and during visits to vegetable farms. Thirty-eight vegetable farms producing bunching onions in crop rotations with vegetables were surveyed in Australia, mainly from Victoria where most of the bunching onion production occurs. The properties were located in the Cranborne, Clyde and Heatherton areas. The presence of white rot and estimated area of land affected and yield losses were recorded at each site.~~

~~*Population of sclerotia in soils*~~

~~Levels of sclerotia of *S. cepivorum* in soil were determined from soil samples collected from six of the farms surveyed. Soil samples were collected from fields selected based on the history of procymidone use (2-10 yrs) and reported inconsistent control of white rot with procymidone. The size of the fields varied from 0.1 to 0.3 ha. Each field was divided into 10-16 sections and a composite soil sample collected from each section. Each composite soil sample consisted of five soil sub-samples collected with a soil core sampler from the top 10 cm of soil. The soil sub-samples were taken from separate locations within each section approximately 2 m apart to provide true replicates and later mixed well. Samples were stored in plastic bags at 5-10ºC until used. All soils assessed were sandy soils. Sclerotia were recovered from soil using a wet sieving method. One hundred grams of soil were wet-sieved through a 500 and 250 micron-screens. Sclerotia were collected from debri in the 250 microns screen.~~

4 General Discussion

This project identified new chemical and biological treatments, and methods for their application, that will help vegetable growers to control onion white rot of bunching onion crops in their farms. The new fungicide Filan™ (boscalid, chemical group G), applied as a soil surface and stem base/foliar sprays, provided reliable effective control of white rot at all high disease field sites. Filan™ is therefore a suitable replacement for procymidone, suspended by APVMA in 2004, for the control of white rot on bunching onion crops. Folicur™ applied as a single soil surface application after sowing also consistently controlled white rot on 12-14-weeks old spring onion crops. The use of Folicur™ will be limited to one application per crop due to its withholding period of 90 days. This fungicide could be used in bunching onion crops grown for at least 14 weeks, typical of crops sown in Winter and harvested in late Spring in Victoria. Amistar™ and Bayfidan™ applied to emerged plants four andsix weeks after sowing were more effective than procymidone treatments in controlling white rot.

Filan™ is the only new fungicide produced in the last 10-15 years with excellent activity against the white rot pathogen. Although Filan™ is highly effective in controlling white rot, its long-term field performance is unknown. Therefore it would be sensible to restrict the use of Filan™ to strategic applications during the growing season when disease risk is high and integrated with other fungicides from different chemical groups to ensure its field efficacy is not lost too soon due to overuse. For instance, Amistar™ and Bayfidan™ could be used in combination with one early season application of Filan™ or Folicur™ to extend the level of disease protection until harvest at high disease field sites. Proper application of fungicides strategically placed in the root zone and base of plants with the right volume of water and at the right time is vital for effective disease control.

The biological control *T. atroviride* C52 applied on formulated prills (Trichopel Ali 52™) in-furrow at sowing showed promise for protecting the roots of growing plants against white rot infection at low disease pressure sites and in soils treated with DADS (<11% plants diseased). *Trichoderma* treatments on their own may not provide acceptable disease control in high-disease sites. Trichopel Ali 52™ therefore needs to be integrated with post-planting application of fungicide (eg Filan™) to ensure effective control of disease is obtained throughout the growing season. Consequently, a sensible strategy would be to apply Trichopel Ali 52™ at sowing to protect against early season infection but to supplement this with 1-2 foliar applications of fungicides, when required, to suppress late season infections. Levels of *Trichoderma* C52 measured in sandy soils were probably below the optimal levels required for effective biocontrol. Future research should therefore investigate the rhizosphere competence and population dynamics of *Trichoderma* in soils, especially in sandy soils to determine how depth *Trichoderma* grows and the effect of frequent irrigation on spore and propagules retention in soil. This research should identify means of modifying the sandy soil around the root zone to increase the levels of *Trichoderm*a colonisation and biocontrol.

Synthetic diallyl disulphide or DADS (80% diallyl disulphide, Alli-Up™) was very effective reducing the population of sclerotia of *S. cepivorum* in soil and disease incidence on spring onion crops. This soil treatment applied before planting can be a cost-effective soil treatment for white rot control on commercial spring and other bunching onion crops. DADS needs to be integrated with other control measures that protect the roots of growing plants from infection to obtain more effective disease control throughout the growing season. For instance, when DADS was combined with correctly applied and timed fungicide treatments (eg Filan™) or early season applications of the biocontrol agent *T. atroviride* (Trichople Ali 52™), effective and sustainable control of white rot was obtained. Commercialisation of DADS in Australia is being prevented by a reliable supplier of DADS, cost of treatments and costly registration process. When registered, DADS has the potential to provide an immediate increase in return per hectare but the benefits of the treatment will persist for several cropping seasons. Other chemical treatments readily available (eg dazomet, metham sodium) can reduce the population of sclerotia in soil but these can be too expensive and would require optimisation before their widespread use for white rot control in Australia. Therefore, the development of alternatives soil treatments to synthetic DADS is required to ensure growers have a variety of cost-effective soil treatments available for reducing sclerotial inoculum levels in soils. Biofumigants, organic *Allium* products containing DADS and nitrogenous soil amendments are among the potential soil treatments which have the capacity to kill sclerotia in soil. These also require further development before their widespread use for white rot control in Australia.

In summary, this project has demonstrated that control of white rot on bunching onion crops will be more effective when using an integrated disease management programme that incorporates a combination of different control strategies. These strategies include the use of DADS integrated with the new fungicide Filan™ and well-developed biocontrol treatments such as *T. atroviride* C52 (Trichople Ali 52™). The use of crop rotations with non-Allium crops and green manure crops with biofumigant activity should be encouraged to help growers to prevent the build up of sclerotia of *S. cepivorum* in their farms.

The project also developed valuable information that will assist vegetable growers to improve the time of application of control measures and make informed decisions about use of the biological treatment *Trichoderma* for managing onion white rot with less chemical input and soil health in vegetable farms.
In sandy soils, in-furrow incorporation of pellets containing humic acids (eg Agrolig™, AgChem) will be required to help *Trichoderma* to grow better in these soils with low levels of organic matter. *Trichoderma* growth will be inhibited by nitrogen released from fertilizers and fresh composted chicken manure. Therefore, these materials should not be applied for at least 2-3 weeks before and after sowing to allow *Trichoderma* spores/propagules to germinate and establish in soils. Field rates of Filan™ and low-nitrogen soil amendments can be applied to plots treated with *Trichoderma. Trichoderma* can be applied safely to soils several weeks after DADS was injected into soil.

5. Technology Transfer

Refereed Scientific Papers

1. McLean KL, Stewart A, Villalta O, Wite D, Porter IJ, Hunt J (2005). Optimising *Trichoderma atroviride* C52 for the control of onion white rot on bunching onions. (in prepation)

2. Villalta O, Wite D, Porter IJ, McLean KL, Stewart A, Hunt J (2005). Comparison of chemical and biological methods of controlling onion white rot on bunching onions in Australia. (in preparation)

Conference Abstracts

1. Villalta *et al* (2004) 'Integrated Control of Onion White Rot in Spring Onions'. 3rd Australian Soil Diseases Symposium, Barossa Valley, SA, pp 155-156.
2. Stewart *et al.* (2004) 'Optimising *Trichoderma* bio-inoculants for integrated control of soil-borne diseases', 3rd Australian Soilborne Diseases Symposium, pp 55-56.
3. Villalta et al. (2005) Alternative fungicide treatments to replace procymidone for control of white rot, 15th Australasian Plant Pathology Conference, Geelong September. pp219
4. Villalta et al. (2005) Optimising *Trichoderma* for the management of onion white rot control on spring onions, 15th Australasian Plant Pathology Conference, Geelong September. pp165
5. Villalta et al. (2005) Evaluating *Trichoderma* for integrated control of white rot on spring onions, 15th Australasian Plant Pathology Conference, Geelong September 2005. pp166
6. Villalta *et al* (2005). Evaluation of dially disulphide for integrated control of onion white rot on bunching onions. Australian Vegetable Industry Conference 2006 (submitted)

Industry publication

1. Report for Onion IAC 'Alli-up™ or DADS and possibilities for registration in Australia for the control of onion white rot', November 2004.

Extension articles/materials

1. 'Onion white rot – causing severe yield losses in spring onions'. National Onion Conference held at Yanco N.S.W. June 2002, pp78-80.
2. 'Integrated control for white rot in bunching onions'. Onions Australia vol 19, 2002, pp21.
3. Fact Sheet 'Onion White Rot – Vegetable matters of facts', VegCheque, Number 5, July 2003.
4. 'Progress Towards An Integrated Control Program for Onion White Rot of Spring Onions'. In 'Controlling Diseases of Spring Onions' Booklet, Cranbourne Victoria September 19, 2003.
5. Project Progress Report. Spring Onion Industry (Vic) Steering Committee Meeting, October 20, 2003.
6. Vegetable Matters-of-Facts 'Onion White Rot Control' in Diseases of Bunching Vegetables. In Booklet for seminars at Lonford, Wynyard and Forth Tasmania, February 26-27 2004.
7. Booklet 'Integrated Control Strategy for Onion White Rot Disease in Spring Onions and other Bunching *Allium* Crops' 2004. Results from first two years of research published and distributed nationally to growers, IDOs and industry people.
8. Article 'Research continues on white rot control', Onions Australia, Vol 21 November 2004, pp7-9.
9. Poster, Villalta et al (2004) 'Integrated Control of Onion White Rot in Spring Onions'. Australian Soil Diseases Symposium.
10. Optimising *Trichoderma* for the management of white rot on bunching onions. Poster
11. Evaluating *Trichoderma* for integrated control of white rot on bunching onions. Poster
12. Alternative fungicides to procymidone for control of white rot on bunching onions. Poster
13. Evaluation of diallyl disulphide (DADS) for integrated control of onion white rot on bunching onions. Poster
14. Control of Onion White (Root) Rot on Bunching Onions – Brochure, December 2005.

Grower extension activities / field walks / workshops

1. Seminar and field day notes ‘Onion White Rot Project’, Cranbourne Victoria 2 July 2002.
2. Seminar and field day notes ‘Onion White Rot Project’, Rochedale, Brisbane Qld 28 August 2002.
3. Seminar and field day notes ‘Controlling Diseases of Spring Onions & Leeks’, Cranbourne Victoria February 28, 2003.
4. Seminar and field day notes ‘Progress Towards An Integrated Control Program for Onion White Rot of Spring Onions’, Cranbourne Victoria September 19, 2003.
5. Seminar ‘Onion White Rot Project’ presented at the Vegetable Forum attended by HAL and vegetable growers and representatives. DPI Victoria Knoxfield, 12 August 2003.
6. Field trials walks, Cranbourne and Heatherton trials, Victoria 10 and 12 December 2003.
7. Project progress report, presented to Spring Onion Steering Committee, Cranbourne 17 March 2004.
8. Field trials walks, Cranbourne and Heatherton, Victoria 17 and 24 May 2004.
9. Spring Onion Grower Seminar Day, seminars presented by Australian and New Zealand project members. Amstel Golf club, Cranbourne, 17th June 2004.
10. Seminar ‘Chemical and biological control of onion white rot in spring onions’ presented at the Bunching Vegetable Workshop, Wanneroo, WA, 18 August 2004. Spring onion farms visited.
11. Seminar presented to onion growers attending the Annual Levy Payers Meeting held at Devonport, Tasmania on 15/11/04.
12. Spring onion growers observed the application of DADS treatments at two field sites in Vic (Cranbourne and Heatherton), September 2004.
13. Project progress report, presented to Spring Onion Steering Committee (7th meeting of project), Cranbourne 20/12/2004.
14. Seminar presented at the National Onion White Rot Workshop held at Devonport, Tasmania on March 2005.
15. Field trial walks conducted at field sites in Victoria during May-June 2005.

6 Recommendations

Recommendations to vegetable growers arising from this project have been summarised and distributed to growers nationally in the booklet ‘Integrated Control Strategy for Onion White Rot Disease in Spring Onions and other Bunching *Allium* Crops’ and the brochure ‘Onion White Rot of Bunching Onions’. The publications outline a range of strategies that enable onion white rot to be managed in short-season onion crops in vegetable farms in Australia.

More successful control of white rot will be obtained when using an integrated management strategy that incorporates different treatments, strategies and tactics for disease control. In general, there are three key strategies that growers can use to obtain effective and sustainable control of white rot on bunching onion crops.

1. The first strategy is to minimise the introduction and spread of the white rot pathogen within and between fields.

- enforcing on-farm hygiene practices is the responsibility of individual growers.
- the build up of sclerotia of *Sclerotium cepivorum* in soil can be prevented by implementing crop rotations with non-*Allium* vegetable crops and break crops (e.g. green manure crops).

2. **The second strategy involves the use of chemical and biological treatments that protect the roots of growing plants against infection.** This project identified new treatments, and methods for their application, which can be used alone and integrated with other strategies for effective control of white rot.

- The new fungicide Filan™ (group G) can provide excellent control of white rot in high disease field sites. It is therefore a suitable replacement for procymidone, suspended by APVMA in 2004.
- The long-term field performance of Filan™ is unknown. Therefore it would be sensible to restrict its use to strategic applications during the year when disease risk is high (determined by soil temperatures). If possible it should be used integrated with other fungicides from different chemical group to ensure its field efficacy is not lost too soon due to overuse.
- Folicur™ (triazole), Amistar™ (strobilurin) and Bayfidan™ (DMI) showed excellent activity against white rot and therefore they should be used alone when possible or integrated with Filan™.
- The use of Folicur™ could be limited to one application per crop/season due to its withholding period.
- Proper application of fungicides strategically placed into the root zone and base of plants with the right volume of water and at the right time is vital for effective disease control.
- Fungicide residue data collected will support applications for minor use permits for Filan™, Folicur™ and Amistar™ in Australia.
- The biocontrol agent *T. atroviride* C52, applied on formulated prills (Trichopel Ali 52™) in-furrow with the seed at sowing showed promise for providing good early and late-season control of white rot at low disease sites and in soils treated with DADS (<11% plant diseased).
- *T. atroviride* C52 treatments on their own will not provide commercially acceptable disease control in high disease sites. Therefore, a sensible strategy to use would be to apply Trichopel Ali 52™ at planting to protect against early season infection but to supplement this with post-planting applications of fungicides (eg Filan™) to suppress late season infections.

3. **The third strategy is to reduce the population of sclerotia of *S. cepivorum* in soil.** This project developed a strategy, and application methods, for the use of synthetic DADS (80% diallyl disulphide, Alli-Up™) to reduce the population of *S. cepivorum* in soil and disease-pressure in soils used for growing bunching onions.

- Two applications of DADS, applied when soil temperatures are between 10-20ºC (Autumn and Spring in southern Australia; Winter in south Queensland), will be required during the year to obtain commercial levels of disease control.
- DADS treatments need to be integrated with other control measures that protect the roots of growing plants against infection to obtain more successful and sustainable disease control throughout the growing season.
- DADS is a cost-effective soil treatment to eradicate sclerotia in soils and reduce disease incidence on commercial spring onion crops and other *Allium* crops. DADS has the potential to provide an

immediate increase in return per hectare with the benefits of the treatment persisting for several cropping seasons.

- At present, however, commercialisation of DADS in Australia is being prevented by a reliable supplier of synthetic DADS, cost of treatments and a costly registration process.
- Although the soil treatments dazomet and metham sodium are readily available and can reduce the population of sclerotia in soil, methods for their application are not well developed and in most cases they would be too expensive for widespread use for white rot control.

The project developed valuable information that will assist vegetable growers to make informed decisions about the appropriate use of the biological treatment *Trichoderma* for managing white rot and soil health in vegetable farms.

- In sandy soils, for example, the use (in-furrow) of pellets containing humic acids (eg Agrolig™, AgChem) will be required to help *Trichoderma* to grow better in these soils with low levels of organic matter.
- *Trichoderma* growth is inhibited by nitrogen released from fertilizers and fresh composted chicken manure. Therefore, these materials should not be applied for at least 2-3 weeks before and after sowing to allow *Trichoderma* spores/propagules to germinate and establish in soils.
- Field rates of Filan™ and low-nitrogen soil amendments can be applied to soil treated with *Trichoderma.*
- *Trichoderma* can be applied to soils treated with DADS several weeks after it was injected into soil.

In summary, in the short and medium-term, onion white rot can be managed with new fungicide treatments and biological controls, when possible. For the long-term, the challenge remains to secure supply and registration of synthetic DADS for *Allium* industries in Australia. Therefore, the future of onion white rot research in Australia will be directed towards the development of cost-effective soil treatments to eradicate sclerotia of *S. cepivorum* and other important sclerotial pathogens of onions and vegetable crops from soils and development of integrated approaches for sustainable disease control. A new project 'Optimising soil treatments for integrated control of white rot and other diseases' has been developed to address some of these priorities.

Selecting the most cost-effective strategy for a given field still involves considerable guess work to estimate the potential level of disease-pressure in soils based on counts of sclerotia of *Sclerotium cepivorum*, previous cropping history and a range of other environmental factors). Therefore the development of methods to predict inoculum potential in soil (eg using PCR-specific probes for *S. cepivorum*) and the optimal time for fungicide applications (eg based on degree-hours) are two key research priorities. Such methods would enable growers to select the most appropriate and cost-effective control options (eg fungicide *vr* biological) for each field. Other research priorities include:

- demonstration programs in each state to facilitate uptake of effective white rot control strategies.
- investigate rhizosphere competence and population dynamics of *Trichoderma* in soils, especially in sandy soils, to identify means of modifying the soil around the root zone to increase the levels of *Trichoderm*a colonisation and disease protection.

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