



Know-how for Horticulture™

Options for managing onion white rot

Gerry MacManus et al
Queensland Department of Primary
Industries

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Horticulture Australia

“Options for managing onion white rot.”

VG 98140

**Final Report
(31/01/03)**



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Gatton Research Station
Queensland Horticulture Institute
Agency for Food and Fibre Science
Queensland Department of Primary Industries**

VG 98140

“Options for managing onion white rot.”

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1. Media Summary

Onion white rot (OWR), a disease caused by the fungus *Sclerotium cepivorum* is a major constraint to onion production in SE Queensland. It has become so widespread that some producers have ceased growing onions or have had to relocate to find 'clean' land. The pathogen produces resting bodies (sclerotes) that can survive in the soil in the absence of a host plant for up to 20 years, making rotations an impractical control option. Fungicides have been the main control option used.

A multi-faceted approach was used in this project to develop practical applications to reduce soil pathogen populations and allow chemical, biological and agronomic strategies to be more effective.

- Diallyl disulfide (DADS) which stimulates sclerotia to grow in the absence of the host, dramatically reduced disease incidence; registration is pending. A metham sodium rig was modified to successfully apply this product and has subsequently been used in Victorian research trials.
- Procymidone and tebuconazole were the only effective fungicides. A minor use permit for tebuconazole treated lime super fertiliser, at planting, has been obtained. (Tebuconazole + limesuper is only registered for use in Tasmania).
- Composted worm castings (vermicomposts) and other biological amendments were ineffective as 'stand alone' treatments.
- Two commercial *Trichoderma* (antagonistic fungi) products showed promise.
- Six breeding lines are being further tested in the hope of developing a line with partial resistance.
- Solarisation using clear plastic mulch was more effective than black (plastic or biodegradable) mulches.
- Manipulation of sowing times can be used as a successful agronomic tool to avoid peak infection periods, which coincide with cool, moist soil conditions.
- Fungicides and *Trichoderma* applied through trickle irrigation were ineffective.
- Seed fungicide and biological treatments were ineffective.
- The use of transplants was considered to be commercially unviable.
- Farm hygiene is crucial to limiting the spread of the pathogen.

An integrated approach using a combination of successful treatments and good farm hygiene practices is recommended to obtain effective disease control.

2. Technical Summary

Onion white rot (OWR), a disease caused by the fungus *Sclerotium cepivorum* Berk., is a major constraint to onion production in SE Queensland. It has become so widespread that some producers have ceased growing or have had to relocate to find 'clean' land. The local industry is looking to develop and expand its overseas markets, particularly in Japan and Europe, and currently recognises OWR as a principal issue preventing a supply of quality product.

A multi-faceted approach, comprising extensive laboratory, replicated glasshouse and field trials, was used in this project to develop practical applications to reduce soil pathogen populations and allow chemical, biological and agronomic strategies to be more effective. Some of these strategies have been implemented in Tasmania but needed confirming/modifying for sub-tropical conditions.

Two sclerotial germination stimulants, diallyl disulphide (DADS) and dry garlic powder (DGP) were studied. DADS was highly effective in one trial, with 10-30 % disease incidence compared to 95 % for the untreated checks. Determination of the efficacy of DGP was inconclusive as there was low disease pressure evident (3 % incidence) in the untreated check. A metham sodium rig was successfully modified to inject the DADS into the soil profile to a depth of 30 cm. Effective application and timing (prior to planting and when soil temperatures fall below 15⁰ C) are critical for success. This equipment was also used successfully in subsequent research trials in Victoria and is likely to be the model to be adopted by industry. The Australian onion industry had been lobbied to support registration of DADS, which is pending.

Six fungicides including three belonging to the newer generation "soft" fungicide group (strobilurin), a phosphonate and an experimental fungicide were evaluated. None of the strobilurins were effective. Procymidone (industry standard) was found to be effective when applied as a soil drench or in-furrow. Tebuconazole (registered in Tasmania only) was found to be effective when applied to lime super fertiliser and drilled in under the seed at planting. It can now be used in Queensland under a minor use permit issued to QFVG, effective until 31 March 2005.

Seed treatments including a procymidone-impregnated seed coating and seed treated with a plant activator product or biological products were found to be ineffective on their own.

Root dip treatments of procymidone or tebuconazole fungicides, had a positive effect on disease suppression but under low disease pressure (11 % incidence in untreated control). Plants treated with tebuconazole produced a phytotoxic reaction resulting in stunted, poorly developed plants that did not produce bulbs of marketable size.

A fungigation field trial using multiple applications of either procymidone or a commercial *Trichoderma* product were ineffective in reducing disease and yielded poorly.

Biological products, which included vermicomposts (composted worm castings from sewerage effluent), various biological supplements and commercial *Trichoderma* products, were evaluated. None of these products worked on their own although two *Trichoderma* products did have a positive effect in one field trial.

Manipulation of sowing times can be used as a successful agronomic tool to avoid peak infection periods, which coincide with cool, moist soil conditions. May/June plantings tend to have a better survival rate than earlier plantings.

Although there are no known varieties with putative resistance, 39 commercial lines derived from USDA, NZ and local seed sources were screened in field trials over four

years. Six of the best lines will continue to be tested, with the hope of developing a commercial line(s) with partial resistance.

The use of transplants was considered to be commercially unviable because of the high input costs and resultant low yields in all four field trials.

Solarisation using either a clear-plastic mulch, a biodegradable black mulch or the standard black polyethylene plastic mulch gave positive disease reductions and yield increases. Low yields were recorded in all these trials and it is considered that the use of mulches would be commercially unviable.

An industry audit in which six growers and 100 pickers were interviewed, produced a very positive feedback and highlighted the need for strict farm hygiene practices to be implemented to ensure the spread of the pathogen was limited. Pocket-size, waterproof extension notes were produced and distributed to growers, pickers, agrochemical resellers and contract harvest companies. These were produced in the three main language groups of the pickers (English, Samoan and Turkish). Other extension activities included grower field days/shed meetings, seminars, articles in local/regional newspapers and in proceedings of national and international symposia and the onion industry journal (*Onions Australia*), a local ABC radio interview and networking with other national and international OWR researchers.

An integrated approach, using a combination of successful strategies outlined and good hygiene practices, is recommended to obtain effective disease control.

Future research could look at developing commercial strains of endemic *Trichoderma* and further field trials to determine the most effective rates of DADS (either as single or split applications) for use in the Lockyer Valley and other onion producing states of Australia.

3. Introduction

Onion white rot (OWR), caused by the fungus *Sclerotium cepivorum*, is a major constraint to the production of onions in SE Queensland. The local industry is looking to develop and expand its overseas markets, particularly in Japan and Europe, and currently recognises OWR as a principal issue preventing a quality supply of product. Some producers have been forced to relocate elsewhere in order to find pathogen-free soil.

This project was developed in response to a request from Queensland Fruit and Vegetable Growers (QFVG) Heavy Vegetable Committee chairman John Bishop and Kerry Qualischefski, Pack House Manager of Qualipac Produce (Growers, Packers and Exporters of Queensland onions), in 1998. Both were concerned about large losses to OWR during the 1996 and 1997 seasons.

Previous HRDC projects VG 209 (completed in 1995), and VG 423 (completed in 1998) addressed particular aspects of OWR management. The intention of this project was to build on these results to develop sustainable strategies for managing this disease in the sub-tropics. In a multi-faceted approach, the project pursued practical applications to reduce soil pathogen populations and allow chemical, biological and agronomic strategies to be more effective. Some of these strategies had previously been investigated in Tasmania but needed confirming/modifying for sub-tropical conditions. Others had not been assessed at all.

Components of the project included:

- a) Assessment of diallyl disulphide (DADS) in SE Queensland onion production areas for control of OWR. This work provided information that was submitted to the National Registration Authority (NRA) to assist with the application for a registration of this product in Australia. The rationale in using DADS was to drastically reduce soil pathogen populations so that follow-up treatments had a better opportunity to be successful. This section of the project aligned closely with complimentary work in Tasmania (VG 423) by Tasmanian Institute of Agricultural Research (TIAR) and Department of Primary Industry, Water and Environment (DPIWE) researchers.
- b) Development of fungicide treatments for practical disease management. These included the use of tebuconazole (Folicur[®]) with lime super (in use in Tasmania), screening new fungicides and investigating fungicide application techniques and timings. This approach is aligned with a project developing export onions to Japan and Europe, which is being conducted in Queensland (VG98005: Sweet onions to Japan and Europe, completed 2002).
- c) Investigating the use of various biological products in controlling OWR. These products included vermicomposts (composted worm castings), biological supplements and commercial *Trichoderma* (beneficial fungi) products.
- d) Screening plant genetic material in field trials for possible resistance to OWR.
- e) Assessing the potential of using onion transplants and associated adjuncts in managing OWR. The rationale included establishing onion seedlings in a pathogen-free mix for up to 9 weeks to enable a healthy rootball to develop, treating this root ball with a fungicide or biological product prior to transplanting, and using mulch to raise soil temperatures above the critical levels for OWR infection.

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- f) Developing awareness among producers and pickers of the importance of hygiene in restricting the movement of inoculum between farms and paddocks, especially where clean ground has been cultivated.

Field trials were conducted at Gatton Research Station (GRS) and five local commercial farms. Laboratory, glasshouse and growth cabinet experiments were conducted at GRS as well as at the plant pathology facilities at Indooroopilly Research Centre (IRC) in Brisbane.

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- VG209: “Interactions between time of planting, inoculum levels and fungicides on onion white rot” (research conducted in the Lockyer Valley, SE Queensland).
 - VG423: “Developing a management strategy for white rot and *Botrytis* in onions” (research conducted in Tasmania).
 - VG98005: “Sweet onions to Japan and Europe” (research conducted in the Lockyer Valley, SE Queensland).

4. Experimental Programme

4.1. Fungicide Efficacy Evaluations

4.1.1. Field screening of fungicides for efficacy against OWR

Introduction

During the 1997 season, OWR was a serious problem for the Lockyer Valley producers. Being a soil borne disease it can be difficult to control and seems to be more problematic in years with cold, wet winters. Concerns were raised by local industry that fungicide control programs were not effective in these conditions. Tasmanian research had shown that using tebuconazole (Folicur[®]) with the fertiliser lime super as an in-furrow treatment improved control in that state to the extent that OWR was no longer regarded as a limiting, seasonal problem. Local industry was keen to see that treatment evaluated under conditions in Queensland. A preliminary replicated field trial was conducted during the 1998 season at Gatton Research Station. The fungicides tebuconazole, procymidone (Sumisclex[®]; subsequently renamed Fortress[®]) and the strobilurin fungicide, azoxystrobin (Amistar[®]), provided a measure of control of the disease compared with the untreated plots.

Materials and Methods

The white rot disease experiment enclosure on Gatton Research Station was used for the experiment and the following treatments were investigated:

1. Folicur[®] with Lime Super (1.0 L/ha + 125 kg/ha) at sowing
2. Amistar[®] (250 g/ha) surface spray at sowing followed by 3 sprays 3 weeks apart
3. Amistar[®] (300 g/ha) surface spray at sowing followed by 3 sprays a month apart
4. Folicur[®] with Lime Super at sowing followed by Amistar[®] (250 g/ha) at 4 sprays 3 weeks apart
5. Folicur[®] with Lime Super at sowing followed by Sumisclex[®] (4 L/ha) at 4 sprays 3 weeks apart
6. Strob[®] (300 g/ha) surface spray at sowing followed by 3 sprays 3 weeks apart
7. Strob[®] (350 g/ha) surface spray at sowing followed by 3 sprays a month apart
8. Flint[®] (300 g/ha) surface spray at sowing followed by 3 sprays 3 weeks apart
9. Flint[®] (350 g/ha) surface spray at sowing followed by 3 sprays a month apart
10. Phospot[®] 400 (2.5 L/ha) basal spray at emergence followed by 3 sprays a month apart
11. Phospot[®] 400 (5 L/ha) basal spray at emergence followed by 3 sprays a month apart
12. Untreated check

The initial applications of surface sprays at sowing and the Phospot[®] 400 basal sprays were applied at 500 L/ha. The following sprays were applied in a volume of 1000 L/ha to allow the fungicides an opportunity to act in and around the root zones.

The sprays following the initial applications were commenced when the 10 cm soil temperatures dropped to 15° C for a minimum of 6 hours. The rationale was to

provide the fungicides an opportunity to be available at times of maximum *S. cepivorum*.

Plots consisted of four rows, 2 m long arranged in a randomised complete block design. The treatments were replicated 12 times in an area, which had a high inoculum (sclerotial) density. Onion seed cv. Wallon Brown was sown on May 17 1999. Disease assessments were carried out weekly from emergence.

Results and Discussion

The Folicur[®] + Lime Super treatments were applied with the seed in the drills at planting. The treatments requiring a surface spray over the seed were applied immediately following sowing onto the surface as a band directly over the drills after the seed was covered.

Soil temperature was recorded at the site. *S. cepivorum* activity is regarded as being temperature responsive. As an arbitrary guide it was decided to delay the follow up spray applications until the temperature at 10 cm reached and remained at 15° C for a minimum of 6 hours. These applications proceeded on 14 June (4 weeks after sowing). Sprays following this application proceeded at the designated times of either 3 weeks (Treatments 2, 4, 5, 6 & 8) or 4 weeks (Treatments 3, 7, 9, 10 & 11).

Cutworm damage became evident in the trial area after 6 weeks. Attempts to control these pests were unsuccessful for the next 3 weeks and the damage done was quite substantial in some plots. Unfortunately the damage was not sustained evenly across the block and there was no opportunity to account for the losses by way of replication. In some cases whole plots were irretrievably damaged. The experiment continued as an observation trial only and as such no attempt was made to apply statistics to the data.

White rot initially appeared during the 10th week from sowing (30 July). Table 1 indicates the total numbers of infected plants appearing each week from that assessment across the trial site. The cumulative total at the final assessment indicated that as a percentage of the total plants remaining across the trial block, 68% of the population became infected with white rot. This figure is substantially higher than the epidemic which was recorded in the same area for the 1998 screening trial, in which only 30 % of the untreated check plot plants became infected. In addition, the distribution of the epidemic was again uneven across the experiment site. There is speculation as to whether after 15 years of white rot experimentation on the site if some natural system may be beginning to exert some influence on white rot incidence and its distribution across the area. In particular the fungus *Trichoderma harzianum* seemed to have become quite prevalent on some infected bulbs indicating a possible build-up of a biological controlling system. More thought and research needs to be applied to this theory.

It seemed apparent again that with Folicur-treated Lime Super, a potentially useful management tool can now be applied with some confidence in Queensland. In spite of the lack of statistical data from this experiment, this treatment recorded the lowest incidence of the disease (Table 2), regardless of whether it was followed by either Amistar[®], or Sumisclex[®] foliar applications, or if applied alone. Unfortunately and coincidentally, these plots also suffered badly from cutworm damage, which may or may not have affected the total incidence of white rot.

The only other treatment which showed some potential was Stroby[®] applied at 3 weekly intervals, however most of these plots were also badly affected by cutworms. Stroby[®] applied at monthly intervals was much less effective. It is thought unlikely

that this product is potentially effective against white rot, although in other work this season, Stroby[®] gave adequate control of downy mildew in onions. Under these circumstances it was very difficult to determine the true influence of Folicur[®] with Lime Super, and Stroby[®]. It can be fairly safely assumed that in spite of the cutworm damage, the fungicides Amistar[®], Flint[®] and Phospot[®] 400 had little effect on white rot incidence compared with the untreated check levels. The dilemma is whether the better control indicated by the former treatments is a false or a true observation.

Table 1. Total number of diseased bulbs at each of 10 assessment dates.

Assessment Date (1999)	Number of bulbs with white rot
1. 30 July	121
2. 6 August	119
3. 12 August	208
4. 20 August	217
5. 27 August	266
6. 3 September	116
7. 9 September	228
8. 17 September	143
9. 23 September	82
10. 8 October*	326
Total	1826

* This assessment was carried out two weeks after the previous assessment.

Table 2. Cumulative incidence of diseased bulbs recorded over 10 assessment dates.

Treatments	Cumulative number of diseased bulbs
1. Folicur [®] with Lime Super	32
2. Amistar [®] (250 g/ha)	152
3. Amistar [®] (300 g/ha)	249
4. Folicur [®] with Lime Super + Amistar [®]	28
5. Folicur [®] with Lime Super + Sumisclex [®]	33
6. Stroby [®] (300 g/ha)	88
7. Stroby [®] (350 g/ha)	182
8. Flint [®] (300 g/ha)	221
9. Flint [®] (350 g/ha)	198
10. Phospot [®] 400 (2.5 L/ha)	218
11. Phospot [®] 400 (5 L/ha)	197
12. Untreated check	228

4.1.2. Field screening metham sodium, phosphonic acid and Geoflora™ products

Introduction

Metham sodium soil treatment has been used by some vegetable producers in the Lockyer Valley to combat soil pest problems. The practice has remained fairly limited and when used it only represents a feasible management tool when the benefits extend over several crops on the treated land. It has not become standard practice for the control of onion white rot, but some growers do use it for this purpose. No data are available on its efficacy in this regard locally, however overseas research indicates that it may be useful.

Phosphonic acid is used for the control of several Phycomycetous pathogens in several crops. It has been shown to be effective against some *Phytophthora* spp. when applied as a soil drench or surface and foliar spray. Although there is no evidence of its activity against the white rot pathogen, it is claimed to have activity against the foliar onion disease, downy mildew. Since phosphonic acid is capable of movement within plants, presumably in onions it may be translocated into roots to potential white rot infection sites, provided it remains active in the system. Laboratory tests have indicated some fungicidal activity against *S. cepivorum* *in vitro*. A range of products has recently become available for testing in Australia. These products are largely organic based soil additives and Geoflora Life Science P/L claim some success in the USA in controlling some soil pathogens including the onion white rot fungus. Several Geoflora™ products were examined in this experiment alone and in combination with phosphonic acid and metham sodium. Apart from any possible direct effect from these organic products on pathogen control, it was hoped that the biological activity in the treated onion beds may benefit from the application of one or more of these products following metham sodium treatment. It was proposed by the manufacturers that the Geoflora™ products may have some positive effects on onion plant health generally.

Materials and Methods

A field trial site was established within a paddock on a commercial farm with a previous history of onion white rot. Plots were 10 m long single beds containing four rows. There were four replications of the following treatments in a randomised complete block design:

1. Metham sodium applied at 500 L/ha
2. Metham sodium plus all Geoflora™ products applied at 6 weekly intervals for 3 applications
3. Metham sodium plus all Geoflora™ products applied at 6 weekly intervals for 3 applications plus Phospot® 400 applied at 5 L/ha at 3 weekly intervals for 5 applications
4. All Geoflora™ products applied at 6 weekly intervals for 3 applications
5. All Geoflora™ products applied at 6 weekly applications for 3 weeks plus Phospot® 400 applied at 3 weekly applications for 5 weeks
6. Untreated Check

The Geoflora™ products consisted of the following:

1. Geohumus™ (20 L/ha)
2. Geofert™ (9:7:2) (20 L/ha)
3. Geocal™ (20 L/ha)*
4. Fulvic Acid (10 L/ha)

5. Biomix™ (20 L/ha)**.

* These fertilisers were applied at the first, third and fifth applications only.

** The Biomix product was not supplied by the company until after the second application. It was then included in the protocol for the third, fourth and fifth applications.

Part of the theory behind applying the Geoflora™ products was their potential to input a rapid increase in biological activity following the broad spectrum activity of metham sodium in the soil. In addition to this the Fulvic acid and Geohumus™ products showed efficacy against germinating *Sclerotium cepivorum* in previous laboratory testing. The other two products (organic based fertilisers) were included at the request of Geoflora. Phospot® 400 contains phosphonic acid at 400 mL/L. Metham sodium was applied by injecting to 20 cm after bed-forming. The surface was rolled after injection and the soil was left undisturbed for 14 days before sowing. All following treatments were applied commencing three weeks after germination at the hook leaf stage of growth. The Phospot® and the Geoflora™ products were applied with a watering can at the equivalent rate of 6 mL of irrigation (15 L/plot). This simulated application through the irrigation system. Weekly assessments were commenced to determine the activity of the white rot pathogen. All diseased plants were pulled but left at the growth site. The numbers were recorded. Hail damage later in the season resulted in premature termination of the trial.

Results

Table 3 indicates the incidence of white rot throughout the six weeks of assessments before the hail damage forced the abandonment of the trial. It appears that metham sodium had the strongest influence on disease incidence and that neither the Geoflora™ products, nor the Phospot® 400 was having an appreciable effect. Immediately prior to the hail damage the grower indicated that some treatments appeared to be superior to the Untreated check plots.

Table 3. White rot disease incidence recorded over six, weekly assessments

Treatments	Number of infected bulbs at each of the six assessment dates						Total
	1	2	3	4	5	6	
1. Metham sodium (500 L/ha)	0	2	1	6	16	22	47
2. Metham sodium + Geoflora™	6	8	29	28	37	143	251
3. Metham sodium + Geoflora™ + Phospot® 400 (5 L/ha)	0	3	11	18	6	25	63
4. Geoflora™ only	1	2	4	25	27	66	125
5. Geoflora™ + Phospot® 400	8	11	52	79	39	195	384
6. Untreated Check	15	23	60	138	127	228	591
Total	30	49	157	294	252	679	1461

Discussion

The disease distribution was still uneven at the time of the final assessment, however it is reasonable to propose that the spread throughout the trial site would inevitably have been fairly even. However, this can only be regarded as speculation. The Geoflora™ products were not applied according to a protocol since technical backup was not available from the company during the time of trial preparation. The protocol

was devised without any knowledge of the products' potential usefulness. Future work with this company and their products will only be made with technical input from the company's agronomists. Despite this, all treatments appeared to be superior to the Untreated check treatment indicating there may be some usefulness in pursuing this line of attack for another season.

4.1.3. Field screening of a plant defence activator, biological products and fungicides to reduce OWR

Introduction

In this field trial there were a number of biological products and fungicides tested for their efficacy in reducing OWR infection. Bion[®], a product that induces host plant defence mechanisms, has previously been found to reduce various root and foliar diseases in horticultural crops and cotton and consequently it was evaluated here.

Materials and Methods

A randomised complete block design of nine treatments with 10 replicates was used. Each replicate was a bed comprised of four equidistant rows, 5.5 m in length with a 0.5 m guard at each end. Lorsban was applied at planting to ensure that the cutworm problem in previous years did not eventuate. Local onion seed cv. Neuendorf Golden Brown was planted on 30 March 2000. The treatments applied were as follows:

1. Geoflora[™] seed dressing (10 g/kg).
2. Residue[™] + Geoflora[™] seed dressing.
3. Lime super (125 kg/ha) + Folicur[®] (1 L/ha) as an in-furrow application at planting
4. Fortress[®] (2 L/ha) as a drench at planting and 6 & 12 weeks post-planting
5. Geoflora seedress[™] (10 g/kg) + Aminogro[®] (10 mL/L) at 3-week intervals (winter) and 2-week intervals (spring/summer)
6. Stroby[®] (1 g/L) applied at 1000 L/ha
7. Bion[®] (0.06 g/L) applied at 1000 L/ha
8. Stroby[®] + Bion[®] (at above rates)
9. Untreated Control.

Disease assessments were on a weekly basis subsequent to the disease being noticed on 16 June. Plants that were infected were removed and numbers recorded at each sampling date. The trial was harvested on 4 September, 157 days after planting.

Results

The first plants showing white rot symptoms were detected on 16 June. There was high disease pressure (32 to 57 %) and correspondingly poor yields, ranging from 13.5 to 23.8 t/ha (Table 4). These results show that there were no differences between treatments for yield and disease incidence, although there were some treatment differences in the mean bulb weight. The large variability within and between treatments was obvious, hence the lack of statistical significance.

Discussion

None of the fungicide or biological treatments was effective in suppressing OWR under the high disease pressure conditions that were prevalent.

Table 4. Treatment effects of a plant defence activator, biological products and fungicides on yield, mean bulb weight and OWR disease incidence.

Treatment	Yield (t/ha)	Mean Bulb Weight (g)	% Disease Incidence
1. Geoflora™ seed dressing	15.5	128 ab	57
2. Residue™ + Geoflora™	16.3	124 ab	56
3. Lime super + Folicur®	23.8	107 a	32
4. Fortress®	15.4	122 ab	52
5. Geoflora™ seed dress + Aminogro®	19.4	123 ab	35
6. Stroby®	13.6	167 c	60
7. Bion®	13.5	137 abc	52
8. Stroby® + Bion®	13.6	138 bc	54
9. Untreated Control	14.0	131 ab	55
LSD (P<0.05)	NSD*(P=0.171)	31	NSD (P=0.329)

NSD* = Not significantly different (P<0.05) using Fisher's protected LSD test.

4.1.4. Evaluation of a plant defence activator as a seed treatment, alone or in combination with procymidone for OWR suppression

Introduction

Bion[®], a plant defence activator composed of salicylic acid when used as a foliar treatment was ineffective in reducing the incidence of OWR in a previous field trial at GRS in 2000. Bion[®] seed treatments produced positive results in cotton, delaying the onset and severity of various root diseases and resulted in significant seedling survival (Nehl *et al.*, 2001). This trial evaluated Bion[®] as a seed treatment, alone or in combination with Fortress[®] as a drench treatment.

Materials and Methods

A randomised complete block design of four treatments and five replicates was established at GRS. Wallon Brown seed was planted on 23 May 2001 and the trial was harvested on 10 October (140 DAP). The Bion[®]-treated seed was soaked in a 0.05 g/L solution for one hour and air-dried. Fortress[®] was applied with a watering can on 24 May, a day after planting, at the rate of 2 L/ha in 10 L of water per plot. Treatments were as follows:

1. Untreated Control
2. Fortress[®] (2 L/ha) applied as a soil drench
3. Bion[®] (0.05 g/L) seed dip
4. Bion[®] (0.05 g/L) seed dip + Fortress[®] (2 L/ha).

Yield and disease assessments were made at harvest from the inner 8 m of the two centre rows of plots 10 m long on 1.5 m centres with 4 single rows/bed.

Results

High disease incidence (44 to 58 %) and low to moderate yields, ranging from 21.3 to 31.8 t/ha was observed in this trial (Table 5). There were no treatment differences recorded for both parameters measured.

Table 5. Bion[®] seed treatments, alone or in combination with Fortress[®] are ineffective against OWR in 2001 field trial.

Treatment	Marketable Yield (t/ha)	% Disease Incidence
1. Untreated Control	29.3	50
2. Fortress [®] (2 L/ha)	28.8	47
3. Bion [®] (0.05 g/L) seed dip	21.3	58
4. Bion [®] + Fortress [®]	31.8	44
LSD (P>0.05)	NSD* (P=0.093)	NSD (P=0.102)

NSD* = Not significantly different (P<0.05) using Fisher's protected LSD test.

Discussion

None of the treatments were effective in reducing OWR under moderately high disease pressure. A single application of Fortress is obviously insufficient under high disease pressure. A follow-up spray 4-6 weeks after planting is recommended.

4.1.5. Putative phytotoxicity in onion seedlings treated with tebuconazole and lime super for suppression of OWR

Introduction

After several years field research in Tasmania and Queensland, a treatment combining the fungicide tebuconazole (Folicur[®]) and lime super fertiliser became available in the 2000 season for growers to apply at sowing to reduce OWR infections. In Queensland the recommendation was: 125 kg/ha of lime super treated with 1 L/ha of Folicur[®] (430 g/L tebuconazole) applied in-furrow at sowing.

Symptoms of severe phytotoxicity, putatively related to the use of Folicur[®] and lime super were observed on four farms in the Lockyer Valley in March 2000. Emergence was erratic along rows treated in the recommended manner and affected seedlings failed to develop normally. Leaf bases appeared flattened and in some cases the tips yellowed and died. The roots failed to develop and in some cases it was noted that affected plants were adjacent to treated lime super particles. Most indications were that the Folicur[®]-treated lime super was responsible for symptoms observed in the field particularly since on one farm, onions planted the same day without the treatment appeared normal. In addition to these four farms, other growers in the Lockyer Valley used the treatment without apparent problems. Observations on these farms showed normal onion emergence and development.

Experimental work conducted in Queensland during 1997-2000 indicated white rot control was possible using lime super fertiliser treated with Folicur[®]. Rates of up to 2 L/ha of Folicur[®] were used in these experiments without affecting onion emergence or establishment. However, when Folicur was applied directly over the exposed seed before furrow closure, seedling emergence rates were slower, plant establishment was reduced and poor growth, indicating phytotoxicity, was apparent for up to a month after sowing.

During extensive discussions with the interested parties several possible explanations were canvassed as to why this problem had appeared on only four farms. Discussions considered the possible implications of water quality, herbicides, fertiliser brands, planting equipment, temperature, soil types and the ability to misinterpret the recommendations resulting in differences in quantities of treated fertiliser applied per unit length of row depending on the number of rows/bed. It was decided to try to recreate the symptoms in observational trials the following season in an attempt to identify the cause of the symptoms on the four affected farms.

Materials and Methods

Planters

Two planters were sourced for the work, one of which (planter A) was associated with a problematic crop in 2000 and the other from a grower who did not experience problems (planter B). Planter A was configured to plant 6 single rows across a 1.5 m bed. The seed was sown marginally above the band of treated fertiliser. This planter drilled 40 000 m of row/ha. Planter B planted 4 double rows/1.6 m wide bed. The seed was sown at the same depth as the treated fertiliser. This planter drilled 50 000 m of row/ha. The main operational difference between these planters was in the number of rows/bed sown/ha. Planter A from the problematic farm planted 10 000 m less row/ha than planter B. As a result, 20% more treated lime super is applied per length of row with planter A than with planter B. It is assumed that planter B

delivered a non-phytotoxic dose of treated lime super at 125 kg/ha (1 L of Folicur[®]), but planter A delivered 150 kg/ha (1.2 L of Folicur[®]).

Observational Trials

Two, unreplicated field trials were designed in 2001 to reproduce the putative phytotoxic effects observed on the four affected farms in 2000.

Trial 1

This trial observed the effects of different rates of lime super applied with a standard rate of 1 L of Folicur[®]/planted ha dependant on the number of rows/ha.

Treatments 1-5 were applied with planter A

1. Control (no lime super; no Folicur[®])
2. 175 kg/ha treated lime super (43.8 g treated fertiliser + 0.25 mL Folicur[®]/100 m of row)
3. 125 kg/ha treated lime super (31.3 g fertiliser + 0.25 mL Folicur[®]/100 m of row)
4. 75 kg/ha treated lime super (18.8 g fertiliser + 0.25 mL Folicur[®]/100 m of row)
5. 125 kg/ha untreated lime super (31.3 g fertiliser only/100 m of row)

Treatments 6-10 were applied with planter B

6. Control (no lime super; no Folicur[®])
7. 175 kg/ha treated lime super (35 g fertiliser + 0.2 mL Folicur[®]/100 m of row)
8. 125 kg/ha treated lime super (25 g fertiliser + 0.2 mL Folicur[®]/100 m of row)
9. 75 kg/ha treated lime super (15 g fertiliser + 0.2 mL Folicur[®]/100 m of row)
10. 125 kg/ha of untreated lime super (25 g fertiliser only/100 m of row)

Trial 2

This trial observed the effects of different rates of Folicur[®] applied with a standard rate of 125 kg/ha of lime super.

Treatments 1-4 were applied with planter A.

1. Control (no Folicur[®]; no lime super)
2. 0.5 L Folicur[®]/ha (0.13 mL/100 m of row)
3. 1.0 L Folicur[®]/ha (0.25 mL/100 m of row)
4. 1.5 L Folicur[®]/ha (0.38 mL/100 m of row)

Treatments 5-8 were applied with planter B.

5. Control (no Folicur[®]; no lime super)
6. 0.5 L Folicur[®]/ha (0.1 mL/100 m row)
7. 1.0 L Folicur[®]/ha (0.2 mL/100 m of row)
8. 1.5 L Folicur[®]/ha (0.3 mL/100 m of row).

Both trials were sown in February 2001 using local seed cv. Neuendorf Golden Brown. Treatments were applied to unreplicated plots 50 m long. Plant emergence was recorded on two occasions after sowing (3 and 4.5 weeks after sowing). All emerged plants in five random 1 m sections of bed were counted at both assessments. Close observations of all plots were conducted throughout the trials to record any growth abnormalities.

Results and Discussion

During season 2000, putative phytotoxicity symptoms as shown in Figure 1 were observed in onion crops growing on four properties in the Tenthill and Carpendale areas of the Lockyer Valley in SE Queensland. Top growth was affected following

apparent root damage. Some plants failed to emerge. No such symptoms were observed in the two observation trials carried out in the 2001 season.

Trial 1

No statistics have been applied to the data since the trials were unreplicated observations only. Table 6 indicates the plant populations recorded at 20 and 32 days after planting (DAP). Although planter B sowed eight rows across each bed, the plant population was lower than for planter A which sowed two less rows/bed (38.4 plants/m of bed established at 32 DAP for Planter B compared to 42.4 plants/m for planter A). It should be noted that limited comparisons can be made between the data from each planter and interpretations should only be drawn from data within the same planter treatments.

Emergence and establishment observations for planter A indicated there may have been a treatment effect of lime super (Table 6). All treatments which received Folicur[®]-treated lime super established fewer plants than treatments receiving either no lime super or lime super without Folicur[®]. The difference in plant populations at 32 DAP was greatest in the strip receiving 175 kg/ha of treated lime super (13.2 % compared with the untreated control), while the strips treated with 125 kg/ha and 75 kg/ha had 6.1 % and 1.0 % fewer plants respectively. These data indicate there may have been a lime super-related effect since all plots received a standard rate of 1 L/ha of Folicur[®] regardless of the rate of lime super used. While caution is recommended with any interpretation of these data, there may be a trend evident indicating a detrimental effect of increasing rates of lime super using planter A. There may be an advantage to be gained by altering the drill placement of the treated lime super in relation to where the seed is delivered in the drill with this planter.

Emergence and establishment results for planter B are variable but the variations do not appear to be related to the rate of lime super used in the treatments. The greatest effect occurred in the treatment receiving 125 kg/ha of untreated lime super in which there were 15.6 % fewer plants/m of bed at 32 DAP than were recorded in the untreated control. The standard recommendation of 125 kg/ha of treated lime super had 10.9 % more plants than the untreated control.

Considering the high soil temperatures during and after planting, these plant populations were considered to be acceptable by the growers who owned the planters.

Trial 2

Table 7 indicates the plant populations recorded in the plots 20 and 32 DAP. There appears to be a small effect associated with increasing the rate of Folicur[®] applied/ha using planter A. When a rate of 1.5 L/ha was applied with planter A, there was a plant population reduction of between 6.5 % and 8.0 % evident when plant counts were done at 32 DAP compared with the populations in the strip which remained untreated. Since the configuration of this planter ensured that more Folicur[®] was delivered per unit length of row at the recommended rate/ha than planter B (0.25 mL/100 m compared to 0.2 mL/100 m respectively), it was surprising to find that establishment numbers were less affected compared with the populations in the planter B-sown plots. At the recommended rate of 1.0 L/ha of Folicur[®] there were 8 % fewer plants than were counted in the untreated control strip.

Surprisingly large numbers of plants either did not emerge or had failed to establish at the 32 DAP assessment in the plot receiving Folicur[®] and sown using planter B. There had been no apparent problems using this machine in the 2000 season. There were up to 27 % fewer plants present in the plot treated with Folicur[®] at 1.5 L/ha than

were recorded in the untreated plot (Table 7). At the recommended rate of 1.0 L/ha, there were 16 % fewer plants at 32 DAP than in the untreated control strip.

Conclusions

In spite of higher temperatures coincident with the trial plantings compared with the problematic period in 2000, no evidence of the 2000 season symptoms was reproduced. All plants emerged and continued to develop normally regardless of the rates of fertiliser or fungicide applied at sowing. Based on this lack of evidence it cannot be concluded that the symptoms observed on the four farms in 2000 was only related to the rates of either Folicur[®] or lime super the growers applied.

Although no conclusions can be reached regarding a possible combination of other factors, it seems apparent that either, or both, lime super and Folicur[®] contributed to the symptoms observed. This conclusion seems true based on an extensive assessment of the facts associated with four affected farms. It should therefore be concluded that whatever the other contributing factor(s) may have been, they were absent or not produced in the trial area in 2001.

Table 6. Onion plant emergence at 20 days after planting (DAP) and plant establishment at 32 DAP in Trial 1. Note that 1 L/ha of Folicur[®] was applied to all treatments and only the rate of lime super varies between plots

Treatment	Planter	Emergence (20 DAP in 1 m of sown bed)	Establishment (32 DAP in 1 m of sown bed)
1. Control (no Folicur [®] ; no lime super)	A ^a	44.8	42.4
	B ^b	39.6	38.4
2. 175 kg/ha of treated lime super	A	37.0 (-17.4 %) ^c	36.8 (-13.2 %)
	B	41.8 (+5.6 %) ^d	43.4 (+13.0 %)
3. 125 kg/ha of treated lime super	A	43.0 (-4.0 %)	39.8 (-6.1 %)
	B	37.2 (-6.1 %)	42.6 (+10.9 %)
4. 75 kg/ha of treated lime super	A	43.4 (-3.1 %)	42.0 (-1.0 %)
	B	36.0 (-9.1 %)	36.6 (-4.7 %)
5. 125 kg/ha of untreated lime super	A	44.4 (-1.0 %)	43.0 (+1.4 %)
	B	38.2 (-3.5 %)	32.4 (-15.6 %)

^a Planter A sowed 6 rows/1.5 m bed.

^b Planter B sowed 8 rows/1.6 m bed.

^c The figure in parenthesis indicates variance from the population recorded in the untreated Control using planter A.

^d The figure in parenthesis indicates variance from the population recorded in the untreated Control using planter B.

Table 7. Onion plant emergence at 20 days after planting (DAP) and plant establishment at 32 DAP in Trial 2. Note that lime super was applied at 125 kg/ha to all treatments and only the rate of Folicur® varies between plots.

Treatment	Planter	Emergence (20 DAP in 1 m of sown bed)	Establishment (32 DAP in 1 m of sown bed)
1. Untreated Control (no Folicur®; no lime super)	A ^a	38.2	40.0
	B ^b	48.4	40.6
2. 0.5 L/ha of Folicur®	A	39.4 (+3.1 %) ^c	40.0 (same)
	B	39.2 (-19.0 %) ^d	31.6 (-22.2 %)
3. 1.0 L/ha of Folicur®	A	35.6 (-6.8 %)	36.8 (-8.0 %)
	B	35.6 (-26.5 %)	34.0 (-16.3 %)
4. 1.5 L/ha of Folicur®	A	32.8 (-14.1 %)	37.4 (-6.5 %)
	B	27.4 (-43.3 %)	29.6 (-27.1 %)

^a Planter A sowed 6 rows/1.5 m bed.

^b Planter B sowed 8 rows/1.6 m bed.

^c The figure in parenthesis indicates variance from the population recorded in the Untreated Control using planter A.

^d The figure in parenthesis indicates variance from the population recorded in the untreated Control using planter B.



(a)

(b)

Figure 1 (a): Healthy seedling compared to stunted seedling apparently affected by lime super + Folicur® treatment (note proximity of treated lime super granules to seedling roots).

Figure 1 (b): Uneven emergence in row treated with lime super + Folicur®.

4.1.6. Field trial evaluation of seed treatments to reduce OWR

Introduction

Lefroy Valley, a local seed company, had recently been promoting the benefits of treating seed with a polymer compound to enhance vegetable seedling establishment and uniformity, and disease suppression when impregnated with a fungicide. It was decided to seedcoat the onion seed, with or without procymidone (Fortress[®]) fungicide and compared these treatments with normal, untreated seed. The current standard practice in the Lockyer Valley is that seed is not fungicide-treated.

Materials and Methods

Local seed cv. Neuendorf Golden Brown was treated by Lefroy Valley as follows:

1. Untreated seed
2. Fungicide-treated granulated seed (100 % ONX seed-coating impregnated with Fortress (2 mL/kg seed)
3. Granulated seed (coated with 100 % ONX)
4. Untreated seed + single soil spray of Fortress (2 L/ha), watered in with a watering can (10 L per 10 m bed) in mid June.

Seed was planted on 27 March 2002 using a randomised complete block design with 12 reps. Samples for disease and yield assessment were taken on 6 September (163 DAP), from the inner 8 m of the two centre rows; beds were on 1.5 m centres with 4 single rows/bed.

Results

There was a lot of variability between and within treatments which resulted in there being no treatment differences for disease incidence and yield. There was moderate to high disease pressure, ranging from 30 to 48 % incidence with low yields of 8.8 to 12.5 t/ha being produced (Table 8).

Table 8. Seed treatments fail to reduce OWR in 2002 field trial.

Treatment	Marketable Yield (t/ha)	% Disease Incidence
1. Untreated seed	9.9	48
2. Granulated seed impregnated with Fortress [®]	12.5	35
3. Granulated seed	8.8	30
4. Untreated seed + Fortress [®] soil spray	10.5	42
LSD (P>0.05)	NSD* (P=0.109)	NSD (P=0.067)

NSD* = Not significantly different (P<0.05) using Fisher's protected LSD test.

Discussion

There is a possibility that there may have been a positive response for disease incidence, had an additional Fortress[®] spray been applied say eight weeks after planting in early June, based on the closeness of the P value of 0.067 to 0.05. Nevertheless, the yield values were very low and would not have represented a commercially viable crop. Average yields below 40 t/ha are considered to be low in the Lockyer Valley.

4.2. Evaluation of Biological Products in Field and Glasshouse Trials.

4.2.1. Glasshouse evaluation of vermicomposts for OWR control

Introduction

Previous small observation experiments in the glasshouse and laboratory have indicated the potential of vermicompost and *Trichoderma* for the control of *Sclerotium cepivorum*. These products have also shown some potential against other soilborne pathogens under controlled conditions. Some of the disease organisms that have been reported to be suppressed by the use of composts include: *Phytophthora* spp., *Fusarium* spp., *Pythium* spp. and *Rhizoctonia solani* (Hoitink, Stone and Haw (1997).

Vermicompost used in these trials is based on castings from worms which have been fed a diet of either sewerage from municipal treatment works, or piggery waste. The material is provided in dry form that can be applied to the surface or incorporated into the profile as an organic amendment.

Materials and Methods

Polystyrene broccoli boxes were filled with field soil which contained sclerotia of *S. cepivorum*, collected within the isolation area at GRS. The 20 boxes were divided randomly into five treatments consisting of four replicates/treatment in a randomized complete block design. The following treatments were applied:

1. Parkville piggery vermicompost (10 % vol:vol)
2. Parkville piggery vermicompost (25 % vol:vol)
3. Redlands sewerage vermicompost (10 % vol:vol)
4. Redlands sewerage vermicompost (25 % vol:vol)
5. Untreated check.

The vermicompost treatments were incorporated evenly within the total soil profile by hand mixing. Two rows of Henderson's Straight Leaf onions (6 plants/row) were transplanted into each box. Normal glasshouse procedures (watering/nutrition etc.) were followed to encourage growth. Disease assessments (presence/absence) were carried out weekly and the soil temperature was monitored daily.

Results

At 12 weeks after transplanting there was control in most boxes compared with the untreated check treatment. However, these differences were no longer apparent at the final assessment, 20 weeks after transplanting (Table 9).

Table 9. The onset of OWR was slowed by the addition of vermicomposts with good control achieved 12 weeks after planting but by 20 weeks there was no control, with no significant treatment differences.

Vermicompost Treatment	% Disease Incidence (12 weeks)	% Disease Incidence (20 weeks)
1. Parkville piggery (10 %)	7	42
2. Parkville piggery (25 %)	0	67
3. Redlands sewerage (10 %)	0	60
4. Redlands sewerage (25 %)	0	29
5. Untreated Check	48	69
LSD (P>0.05)		NSD*

NSD* = Not statistically different (P<0.05) using Fisher's protected LSD test.

Discussion

It was assumed that in this type of confined experiment, which was taken over a long period of time (in this case 20 weeks), there was ample opportunity for infection to move between plants after initial infections took place. On its own vermicompost does not appear to have the ability to control OWR for the life of the crop. It may be that the controlling mechanism(s) that was evident early in the experiment might only be active in the short-term. In addition we did not establish the mechanism(s) of this control, consequently, whether the effect was biological and whether the products affected the host or the pathogen, remains unknown. In preliminary laboratory tests, *S. cepivorum* growth was inhibited by the vermicompost but its effect on onion growth in regard to stimulatory or induced resistance effects was not determined.

4.2.2. Field screening vermicomposts and fungicides (procymidone and azoxystrobin) for OWR control

Introduction

Earthworms reportedly have a positive influence on disease reduction and plant yield through increased biological activity in the soil. It is thought likely this influence is exerted via the castings rather than the worms themselves although the mode of action has not been shown. Commercial quantities of castings are now available in Australia and experimental work has commenced to examine their effects in several crops.

A glasshouse experiment (section 4.2.1) was run in conjunction with this field trial and there were indications that at least early in the experiment, vermicompost reduced white rot incidence. However, the effect diminished with time.

In this experiment, vermicompost derived from piggery waste were evaluated as treatments, alone and in combination with either the strobilurin fungicide Amistar[®] (azoxystrobin) and Sumisclex[®] (procymidone) for efficacy against white rot of onions. The strobilurin fungicide, Amistar[®], provided encouraging control of white rot in a preliminary experiment during 1998. (Sumisclex[®] is registered for use against onion white rot in Queensland and is effective as an in-furrow spray at sowing (2 L/ha) and as a soil surface spray at sowing with a follow-up application 10 weeks later). The experiment was conducted at a commercial field site with a history of severe white rot incidence.

Materials and Methods

The experiment was a split plot, randomised block design with seven main treatments replicated five times across a site which had a history of severe OWR infection resulting in major plant loss to crops in the recent past. Seed was sown on 22 May 1999. The following vermicompost treatments were applied to the soil surface and later incorporated just prior to planting:

1. BiovermTM (1 m³/ha) applied in a 10 cm band along the rows after plant emergence
2. BiovermTM (1 m³/ha) broadcast across the beds before sowing
3. BiovermTM (2 m³/ha) applied in a 10 cm band along the rows after plant emergence
4. BiovermTM (2 m³/ha) broadcast across the beds before sowing
5. BiovermTM (4 m³/ha) applied in a 10 cm band along the rows after emergence
6. BiovermTM (4 m³/ha) broadcast across the beds before sowing
7. Untreated Check

Amistar[®] was applied at 250 g/ha in two applications 3 weeks apart, followed 3 and 6 weeks later by another two applications at a rate of 500 g/ha. Amistar[®] was sprayed over the onions at 1000 L/ha so that there was runoff to the plant bases. In this experiment, Sumisclex[®] was applied according to the same schedule as Amistar[®] at 2 L/ha for all four applications, alone and in combination with the listed BiovermTM treatments. The Sumisclex[®] spray was directed at the base of the onion plants at 1000 L/ha. The first sprays were applied 4 weeks after sowing and coincided with a drop in soil temperatures to around 15°C at 10 cm for more than 6 hours continuously. The experimental site was inspected weekly and assessed for disease incidence. All infected onion plants were removed from the site at each assessment. Applications of the fungicides were as follows: 1) 18 June, 2) 8 July, 3) 30 July and 4) 20 August.

Results and Discussion

The experiment was sown on 22 May and white rot appeared in the plots on 8 July, 7 weeks later (3 weeks after the first fungicide applications were made). The mean cumulative disease incidence over 14 assessment dates is given in Table 10. A total of 28 400 plants with white rot symptoms were removed from the experimental site during the course of the trial (Figure 2), which constituted 59 % of the total population. The figure shows a gradual increase in weekly incidence during the July-August period when soil temperature conditions were favourable for disease development (still under 20^o C for much of the time) rising rapidly during early-mid September.

Sumisclex[®] provided the main fungicidal activity in this trial and significantly fewer diseased plants were harvested from the plots where the fungicide was applied, regardless of whether it was applied in combination with the Bioverm[™] treatments. This chemical was not applied according to the label standard in this trial but very good control was achieved in spite of the extremely high level of disease in surrounding plots. It may reasonably be expected that control may have been improved had Sumisclex[®] been applied as an in-furrow spray at sowing according to its registration. There was no evidence here that Sumisclex[®] was ineffective against white rot as district anecdotes sometimes implied.

Amistar[®] did not give the same level of control of white rot as it had in a previous experiment in 1998. In the earlier trial, the fungicide had provided good control of the disease in circumstances which were probably not as conducive to disease development as the 1999 seasonal conditions, and at a trial site which did not have high disease pressure. On the basis of these results, Amistar[®] is not worth pursuing as a white rot control fungicide.

The Bioverm[™] vermicompost did not control the disease in this trial. There was no apparent indication of any growth effects in plots which received this product. The failure of this product may indicate that the expected increase in biological activity following its application did not eventuate. Low levels of soil organic matter may have partly accounted for this. Organic matter is critical for biological activity to be maintained. In this system it may be necessary to increase organic matter levels so that biological activity can be sustained following application of this product.

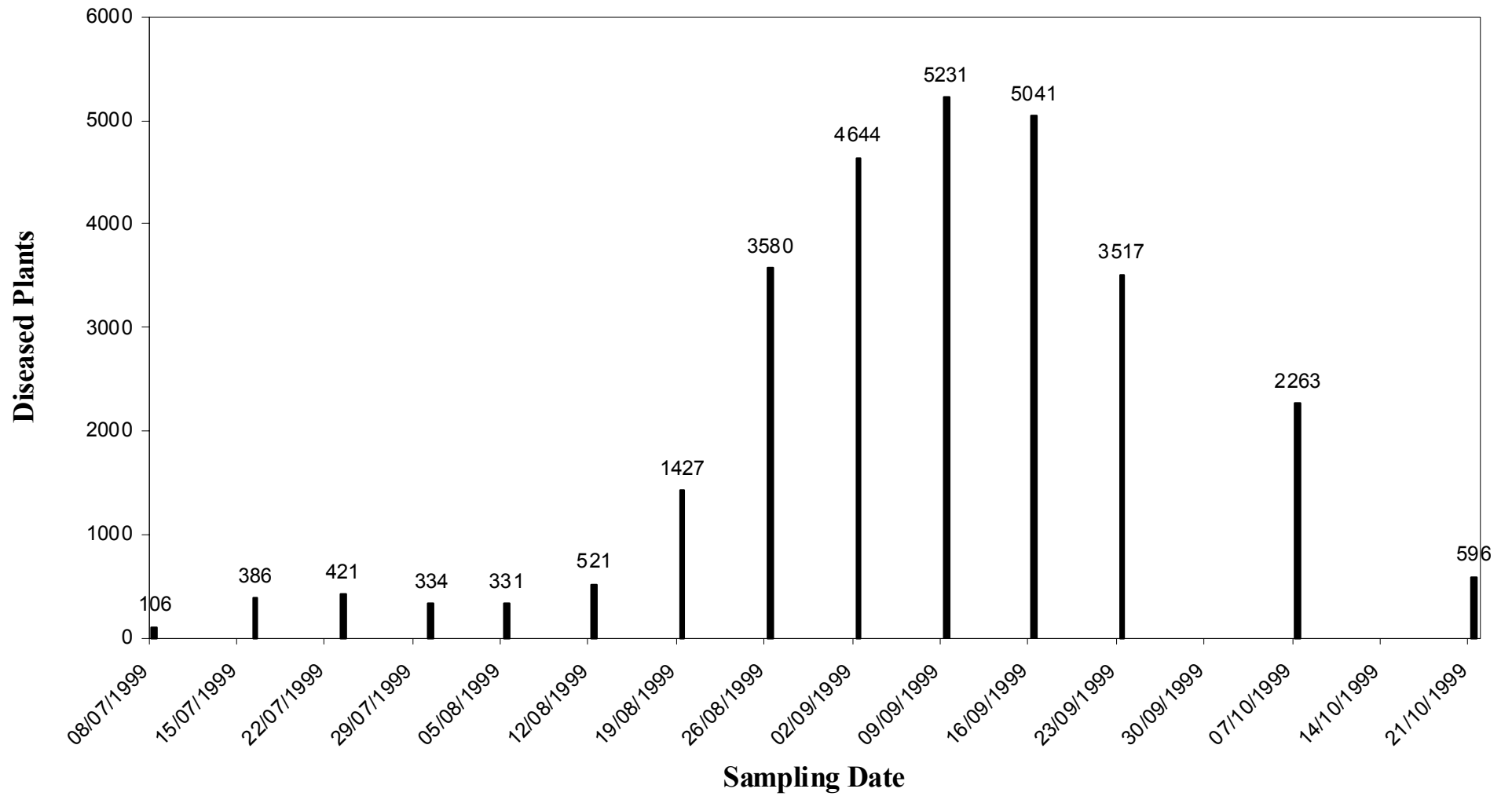
Table 10. White rot incidence recorded as a cumulative total of infected plants in BiovermTM treated field products.

Bioverm TM Treatment	Mean number of onions with white rot*		
	No Fungicide	Amistar	Sumislex
1. 1 m ³ /ha banded	378 bcdef*	378 bcdef*	75 a*
2. 1 m ³ /ha broadcast	440 f	399 ef	67 a
3. 2 m ³ /ha banded	386 cdef	304 b	62 a
4. 2 m ³ /ha broadcast	311 bc	339 bcd	82 a
5. 4 m ³ /ha banded	417 ef	422 ef	76 a
6. 4 m ³ /ha broadcast	433 f	330 bcd	75 a
7. No Bioverm TM	385 cdef	357 bcde	78 a

* Means are cumulative totals from 14 assessments and 5 replications.

**Means followed by the same letter are not significantly different (P< 0.05) using Fisher's protected LSD test.

Figure 2. Total number of plants with white rot at each assessment date



4.2.3. Field screening of endemic isolates of Trichoderma harzianum for control of OWR

Introduction

The use of *Trichoderma* spp. to provide biological control of some soilborne pathogens has received considerable attention in recent years. *Trichoderma* spp. exist naturally in many soil ecosystems and the strain variation may presumably be very wide in response to their adaptation to the food sources available in each system. It is believed the genus has a strong ability to exist as a saprophyte on a variety of substrates in the soil. Some strains form affinities with plant roots while others presumably forage within the soil environment without becoming associated closely with plants. *Trichoderma harzianum* (Rifai) was found associated with *S. cepivorum* sclerotia obtained from infected onions growing in the white rot quarantine enclosure at Gatton Research Station during the 1998 season. It was also observed that the onions growing in these trials did not sustain a high incidence of the disease considering the relatively high population of sclerotial inoculum present. The likelihood of a 'natural control' system developing around the endemic *Trichoderma* spp. population was considered possible.

In this field trial three isolates of the soil fungus *Trichoderma harzianum* were examined for their potential to colonise organic matter and provide control of *S. cepivorum* in onions.

Materials and Methods

Three *T. harzianum* isolates were obtained from sclerotia collected from the white rot quarantine enclosure at GRS in 1998. An area was divided into 5 m x 10 m plots and half the area was sown to barley in late winter, 1998. The barley was allowed to mature and hay-off before being treated with the following:

1. *Trichoderma harzianum* (Isolate T1)
2. *Trichoderma harzianum* (Isolate T2)
3. *Trichoderma harzianum* (Isolate T3)
4. No treatment.

Bare plots with no barley or plant material were also treated with the above isolates which had been grown on inoculated sorghum seed in 4 L flasks in the laboratory. Spore suspensions were made from this material and adjusted to 3×10^6 spores/mL and sprayed over the plots (containing either no plant material or hayed-off barley) during a period of showery weather in November 1998. One month after spraying the plots were rotary-hoed and the area was prepared for sowing to onions cv Wallon Brown in 1999. Weekly assessments were made to record the incidence of white rot in the plots which consisted of seven beds comprising 4 x 9 m rows/bed. The plots were not replicated and disease assessments were made from the centre 3 beds/plot.

Results and Discussion

There was a distinct trend indicating control of white rot in plots which received the barley x *T. harzianum* inoculation. In contrast, bare fallow plots treated with *Trichoderma* appeared to have a greater disease incidence (Table 11). It is possible that the fungus was able to use the barley as a substrate while existing both above and below the soil surface, whereas in the absence of a nutrient source (bare fallow), the soil population of all strains may have declined before onions were sown. In terms of their potential efficacy as biological control agents for OWR, the three *T. harzianum* isolates utilised in this study could not be differentiated with most parameters. There

was sufficient evidence from this trial that more work with these and perhaps other endemic isolates of *T harzianum* may reveal a potential biological control system may be already established in the white rot quarantine enclosure on GRS. During harvest of these plots, it was apparent that *Trichoderma* spp. had colonised both healthy and diseased onion roots and base plates. We speculate that the fungus may be capable of preventing severe infections on the trial site, but the mechanism by which it would achieve this is less clear.

Further work is required in laboratory, glasshouse and field to understand the relationship between onions, *Trichoderma* spp. and *S. cepivorum* in the Lockyer Valley. There may be scope to encourage natural control systems to play a major role in containing white rot should these strains be widespread in the area.

Table 11. Plant population, incidence of white rot and yield from an observational experiment to examine the efficacy of three isolates of *Trichoderma harzianum* (T1, T2 & T3) against *Sclerotium cepivorum*.

Treatment	Total plant population	Diseased onions (%)	Yield of healthy bulbs (kg/plot)	Average bulb wt (g)
1. Check (no <i>Trichoderma</i> ; no barley)	457	45	36.9	146
2. <i>Trichoderma</i> T1 on bare soil	370	30	34.7	133
3. <i>Trichoderma</i> T2 on bare soil	558	53	30.2	116
4. <i>Trichoderma</i> T3 on bare soil	246	11	34.8	159
5. Barley only	469	37	44.8	151
6. <i>Trichoderma</i> T1 with barley	389	16	56.8	173
7. <i>Trichoderma</i> T2 with barley	290	19	44.0	187
8. <i>Trichoderma</i> T3 with barley	337	13	56.6	193

Note: These data are from an unreplicated, observational experiment, hence no statistical evaluation has been attempted.

4.2.4. Field screening efficacy of *Trichoderma harzianum*, vermicompost and wheat mulch as biological control measures to reduce OWR

Introduction

Previous trials conducted at GRS in 1998 using *Trichoderma* spp.-based products Tri-D25[®] and Trichoflow[®] did not control onion white rot. However, in 1999 there was a promising indication that local strains of *T. harzianum* that were inoculated onto mulched barley straw that was used as a green manure crop, were providing some level of control. There was also some indication from previous glasshouse and field trials that there was some measure of control using vermicompost, hence its inclusion in this trial.

Materials and Methods

The best-performing isolate (T3) from the field trial in 1999 at GRS was cultured on sterilised millet seed for three weeks, mixed with damp wheat straw or with vermicompost and incubated for a week. It was bulk multiplied and spread on the soil surface and immediately incorporated into the soil using a rotary hoe. In the 1999 trial there was evidence that *Trichoderma* in combination with the barley substrate was better than *Trichoderma* alone, hence the wheat treatment which was available at the time (there was no barley straw available). A randomised complete block design of eight treatments with 10 replicates was used. Each replicate was a bed comprised of four equidistant rows 4.0 m in length with a 0.5 m guard on each end. This relatively large number of replicates was used to ensure that variability across the trial area would be accounted for, which compared with only three replicates in the 1999 trial. Lorsban[®] was applied at planting to ensure that the cutworm problem in previous years did not eventuate. Local seed, Neuendorf Golden Brown was planted on 30 March. The treatments applied were as follows:

1. Control.
2. *Trichoderma* (T3).
3. Wheat (W) applied at equivalent of 120 bales/ha.
4. Vermicompost (V) applied at equivalent of 10 t/ha.
5. Wheat inoculated with *Trichoderma* (W+T3).
6. Vermicompost inoculated with *Trichoderma* (V+T3).
7. WT3 (5 t/ha) + VT3 (60 bales/ha).
8. V (5 t/ha) + W (60 bales/ha).

The soil amendment treatments were spread over the surface of the beds by hand and incorporated using a manual cultivator and irrigated immediately thereafter. Disease assessments were done on a weekly basis subsequent to the disease being noticed on 16 June 2000. Plants that were infected were removed and numbers recorded at each sampling date. The trial was harvested on 6 September, 159 days after planting.

Results and Discussion

Disease was first noticed on 16 June 2000. There were no treatment differences with all the treatments showing high infection levels (64 to 78 %) and consequently, low yields, ranging from 14 to 26 t/ha (Table 12). Large variations between and within treatments occurred. As for the other trials conducted at GRS, there was concern about the inconsistencies from year to year and it has been resolved that the bulk of research needs to be done off the station.

Table 12. Biological amendments were ineffective in reducing OWR incidence in 2000 field trial.

Treatment	Yield (t/ha)	% Diseased	Mean bulb weight (g)
1. Control	16.1	77	175
2. <i>Trichoderma</i> (T3)	20.1	74	203
3. Wheat (W)	14.2	76	206
4. Vermicompost (V)	26.1	65	255
5. (W) + (T3)	16.7	78	174
6. (V) + (T3)	24.5	64	182
7. (W +T3) + (V + T3)	19.1	75	185
8. (V) + (W)	23.1	66	220
LSD (P>0.05)	NSD*	NSD	NSD

Treatment means followed by the same letter are not significantly different ($P < 0.05$) using Fisher's protected LSD test. NSD* = Not statistically different.

There were high levels of infection in the Control treatment and all the other treatments, either singly, or in combination. This has been a major concern of field trials conducted in the isolation area at GRS. This was highlighted at the recent mid-term review in August 2000. For this reason there is the need to find suitable sites off the station where there is a history of severe infection, such as at Shane Osborne's, Reg Kluck's and Russell Qualischefski's farms. Every attempt has been made to ensure a uniform distribution of infected bulbs across the paddock by cross-cultivating a number of times in the land preparation operations prior to planting at GRS. A detailed disease map of the area at just prior to harvest in 1999 has identified that there is a general trend of increasing level of infection in the low-lying areas.

An article by Adams (1987) emphasised that in order to compare treatments adequately, at least 50 % of the plants in the control plots should become infected with the pathogen. If such a site cannot be found then the plot could be infested with the pathogen prior to establishing the trial. This method was also suggested by Fred Crowe (2000, pers. comm.). We may need to introduce the pathogen that has been artificially cultured on sterilised grain seed, such as millet, prior to planting to combat this inherent problem.

4.2.5. Field screening biological treatments as potential control agents of OWR

Introduction

Anecdotal reports from some local growers indicate that the bio-compost, vermicompost, had produced promising results against OWR. In this trial vermicompost was used at relatively high rates (up to 8 t/ha, as single or split applications) and compared to procymidone fungicide (Fortress[®]), a commercial *Trichoderma* formulation (Trich-A-Soil[®]) and a biological fumigant (FumaFert[®]) which contains mustard seed and neem and is reported to aid in the control of soil borne insects, diseases and nematodes.

Materials and Methods

A field trial was established at Gatton Research Station as a randomised complete block design of eight treatments with six replicates. Onion seed cv. Wallon Brown was planted on 9 May 2001 and harvested on 3 October (157 DAP). Each plot comprised two beds, 10 m long with a 1 m buffer on each end. Assessments for disease incidence and marketable yield were made from the centre two rows at harvest. Treatments were as follows:

1. Untreated Control
2. Fortress[®] (2 L/ha at planting and 6 weeks later)
3. FumaFert[®] (1 t/ha at planting)
4. Trich-A-Soil[®] (at planting)
5. Vermicompost (2 t/ha at planting)
6. Vermicompost (4 t/ha at planting)
7. Vermicompost (8 t/ha at planting)
8. Vermicompost (4 t/ha at planting and 4 t/ha 6 weeks later).

Fortress[®] and Trich-A-Soil[®] were applied in 10 L water/bed using a watering can; vermicompost and FumaFert[®] were broadcast by hand and incorporated just prior to planting.

Results and Discussion

There were no significant treatment differences reported (Table 13), with all treatments being ineffective. Disease expression was low for all treatments (17 to 27 %) with low yields also being recorded (24 to 28 t/ha).

Table 13. Biological amendments were ineffective in reducing OWR incidence in 2001 field trial.

Treatment	% Disease Incidence	Marketable Yield (t/ha)
1. Untreated Control	25	27
2. Fortress [®] (2 L/ha x 2)	17	28
3. FumaFert [®]	27	24
4. Trich-A-Soil [®]	28	24
5. Vermicompost (2 t/ha)	21	27
6. Vermicompost (4 t/ha)	23	28
7. Vermicompost (8 t/ha)	26	28
8. Vermicompost (4 + 4 t/ha)	27	25
LSD (P>0.05)	NSD* (P=0.633)	NSD (P=0.874)

NSD* = Not statistically different using Fisher's (P<0.05) protected LSD test.

4.2.6. Glasshouse evaluation of commercial *Trichoderma* products for OWR control

Introduction

The purpose of this glasshouse experiment was to determine how effective three commercial *Trichoderma* products were compared to the industry standard procymidone fungicide (Fortress[®]) treatment in controlling OWR. A field trial using two of these biological treatments was also conducted concurrently.

Materials and Methods

This experiment was conducted in a glasshouse at Indooroopilly Research Centre, Brisbane. Soil taken from a commercial onion farm with a history of severe OWR was transferred into polystyrene broccoli boxes (0.25 m x 0.54 m) to a depth of 0.2 m. Nine-week-old seedlings of cv. Neuendorf Golden Brown (planted on 30 April 2002), were removed from OWR infested soil at GRS, thoroughly washed to remove any dirt, then transplanted (20 per box) into the boxes on 9 July. The following treatments were applied in a completely randomised design with four replicates:

1. Untreated Control
2. TrichopelTM-ALI 52 (50 kg/ha, 2.7 g/4 boxes)
3. Promot[®] (1 kg/ha, 0.054 g/4 boxes)
4. Trich-A-Soil[®] (soluble) (1.25 kg/ha, 0.0675 g/4 boxes)
5. Fortress[®] (2 L/ha).

Each of the treatments was applied in 1 L of water using a domestic atomiser spray bottle. The plants were then watered in. Regular assessments for plants showing symptoms of infection were made up until 24 October when the experiment was concluded.

Results

Disease incidence data are recorded (Table 14). Disease incidence was quite variable between and within treatments, which nullified what appeared to be significant treatment differences. Values ranged from 25 % in the Fortress[®] treatment to 60 % for the Control treatment, without there being any statistically significant differences.

Table 14. *Trichoderma* products and procymidone fungicide were ineffective against OWR in 2002 glasshouse trial.

Treatment	% Disease Incidence
1. Untreated Control	60
2. Trichopel TM -ALI 52	35
3. Promot [®]	36
4. Trich-A-Soil [®]	41
5. Fortress [®]	25
LSD (P> 0.05)	NSD* (P= 0.076)

NSD* = Not statistically different (P<0.05) using Fisher's protected LSD test.

Discussion

The high degree of variability recorded in this trial is similar to that observed in similar experiments in the field. 'Clean' soil with a pre-determined number of sclerotia, which typified a sclerotial density similar to an infested field site, could have been used to better determine treatment differences. However, the rationale has always been to try and closely reproduce field conditions, hence infested field soil was used. As was highlighted in the mid-term review (August 2000), glasshouse trials are perhaps of limited value, depending what one is trying to achieve, hence later in the project more focus was devoted to field trials on commercial sites.

4.2.7. Field screening commercial *Trichoderma* products as biological control agents of OWR

Introduction

Trichoderma harzianum was identified as being the endemic species of *Trichoderma* in earlier trials conducted at GRS. This beneficial fungal antagonist of the OWR pathogen is commonly observed towards the end of the onion season from September onwards when soil temperatures are increasing. Successful colonisation of the fungus had resulted in halting white rot infection and produced marketable bulbs that would otherwise not have been harvested. Other Australian and overseas researchers found that *Trichoderma* could afford acceptable levels of control under low to moderate infection levels, but were ineffective under high disease pressure.

In this experiment three different commercial products were evaluated for their effectiveness in reducing OWR.

Materials and Methods

A cover crop of forage sorghum was grown over the summer and as a green manure crop and mulched in on 15 February 2002. This crop was also grown to provide a substrate for the *Trichoderma* to grow on. A randomised complete block design of four treatments and 20 replicates was used. Each plot was 10 m long with samples being taken from the inner 8 m of the two centre rows; beds comprised four single rows on 1.5 m centres. The trial was planted on 30 April with cv, Neuendorf Golden Brown seed and harvested on 27 September 2002 (150 DAP). Treatments were as follows:

1. Untreated Control
2. Trichopel[®]-ALI 52 (50 kg/ha) drilled in with seed at planting
3. Trich-A-Soil[®] (Granular, 2.5 kg/ha) drilled in with seed at planting
4. Trich-A-Soil[®] (soluble, 1.25 kg/ha) watered in at planting.

As there was poor weed control on the western section of the trial the number of replicates for final yield and disease assessments was reduced from 20 to 12.

Results and Discussion

Moderate to high disease pressure was recorded with incidence ranging from 35 to 49 %, which resulted in low yields ranging from 10.8 to 13.3 t/ha (Table 15). There were no significant treatment differences thus all the *Trichoderma* products proved to be ineffective in controlling OWR. As with previous trials there was significant variability between and within plots.

Table 15. Commercial *Trichoderma* products were ineffective against OWR in 2002 field trial.

Treatment	% Disease Incidence	Marketable Yield (t/ha)
1. Untreated Control	49	10.8
2. Trichopel [®] -ALI 52	35	13.3
3. Trich-A-Soil [®] Granular	37	12.9
4. Trich-A-Soil [®] Soluble	39	12.3
LSD (P> 0.05)	NSD* (P=0.132)	NSD (P=0.368)

NSD* = Not statistically different (P<0.05) using Fisher's protected LSD test.

4.3. *Field evaluation of sclerotial germination stimulants*

Introduction

Sclerotial germination stimulants, sometimes referred to as artificial garlic oil or artificial onion oil have been used with varying success to obtain mass germination of soilborne sclerotia of *Sclerotium cepivorum* in *Allium* crops. Diallyl disulphide (DADS) is a petroleum derivative, which mimics some volatile sulphur compounds exuded by onion roots. DADS is applied in water and injected into the soil before planting, inducing sclerotia to germinate in the absence of the host onion roots. Germinating sclerotia exhaust their food reserves and die. Positive results have also been obtained in the USA using commercial, food-grade dry garlic powder (DGP). If these experiments show that these treatments can perform as indicated, it is expected there would be sufficient reduction of the sclerotial population to enable onion sowings to follow without a major threat of OWR. This would then be expected to enable supplementary treatments including fungicides, *Trichoderma* formulations and certain cultural methods to be more effective and integrated into a complete management package.

The purpose of these field trials is to evaluate the efficacy of DADS and dry garlic powder in reducing onion white rot incidence. It was anticipated that if successful, data from these trials would expedite the registration process for DADS in Australia.

Materials and Methods

Two experimental sites were established in 1999/2000 and three sites in 2001/2002 to examine the potential of DADS and DGP in Queensland.

1999/2000 Trials

In 1999 different application rigs, which were modified versions of existing equipment, were used at the two sites. A brief description of the machinery follows. Site A was established on Gatton Research Station (GRS). An Agrow plow was set up with 7 tynes at 225mm spacings (3 tynes on the front bar and 4 on the back bar). A tank was mounted across the bars and a volume pump delivered 8 L/min to 4 outlets on each tyne. The outlets consisted of small orifice solid-set irrigation nozzles placed at 75 mm spacings into 25 mm galvanised water pipe attached to the back of each tyne to a depth of 300 mm (see Figure 3). Immediately after application the treated area was given 20 mm irrigation.

Site B was established on a commercial farm at Mulgowie, belonging to Mr Shane Osborne. A standard, locally manufactured metham sodium fumigation rig ("Starkbuilt") was modified with the addition of 2 nozzles/tyne on 9 tynes set at 300 mm spacings on two toolbars. One nozzle, a 110° fan was set vertically 100 mm above the tyne foot. Under the foot, a 180° fan nozzle was set horizontally. The pump delivered DADS at a pressure of 200 kPa (see Figure 4).

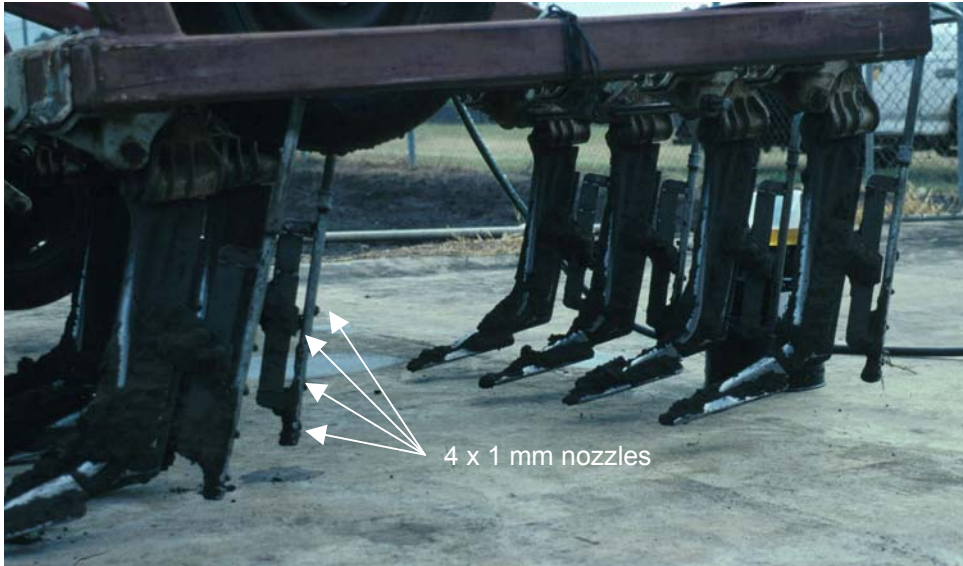
Treatments at the two sites were as follows:

Site A.

1. DADS applied (14 L/ha in a single dose May)
2. DADS applied (14 L/ha in May followed by 7/ha in July)
3. DADS applied (14 L/ha in May followed by 9.5 L/ha in July)
4. DADS applied (14 L/ha in May followed by 14 L/ha in July)
5. Untreated check.

Figure 3

Site A: Agrow Plow used at Gatton Research Station (GRS).



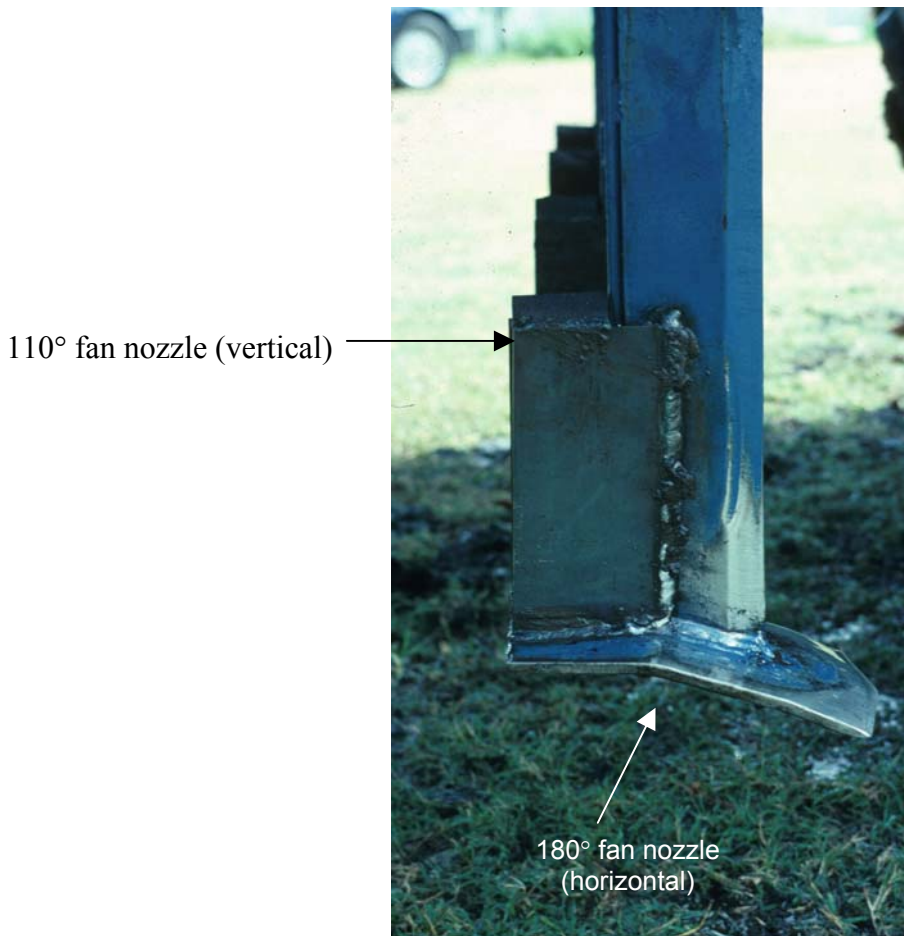
Nozzles spaced 75 mm.
Foot depth 300 mm.
Tyne centres 225 mm.



Plot size: 5 m x 3 m.

Figure 4

Site B: Modified metham sodium rig used at Shane Osborne's, Mulgowie.



Nozzles spaced 100 mm.
Foot depth 300 mm.
Tyne centres 300 mm.



Plot size: 5.2 m x 10 m

Site B.

1. DADS applied (9.5 L/ha in May followed by 14 L/ha in July)
2. DADS applied (9.5 L/ha in May followed by 9.5 L/ha in July)
3. DADS applied (14 L/ha in May followed by 9.5 L/ha in July)
4. DADS applied (9.5 L/ha in a single dose in May)
5. DADS applied (14 L/ha in a single dose in May)
6. Untreated check.

Plot size at site A was 15 m² (5 m x 3 m); while at site B, the plot size was 52 m² (5.2 m x 10 m). At both sites the plots were rolled following application and watered immediately to seal the surface in an attempt to retain the DADS for as long as possible. DADS was applied in water at 750-850 L/ha. The initial applications were made in 1999 on May 6 (site A) and May 8 (site B). Follow-up applications were made 10 weeks later on July 15 (site A) and July 16 (site B). The follow-up applications were therefore made 10 weeks after the initial applications at both sites. Summer cover crops of forage sorghum and millet were planted at sites A and B respectively.

Local onion seed cv. Neuendorf Golden Brown was sown on 31 May 2000 and 28 March 2000 for sites A and B respectively. A randomised complete block design with three replicates was used for both trials. At site A each plot comprised two beds 5 m long with 4 rows/bed on 1.5 m centres. At site B each plot comprised two beds, 10 m long with 4 double rows/bed on 1.6 m centres. At site A disease incidence data was only collected at harvest while at site B weekly disease assessments commenced from 14 July to 18 August with infected bulbs being removed at each sampling time. Soil temperatures at 15 cm depth were recorded. The trials were harvested on 12 October and 23 August 2000, 134 and 148 days after planting (148 DAP) at sites A and B respectively, with the number of marketable bulbs and yield being recorded. Bulbs were removed for the inner two rows for site A and the inner four rows for site B. Statistical analysis (ANOVA) was performed using GENSTAT5 (Genstat5 Committee, 1998).

Results**Site A**

There were no treatment differences for both disease incidence and marketable yield (Table 16).

Table 16. DADS treatments were ineffective in reducing OWR and increasing marketable yield of bulb onions at site A in 2000 field trial.

Treatment Rate (L/ha) & timing of DADS applications	% Disease Incidence	Marketable Yield (t/ha)
1. 14 L (May)	7.2	27.0
2. 14 L (May) + 9.5 L (July)	12.6	31.8
3. 14 L (May) + 9.5 L (July)	13.2	32.8
4. 14 L (May) + 14 L (July)	19.2	35.7
5. Untreated Control	24.6	37.7
LSD (P>0.05)	NSD* (P=0.731)	NSD (P=0.766)

NSD* = Not statistically different (P<0.05) using Fisher's protected LSD test.

There was large variability in results from within the respective treatments, which explains the lack of significance between the treatments.

Site B

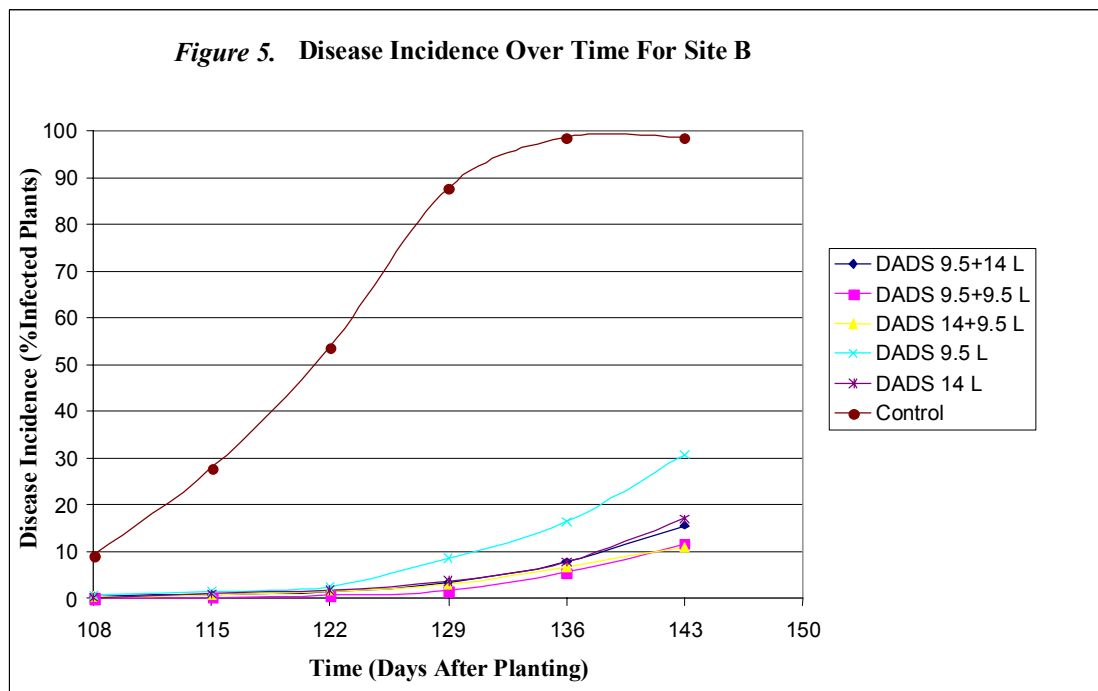
First infection was noticed in the Untreated Control plots on 31 May when the soil temperature ranged from 13.4 to 16°C. Levels of disease incidence and marketable yield are presented in Table 17.

Table 17. DADS treatments reduce disease incidence and increase marketable yield of bulb onions at site B in 2000 field trial.

Treatment Rate (L/ha) & timing of DADS applications	% Disease Incidence	Marketable Yield (t/ha)
1. 9.5 L (May) + 14 L (July)	15.4 a*	37.5 ab*
2. 9.5 L (May) + 9.5 L (July)	12.2 a	37.7 ab
3. 14 L (May) + 9.5 L (July)	10.6 a	41.1 a
4. 9.5 L (May)	30.7 b	29.7 bc
5. 14 L (May)	21.2 ab	25.2 c
6. Untreated Control	95.1 c	0
LSD (P<0.05)	14.2	10.9

*Treatment means followed by the same letter are not significantly different (P<0.05) using Fisher’s protected LSD test.

The Control treatment showed very high levels of disease (95.1 % plants infected) and no marketable yield. In contrast, the DADS treatments showed significantly lower infection levels, varying from 10.6 % to 30.7 %, with marketable yield ranging from 25.2 to 41.1 t/ha. Within the split application treatments and within the single application treatments, there was no benefit derived from using the higher rate of DADS for disease incidence or marketable yield. The single 9.5 L/ha DADS treatment applied in May was worse than all of the split application treatments for disease incidence, while for marketable yield, the single application of 14 L/ha DADS was worse than all the split application treatments. The Control treatment was omitted from the analyses since its variability differed to the DADS treatments and to include it would have violated the assumptions of ANOVA. The disease progress curve Figure 5 shows clearly that 4 weeks prior to harvest (122 DAP, on 28 July) there was very little infection in the DADS treatments (0.6 % to 2.6 %) compared to 53.8 % for the Control. One week later (129 DAP) the level of disease in the DADS treatments was still very low, ranging from 1.7 % to 8.7 %, while 87.8 % of the plants in the Control plots were infected.



Discussion

These results clearly show that DADS has a significant impact on reducing disease incidence at site B. White rot infection was first noticed in response to decreasing soil temperatures. This in agreement with findings by Riley (1995) that soil temperatures at 10 cm of less than 14⁰ C for at least 2 weeks are necessary for symptom development in the Lockyer Valley. At site A the low level of disease in the Control treatment was unexpected considering that this part of the trial had been inoculated with thousands of diseased bulbs that had been removed from another field trial in 1999. The relatively high level of disease incidence for Treatment 4, with the highest DADS application rates as a split application, was also unexpected. However, it is quite likely that there is effective suppression of the OWR pathogen from other microbial activity in the soil, especially with local strains of *Trichoderma harzianum* being observed on many of the bulbs at harvest time. The proliferation of *T. harzianum* was not surprising in this crop, being a later planting, with the bulbs being exposed for a longer period to higher soil temperatures (include soil temperature range data) towards the end of the onion lifecycle. The higher soil temperatures are more favourable to *Trichoderma* than they are to the OWR pathogen. Domsch *et al.*, (1980) reported that for *T. harzianum* the optimum temperature for growth is in the wide range of 15-35⁰C, with 30⁰ C representing a good average for most isolates. While the application equipment for DADS differed for these two trials there was no indication to suggest that the one used on the GRS was ineffective, but it is speculated that the application equipment on the trial site at Shane Osborne's may in fact have been superior.

In NZ Alli-Up[®], a commercial formulation of DADS (900 g/L a.i.) is recommended for use at 5-10 L/ha as split applications (spring and autumn) when soil temperatures are in the 12⁰ C-20⁰ C range.

It is proposed that the subsequent late infection in the DADS treatments was most likely due to sclerotia germinating from below the 30 cm treated zone of the soil profile which concurs with other research findings (Crowe, 1995).

Conclusions

These results clearly show that DADS has a significant impact on reducing disease incidence at site B. In future trials we plan on using lower rates of DADS (ranging from 5 to 9.5 L/ha, as single or split applications) and integrating other fungicide and biological (*Trichoderma* and vermicomposts) treatments to curtail late infection.

Materials and Methods

2001/2002 Field Trials

The same application rig that was used at site B was used to inject DADS at three field sites (commercial farms) during 2001. The only modification was that the vertically oriented fan nozzles were changed from 110° to 80° fan nozzles. This was found to eliminate loss of DADS. Site C was the same block used for site B in 2000, except that the rows were oriented perpendicular to those previously. Site D was about 500 m from site C but had not experienced losses due to OWR as severe as those on site B. Site E was located at a farm approximately 10 km away where there was 100% crop loss from OWR in 1999. This site had not been sown to onions since this time. Randomised complete block designs were used for all trials. Disease incidence assessments were made at harvest and marketable yield data were obtained as previously mentioned. Treatments and specific site details were as follows:

Site C

1. Untreated Control
2. DADS*
3. DADS + Trichoshield^{®1} (1 kg/400 L/ha)
4. DADS + Trich-A-Soil^{®2} (10 g/m of bed)
5. DADS + Trichopel[®]-ALI52³ (50 kg/ha incorporated between each double row)
6. DADS + Fortress[®] (2 L/ha).

A randomised complete block design of six treatments and 4 replicates was used. Each plot comprised two beds 20 m long with four double rows. Sampling was from within a 10 m strip of the inner four rows of one of the beds.

*DADS was applied as a single application at 9.5 L/ha on 30 May 2001.

^{1, 2, 3} are commercial formulations of *Trichoderma* and Fortress (procymidone) is the industry standard fungicide used. The trial was planted with local Early Lockyer Brown seed on 20 March 2002 and harvested on 29 August 2002 (162 DAP). A single application of each of the supplementary products, at recommended label rates, was made on 13 May 2002 and irrigated immediately thereafter.

Site D

1. Untreated Control
2. DADS (5 L/ha)
3. DADS (7 L/ha)
4. DADS (9.5 L/ha)
5. DADS (5 + 7 L/ha)
6. DADS (7 + 7 L/ha)
7. DADS (9.5 + 9.5 L/ha)
8. DGP (100 g/m³ broadcast, incorporated to a depth of 15 cm on 29 May 2001).

A randomised complete block design of six treatments and four replicates was used. Each plot comprised 2 beds of 45 m with four double rows. Sampling was from within the inner four rows (4 double rows/bed on 1.6 m centres) of one of the beds, at three sites, each of 1-2 m.

The single DADS treatments were applied on 30 May with a follow-up application on 25 July 2001 for the split application treatments. The trial was planted with Early

Lockyer Brown seed on 19 March 2002 and harvested on 29-30 August 2002 (164DAP).

Site E

1. Control
2. DADS (5 L/ha)
3. DADS (7 L/ha)
4. DADS (9.5 L/ha)

A randomised complete block design of six treatments and five replicates was used. Each plot comprised two beds 90 m long with four single rows. Sampling was from within the two inner rows of one of the beds (4 rows/bed on 1.5 m centres) at five sites, each of 1 m. DADS was applied on 30 May 2001. The trial was planted with local Golden Brown seed on 29 March and harvested on 30 August 2002 (154 DAP).

Results

Site C

There was very high disease incidence recorded for all treatments, with levels ranging from 61-95 %. Low marketable yields were recorded, ranging from 2-28 t/ha (Table 18). The only treatment that showed any reduction in disease, and increase in yield was the combination treatment of DADS + Fortress[®]. DADS on its own and DADS + Trichopel[®]-ALI 52 were ineffective in controlling OWR. There were no significant differences between any of the combination treatments of DADS and *Trichoderma* for disease or yield.

Table 18. Disease incidence and marketable yield data for DADS treatments, alone or in combination with *Trichoderma* products or procymidone fungicide at site C in 2002.

Treatments	% Disease Incidence	Marketable Yield (t/ha)
1. Untreated Control	95 c*	2.2 a*
2. DADS (9.5 L/ha)	83 bc	12.1 ab
3. DADS + Trichoshield [®]	79 b	15.3 b
4. DADS + Trich-A-Soil [®]	79 b	14.8 b
5. DADS + Trichopel [®] -ALI 52	86 bc	9.2 ab
6. DADS + Fortress [®]	61 a	27.7 c
LSD (P<0.05)	14	11.8

*Treatment means followed by the same letter are not significantly different (P<0.05) using Fisher's protected LSD test.

Site D

There were no significant differences between treatments for disease incidence and marketable yield (Table 19). Very low infection was observed (0-3 %) and all treatments resulted in high yields (79-94 t/ha).

Site E

There was moderate disease incidence (26-32 %) with low marketable yields (13-24 t/ha). There was quite a lot of variability within and between treatment plots which resulted in there being no significant differences between the DADS treatments and the Untreated Control (Table 20).

Table 19. Germination stimulants (DADS and DGP) were ineffective in reducing OWR at site D in 2002 field trial. Low infection was recorded in all treatments.

Treatment	% Disease Incidence	Marketable Yield (t/ha)
1. Untreated Control	3.4	86
2. DADS (5 L/ha)	0.9	82
3. DADS (7 L/ha)	1.1	83
4. DADS (9.5 L/ha)	0	89
5. DADS (5 + 7 L/ha)	0.5	86
6. DADS (7 + 7 L/ha)	0.2	88
7. DADS (9.5 + 9.5 L/ha)	1.0	94
8. DGP (100 g/m ³)	2.0	79
LSD (P>0.05)	NSD* (P=0.507)	NSD (P=0.565)

NSD*= Not significantly different (P<0.05) using Fisher's protected LSD test.

Table 20. DADS was ineffective in reducing OWR at site E in 2002 field trial. Moderate levels of infection were recorded in all treatments.

Treatment	% Disease Incidence	Marketable Yield (t/ha)
1. Untreated Control	3.4	86
2. DADS (5 L/ha)	0.9	82
3. DADS (7 L/ha)	1.1	83
4. DADS (9.5 L/ha)	0	89
LSD (P>0.05)	NSD* (P=0.824)	NSD (P=0.603)

NSD*= Not significantly different (P<0.05) using Fisher's protected LSD test.

Discussion

The failure of any of the DADS treatments in the 2002 trials, singly or as split applications, was quite unexpected considering the highly effective results achieved with DADS during the 2000 season. Similar levels of infection were recorded at sites B and C (95 % disease incidence). It is speculated that the DADS may have lost some of its efficacy as it had been stored for some time prior to use. Unfortunately we were unable to source 'fresh' product from the producers in the USA despite us requesting it months in advance of undertaking these series of trials. It is our opinion that storage of DADS under cool, dry conditions is critical, following comments made by Richard Ostrowski of United Agri Products during his visit to the Lockyer Valley on 4 July 2000.

Two of the four commercial *Trichoderma* products, namely, Trichoshield[®] and Trich-A-Soil[®] in combination with DADS provided some level of disease control and yield increase, being superior to the untreated check. However, the levels of disease incidence and yields were considered to be commercially unacceptable.

Variable results from year to year have also been reported in overseas research trials in onion and garlic using fungicides and sclerotial germination stimulants (Crowe, 1995; Melero-Vara, Padros-Ligero and Basallote-Ureba, 2000). The fungicide Fortress[®] while having some positive effect did not give commercially-viable levels of disease suppression with the single treatment. It is therefore recommended that in

the future a second application be applied at the start of June, which coincides with soil temperatures falling below the critical 15⁰ C for optimum pathogen growth.

The low disease incidence (1-3 %) recorded for all treatments in the trial at site D meant that there was inconclusive evidence that the DGP treatment would be effective in reducing disease. Crowe (2000) reported that a single application of food-grade dehydrated garlic powder used in large field trials in the United States of America lowered populations of *S. cepivorum* by 92-100 % when used at rates of 111, 148 and 185 g/m³ and applied within the optimal range of soil temperature and moisture for sclerotial germination.

A New Zealand agri-chemical company is currently in the process of seeking registration of DADS in Australia with the National Registration Authority. This follows United Agri Products' (manufacturers of DADS) decision to cease progress with the registration in 2001. The positive results obtained for the DADS field trial at site B in the 2000 season, were presented at a number of international and national symposia (refer to section 5) with widespread industry support gained to progress registration of this product.

4.4. *Trickle/Transplant Field Trials*

Introduction

Transplant establishment of onions currently has no major backing within the Queensland industry. It is used in some overseas operations and one local exporter had expressed an interest in the method from the viewpoint of producing a more even quality line of product. When combined with drip irrigation and plastic mulch there is obvious potential for better weed control and better water management using transplants. Several theories based on using onion transplants are being examined for their efficacy in managing OWR. The use of transplants enables several measures to be applied to the production system, which may allow potential for developing novel control techniques such as:

1. Avoiding early OWR infection by growing plants in a pasteurised mix for up to 10 weeks before transplanting.
2. Raising soil temperatures beyond the optimum for OWR infection ($>20^{\circ}\text{C}$) using mulches.
3. Allowing water, fertilisers and fungicides to be applied via trickle irrigation.

Preliminary laboratory experiments to determine efficacy of fungicides against *Sclerotium cepivorum in vitro* indicated good levels of control of growth of sclerotial material on agar. While this type of experimentation does not necessarily reflect the response *in planta*, it may be used to eliminate fungicides, which show no response *in vitro*.



Figure 6. Onion transplants on black plastic with trickle lines running between rows.
Figure 7. Transplants at harvest showing lots of seed stems.

4.4.1. Glasshouse evaluation of fungicides with bare-rooted transplants

In preparation for a small-scale field trial in 2000 the fungicides which indicated potential in the laboratory, were examined in a glasshouse phytotoxicity experiment. Three new ‘soft’ fungicides (Amistar[®], Strobby[®] and Flint[®]) belonging to the strobilurin group were included along with tebuconazole (Folicur[®]) and phosphonic acid (Phospot[®] 400), which have registration against a number of fungal diseases in vegetable crops.

Materials and Methods

The following treatments were included in a glasshouse trial at Indooroopilly Research Centre (IRC):

1. Amistar[®] (0.5 g/L)
2. Strobby[®] (0.4 g/L)
3. DPX KZ165* (0.5 g/L)
4. Flint[®] (0.07 g/L)
5. Folicur[®] (3 mL/L)
6. Phospot[®] 400 (10 mL/L)
7. Phospot[®] 400 (5 mL/L)
8. Untreated check.

* Experimental fungicide produced by Du Pont.

The treatments were mixed in 200 mL beakers and the roots of six week-old onion cv. Henderson’s Straight Leaf onion plants were dipped into the suspensions for one minute after being washed to remove any potting media. The untreated check plants were dipped in water. After treatment, the seedlings were transplanted into OWR-infected field soil in polystyrene broccoli boxes on 3 May 1999. Two rows of 6 plants/row were transplanted into each box. Two replicates of each treatment were placed in a completely randomized design on glasshouse benches. The plants were watered and maintained to promote uninterrupted growth and checked weekly for growth abnormalities for 16 weeks during autumn-winter season.

Results

No phytotoxic symptoms were observed in any treatment at any stage of growth. All plants grew normally, suggesting no fungicide treatment inhibited agronomic development. Amistar, DPX KZ 165, Flint and Folicur showed better disease control than Phospot, Strobby and the Untreated Control (Table 21).

Discussion

Further glasshouse and field trials will be carried out to examine the usefulness of pre-transplant fungicide treatment of onion plants through either:

1. Root dip fungicide treatment, or
2. Fungigation through dripper systems.

Table 21. Reaction of onion transplants to fungicides and the level of disease control.

Treatment	Disease Incidence (%)	Phytotoxic Reaction?
1. Amistar [®]	0	Nil
2. Strobby [®]	42	Nil
3. DPX KZ165	4	Nil
4. Flint [®]	4	Nil
5. Folicur [®]	0	Nil
6. Phospot [®] 400	50	Nil
7. Phospot [®] 400	25	Nil
8. Untreated check	50	Nil

* No LSD values were assigned as the main purpose was to determine whether or not fungicides induced a phytotoxic reaction.

Field Evaluation of Fungicides With Transplants for Control of OWR

Materials and Methods

Nine-week old seedlings of onion cv. Neuendorf Golden Brown were used in these series of trials conducted in the isolation area at GRS. All trials were planted in the last week of May 2000. Trickle tape (T-tape) with 30 cm dripper spacings was used. Plants were manually transplanted and spaced at 10 cm intervals within rows, in rows 30 cm apart. Each treatment replicate was a 5 m raised bed with three equidistant rows of transplants with two trickle lines running between the rows. All the trials were arranged as randomised complete block designs. Disease assessments, which involved the removal of infected plants, were carried out weekly once infection was first noticed. At harvest time all the marketable bulbs were removed from within the entire length of the beds and weighed.

4.4.2. Artificial mulches to reduce field infections of OWR

Introduction

The aim of this trial was to determine if the use of ‘artificial’ mulches, could sufficiently raise soil temperatures above the optimum for OWR infection ($>20^{\circ}\text{C}$) and thus suppress infection. Black plastic mulch and an imported biodegradable mulch were compared with bare soil.

Materials and Methods

A randomised complete block design of three treatments and five replicates was used at GRS. The treatments were as follows:

1. Control (bare soil)
2. Black plastic mulch
3. Biodegradable mulch (Mater-Bi, Novamont Pty Ltd).

The mulches (standard silver-backed black plastic mulch and a black, biodegradable organic mulch) were laid manually 2-3 days before transplanting. The trial was transplanted on 26 May and harvested on 18 September 2000, 114 days after transplanting.

Results

There were highly significant treatment differences for the yield parameters and disease incidence (Table 22). The results are shown in the following table.

Table 22. Mulches reduce disease and increase yield in field-grown bulb onions.

Treatment	Yield (t/ha)	Marketable No./plot	Mean Bulb Weight (g)	% Disease Incidence
1. Control (Bare soil)	14.0 c*	73 c	146.8 b	32.8 b
2. Black plastic mulch	27.4 a	111 a	170.2 a	14.9 a
3. Biodegradable mulch	21.0 b	93 b	186.6 a	23.5 ab
LSD (P<0.05)	3.5	13	18.9	11.6

*Treatment means followed by the same letter are not significantly different (P<0.05) using Fisher’s protected LSD test.

The black plastic mulch produced significantly higher yield and marketable bulbs than the biodegradable mulch and bare soil treatments. There was a similar level of disease incidence for the mulch treatments, with both being comparable to one another and significantly less than the bare soil treatment. The better performance of the mulch treatments for the yield and disease parameters can be related directly to the marginally higher soil temperatures generated by these products (mean of 15.6⁰, 14.9⁰ and 12.7⁰ C respectively for the black plastic, biodegradable mulch and bare soil).

Discussion

The higher marketable yields that were obtained when onions were grown on plastic mulch is in agreement with research by Vavrina and Roka (2000) on short-day onions in southern Florida. Results showed that in a semitropical environment, white-on-black plastic mulch provided the greatest yield enhancement from increased bulb weight and bulb size. It is quite likely that if these mulches were laid down earlier, in the summer, that the benefits could have been even more accentuated. For next year's trials we plan laying the mulch during the summer months in order to take advantage of the higher soil temperatures generated during this time.

4.4.3. Fungigation to reduce OWR infection

Introduction

In this trial three fungicides (procymidone, tebuconazole and strobilurin) were applied through the trickle system on three occasions: 1) at planting, 2) 7 weeks, and 3) 11 weeks after transplanting.

Materials and Methods

A randomised complete block design of four treatments and five replicates was used. Treatments were as follows:

1. Untreated Control
2. Folicur[®] (tebuconazole, 1 L/ha)
3. Fortress[®] (procymidone, 2 L/ha)
4. Stroby[®] (strobilurin, 250 g/L).

The same criteria for disease and yield assessment were used for the mulch trial. The seedlings were transplanted on 29 May 2000. The fungicide treatments were applied through the trickle on 29 May, 12 July and 21 August (0, 44 and 77 days after transplanting). This trial was harvested on 19 September, 112 days after transplanting.

Results

There was a considerable delay in expression of OWR symptoms in this trial. The first disease symptoms were noted in the Control, Fortress[®] and Stroby[®] plots on July 24, while no symptoms appeared in the Folicur[®] treatment until 7 August 2000. The results (Table 23), show that there are no significant treatment differences for marketable yield, marketable number of bulbs and % disease incidence. However, the mean bulb weight was higher in the Folicur[®] and Fortress[®] treatments compared to the Stroby[®] and Control treatments. Overall, there was low disease expression across all treatments.

Table 23. Fungicides fail to reduce OWR or increase yield in field-grown bulb onions under low disease pressure conditions.

Treatment	Yield (t/ha)	Marketable No./plot	Mean Bulb Weight (g)	% Disease Incidence
1. Control (Untreated)	26.6	117	170 a*	6.9
2. Folicur (1 L/ha)	32.2	122	198 b	7.1
3. Fortress (2 L/ha)	27.3	113	180 ab	10.3
4. Stroby (250 g/ha)	26.2	113	175 a	11.0
LSD (P<0.05)	NSD	NSD	20	NSD

*Treatment means followed by the same letter are not significantly different (P<0.05) using Fisher's LSD test. NSD= Not statistically different.

Discussion

In this same area in 1999 there was also a low level of disease incidence. The positive effect of the black plastic mulch in directly raising the soil temperature in the upper 10 cm of the soil profile, may also have contributed to lowering the level of disease expression, even in the Control treatment.

4.4.4. Fungicidal root-dips to reduce OWR infection

Introduction

In this trial the same fungicides that were being evaluated in the fungigation trial were used. Effective rates of application of these fungicides that resulted in good control and without phytotoxic side effects were established from preliminary glasshouse trials in 1999 using bare-rooted transplants. These rates of application were subsequently used in this field trial.

Materials and Methods

A randomised complete block design of four treatments and five replicates was used. Treatments were as follows:

1. Untreated Control
2. Folicur[®] (2.5 mL/L)
3. Fortress[®] (5 mL/L)
4. Stroby[®] (0.4 g/L)

All the transplants were drenched with the respective treatments while still in the seedling trays (30 minutes; 10 L/600 plants) just prior to planting out on 29 May. These plots were given a further fungicide application (same rates as indicated in the previous trial and in the table below) via the trickle system six weeks after transplanting. This trial was harvested on 20 September 2000, 113 days after transplanting.

Results

There were highly significant treatment differences for both yield and disease incidence (Table 24). The most notable finding was that the Folicur[®] treatment resulted in a severe phytotoxic response, with plants being severely stunted and subsequently producing only few bulbs of a marketable size. There was no phytotoxic response for the other two fungicides. There were significant treatment differences for disease incidence, with Folicur[®] and Fortress performing better than Stroby[®] and the Control. However, there were no differences in yield between the Control treatment and Fortress[®] and Stroby[®] fungicides, with all these treatments being superior to the Folicur[®] treatment.

Table 24. Fungicidal effects on OWR disease control and yield of field-grown bulb onions.

Treatment	Yield (t/ha)	Marketable No./plot	Mean Bulb Weight (g)	% Disease Incidence
1. Untreated Control	26.1 a	106 b	185 a	11.2 b
2. Folicur [®] (1 L/ha)	8.4 b	44 c	144 b	1.2 a
3. Fortress [®] (2 L/ha)	26.3 a	127 a	155 b	2.0 a
4. Stroby [®] (1 kg/ha)	25.9 a	113 b	175 a	11.0 b
LSD (P<0.05)	3.0	10.1	15.3	6.3

*Treatment means followed by the same letter are not significantly different (P<0.05) using Fisher's protected LSD test.

Discussion

Similar to the fungigation trial there was a relatively low level of disease incidence in the plots and hence the positive result of Fortress[®] in disease suppression should be viewed with caution. Severe stunting and plant death early in the growth of the seedlings was detrimental to producing yields comparable to the other fungicide treatments and even that of the Control. The transplants in the glasshouse trial of 1999 grew normally after being dipped in Folicur[®], but since the root balls were relatively free of potting mix in that experiment, it is feasible that Folicur[®] was not retained around the roots long enough to produce a phytotoxic response. In this field trial however, the fungicide may have bound strongly to the peat/vermiculite seedling potting mix, thus being exposed to the roots for a greater length of time. A similar scenario has occurred in Tasmanian field trials with lime super + Folicur[®] treatment at planting resulting in some stunting and delay of emergence in seedlings but by harvest there was no apparent detrimental yield suppression.

The consistent poor yields, in addition to high labour and material inputs used in these trickle trials would be expected to render this system commercially unviable, even though there would be expected to be cost savings in terms of water usage. The possible scenario of more uniform size of bulbs did not eventuate in these trials and therefore it was decided that further research should be limited.

4.4.5. Solarisation using black plastic mulch to reduce OWR infections

Introduction

Following on from the 2000 field trial using black plastic mulch it was decided that the mulch should be laid earlier in the summer to take advantage of higher temperatures in anticipation of reducing OWR. Field trials in Egypt, Western Australia and South Australia (Porter and Merriman, 1983) have shown good results using the solarisation principle.

Materials and Methods

Black plastic mulch was laid on 14 February and left for the duration of the trial, which was harvested on 10 October 2001. Nine week-old seedlings of local onion cv. Neuendorf Golden Brown seed were raised in a commercial nursery and transplanted into the field on 26 April. A randomised complete block design of six treatments and four replicates was used. Each bed consisted of four equidistant 10 m rows of 15 cm, with an intra-row plant spacing of 10 cm. Trickle irrigation lines (T-Tape with 20 cm dripper outlets) were positioned between the two outer rows. Treatments were applied as follows:

1. Bare soil
2. Bare soil + Fortress[®]* (6 weeks after transplanting)
3. Bare soil + Fortress[®] (6 & 12 weeks after transplanting)
4. Black plastic
5. Black plastic + Fortress[®] (6 weeks after transplanting)
6. Black plastic + Fortress[®] (6 & 12 weeks after transplanting)

*Fortress[®] applied as a drench using a watering can at the rate of 2 L/ha (1 mL/10 L/bed; effective bed width taken as being 0.5 m).

Results

There were no treatment differences for the number of infected bulbs as can be seen in Table 25. No yield data were recorded as most bulbs were either too small or had produced seed stalks at harvest time.

Table 25. Mean disease incidence from field trial using black plastic mulch, with or without a fungicide.

Treatment	Mean number diseased bulbs
1. Bare soil	55
2. Bare soil + Fortress [®] (6 weeks)	61
3. Baresoil + Fortress [®] (6 & 12 weeks)	69
4. Black plastic	55
5. Black plastic + Fortress [®] (6 weeks)	55
6. Black plastic + Fortress [®] (6 & 12 weeks)	54
LSD (P<0.05)	*NSD (P=0.518)

*NSD = No significant differences (P<0.05) using Fisher's protected LSD test.

Discussion

The lack of treatment differences was quite unexpected. It should be noted that the seedlings had been pruned in the nursery a couple of weeks earlier, prior to delivery,

to reduce 'legginess' (etiolation), and had already begun to produce bulbs. After being in the field for about a month the plants reverted back to the vegetative stage. At harvest time there were very few bulbs of marketable size and the majority of those that did reach desired marketable size were not marketable because they had produced seed stems (Figure 7). On this basis and from an economic perspective it was decided that there would be no benefit from yield assessments. After consultation with the senior plant breeder from Yates, Mr Lewis Lydon, it was verified that the pruning stress and the competition between plants in the seedling trays for light etc. may have adversely affected the growth habit of the onion, causing premature seed head formation. It is also common knowledge in the Lockyer Valley that, generally, bolting is more likely to result in crops sown prior to 25 April.

4.4.6. Solarisation using clear plastic mulch

Introduction

Continuing on from the 2000 and 2001 field trials using black plastic mulch, in which the soil temperature was not sufficiently raised to suppress OWR, it was decided that clear plastic mulch should be used and laid earlier in the summer to take advantage of higher temperatures. Field trials in Egypt, Western Australia and South Australia had shown good results using solarisation (Porter and Merriman, 1983). It is quite feasible that solarisation may be beneficial, especially as it is not uncommon, for bare soil surface temperatures on the local black cracking clays to reach up to 60⁰ C by mid-afternoon on hot summer days. This temperature was recorded at the trial site in mid-February.

Materials and Methods

In this trial the use of a double layer of 100 µm clear plastic was compared to bare soil (Control). The plastic mulch was laid on 23 January 2002 using a commercial bed layer and removed on 10 April. On 30 April cv. Neuendorf Golden Brown seed was sown in 25 m plots, on 1.5 m centers at Gatton Research Station. A randomised complete block design of two treatments and 14 reps was used. Disease and yield assessments were made from the inner 15 m of the two center rows on 23 September (146 DAP).

Results

Both treatments gave low yields, 12.5 and 20.1 t/ha respectively, with the solarised treatment producing a significantly higher yield. The disease incidence was relatively high in both the solarised (52.5 %) and the Control plots (41.5 %), however the differences were not significantly different (Table 26).

Table 26. Clear plastic mulch increases yield of bulb onions in a field with moderately high OWR infection.

Treatment	Marketable Yield (t/ha)	% Disease Incidence
1. Control (bare soil)	12.5 b	52.5 a
2. Clear Plastic	20.1 a	41.5 a
LSD (P<0.05)	5.3	12.7

Treatment means denoted by the same letter are not significantly different (P<0.05) using Fisher's protected LSD test.

Discussion

Although the solarisation treatment resulted in a significant yield improvement, the added costs associated with this treatment would have made it uneconomical because of the resultant low yield. The effect of solarisation may have been further enhanced had the site been wetter at time of laying the plastic. This is due to the increased thermal sensitivity of the soil microflora and fauna as well as increased heat transfer or conduction in the soil. Positive results were obtained in New Zealand using clear polythene (50 µm) mulch. The clear polythene is used more commonly as coloured polythene tends to absorb heat rather than allow it to be transmitted in the soil (McLean, Swaminathan and Stewart, 2001). In Southern Italy, Di Primo and Cartia (1998) demonstrated that transparent mulch was better than black plastic mulches for

enhancing death of sclerotia of *S. cepivorum* that were recovered from soil depths of 15 cm and 30 cm.

4.4.7. Fungigation field trial

Introduction

The purpose of this trial was to evaluate the use of procymidone fungicide (Fortress[®]) and a commercial *Trichoderma* formulation (Trichoflow[®]-ALI 52), to suppress OWR using a trickle system.

Materials and Methods

The trial was conducted at the Gatton Research Station in 2002. A randomised complete block design of four treatments and 10 replicates was used. Each bed was 10 m long with four single rows per bed. Neuendorf Golden Brown seed was sown on 18 March in beds on 1.5 m centers. Trickle tape (T-Tape with 20 cm emitter spacings) was laid once the seedlings had emerged. The tape was laid at a depth of 5 cm between the two outer rows and covered with soil. Treatments were applied as follows:

1. Fortress[®] (2 L/ha) fortnightly from when soil temperature at 15 cm was <15⁰ C, (from 18 June)
2. Fortress[®] (2 L/ha; 2 applications in June/August, 9 weeks apart)
3. Untreated Control
4. TrichoflowTM-ALI 52 (50 g/application using a 75/15/10 pulse; 4 applications at 3 week intervals starting 17 June).

Disease and yield assessments were taken on 4 September (149 DAP) from the inner 8 m of the two center rows.

Results

There were moderate to high levels of disease, ranging from 34 to 54 %, with low yields ranging from 18 to 25 t/ha (Table 27). The fungicide and *Trichoderma* treatments were ineffective in suppressing OWR.

Table 27. Fungicide and *Trichoderma* treatments were ineffective in suppressing OWR in field-grown bulb onions using trickle irrigation.

Treatment	Yield (t/ha)	% Disease Incidence
1. Fortress [®] (fortnightly from 18 June)	24.1	35
2. Fortress [®] (2 applications)	20.2	52
3. Untreated Control	18.2	54
4. Trichoflow TM -ALI 52 (4 applications)	24.8	38
LSD (P<0.05)	NSD* (P=0.273)	NSD (P=0.192)

NSD* = not significantly different (P<0.05) using Fisher's protected LSD test.

Discussion

The ineffectiveness of the Fortress[®] and TrichoflowTM-ALI 52 treatments was quite unexpected as it was hoped that placing these products in the immediate vicinity of the roots would be expected to enhance their efficacy, compared to soil drenches.

4.5. Root Infection Study

Introduction

Tasmanian and overseas research has found that white rot infection is initiated primarily from sclerotia in the upper 10 cm of the soil profile. Infections that occur toward the end of the growing season are reportedly due to sclerotia which have originated at depths of 30 cm or beyond (Metcalf and Dennis, 1997; Crowe, 1995). The purpose of this glasshouse experiment was to determine the soil depth at which infection is most likely to occur in Lockyer Valley soils. This may in turn determine the optimal depth of cultivation, optimal depth of DADS placement and have an influence on irrigation practices with respect to the likelihood of minimising OWR losses.

Materials and Methods

Soil samples from the surface 15 cm of the soil profile were taken from two cultivated field sites at GRS, one with a history of severe white rot and the other site that was free of white rot. This soil was placed in stratified layers, each of 10 cm depth (up to a total of 30 cm) in plastic containers, which had been fitted with a perspex-viewing window on one side so that root development/infection could be easily assessed. Containers were then placed in an evaporatively-cooled glasshouse at Indooroopilly Research Centre in a completely randomised design. Onion seed cv. Henderson Straight Leaf was sown in May 2000 and when the seedlings sprouted they were then thinned to 10 plants per container. Plants were monitored regularly for OWR symptom development throughout the duration of the trial. There were three treatments as depicted in Figure 8, with each replicated four times as follows:

1. Infected soil (0-10 cm), clean (11-30 cm)
2. Infected soil (11-20 cm), clean (0-10, 21-30 cm)
3. Infected soil (21-30 cm), clean (0-20 cm).

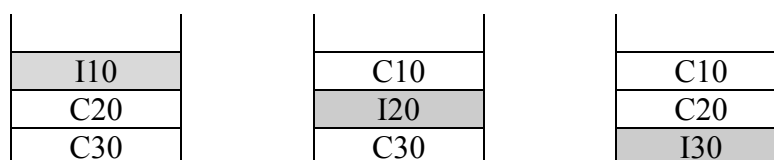


Figure 8: Soil profile within containers showing I= infected soil and C= clean soil at 10, 20 and 30 cm depths.

Results

No white rot infection recorded in any of the treatments.

Discussion

The failure of any of the treatments to show infection would tend to indicate that soil in the sampling depth did not contain any viable sclerotia. Perhaps at this depth of cultivation from which the samples were taken there was sufficient solarisation to render the sclerotia unviable. It is considered very unlikely that the infested soil contained no sclerotia as the soil was taken from within the quarantine area at GRS where at the end of each season infected bulbs with attached sclerotia are ploughed black into the soil and cross-cultivated to ensure thorough and even distribution throughout the trial sites. Porter and Merriman (1983) found from their research in

Victoria that high temperatures and fluctuating sub-lethal temperatures in the soil were responsible for both a reduction in sclerotial numbers and their viability. Recent studies by McLean, Swanminathan and Stewart (2001) in New Zealand soils support these findings. It was proposed that both thermal influence and biological control activity reduced sclerotial viability in these soil solarization trials. Fluctuating temperatures may increase the vulnerability of *S. cepivorum* sclerotia to soil micro-organisms or increase heat resistant saprophyte populations.

Maximum daily soil surface temperatures on the black, cracking clays in the Lockyer Valley can reach as high as 60⁰ C during summer and range between 25-40⁰ C during the summer/autumn at 15 cm depth. It is considered plausible that similar activity to that reported by the above-mentioned researchers may have occurred in the Lockyer Valley soil that was used in this study.

4.6. Plant Resistance Screening

Introduction

As part of an integrated approach to the management of OWR, the use of genetic resistance is considered to be of major importance. Although resistance to this disease in commercial lines has not been generally recognised, the US Department of Agriculture (USDA) has developed lines with some putative partial resistance. Yates plant breeders have used these lines in crosses with local early Lockyer types (whites and browns) to develop commercially acceptable varieties for use in Queensland. Field trials were conducted at the Gatton Research Station within the designated quarantine enclosure from 1999-2002 to assess these varieties for partial resistance to OWR.

Materials and Methods

1999 Trial

The experiment contained 39 lines consisting of 20 F2 populations derived from crosses between the USDA material and Early Lockyer White (ELW) or Gladalan White varieties; six F1 crosses between the USDA material and Early Lockyer Brown (ELB) varieties; eight USDA lines with putative partial resistance to OWR, and five commercial lines (ELW, ELB, Wallon Brown, Straight Leaf and Cavalier).

Plots consisted of 2 rows x 2 metres, which were planted using an Earthway Seeder dropping seed at 3 cm spacings along the rows. There were four replicates. The experiment was planted on 18 May 1999 with normal crop husbandry practices being implemented. Assessment of disease incidence was made at harvest and healthy bulbs with good marketability traits were selected for further breeding work in the following year (2000) at the Yates Narromine Research Station (Northern NSW). Seed derived from this generation would then be used in the 2001 trial at GRS.

2000 Trial

A total of 11 varieties were assessed. These included 10 of the best varieties from the 1999 season and a selected New Zealand line. Seed was planted on 30 May 2000. Selections were made as for the previous year.

2001 Trial

In all a total of 20 lines derived from various crosses from the 1999 season were seeded on 23 May and harvested on 4 December 2001.

2002 Trial

Six superior lines, which were crosses between Early Lockyer White and Gladalan White x USDA Brown Long Day maturity storage lines with putative white rot partial resistance, were sown on 2 May and 6 June 2002. Bulbs that were disease-free and showed good marketability traits were harvested on 26 November and will be used for future breeding lines.

Results

Table 28 indicates the level of white rot encountered at harvest in 1999 and the 10 superior lines (1, 2, 9, 11, 13, 15, 16, 17, 18 and 19), which were sown during the 2000 season. During the early growth period the site was heavily infested with cutworms, which caused plant losses in several plots. However, the final populations were sufficient to form opinions about the relative resistance of the lines in the trial. Disease-free bulbs were selected for seed increase based on their favourable agronomic characteristics, namely, absence of seed heads and 'doubles', desired shape/size/skin quality and firmness/storage quality etc.

Discussion

At the end of each season, disease-free bulbs were removed from the trial site at GRS and planted the following season in Narrromine from which various crosses were made. Seed derived from these lines would subsequently be sown the following season at GRS. Thus, to produce a single generation would take two years. This ongoing type of research is very time-consuming with no guaranteed results. At the end of these trials six lines that showed superior performance were derived from crosses between ELW and Gladalan White x USDA storage lines with putative partial resistance and will be further tested in 2003 and beyond. While there is a low likelihood of getting really useful resistance from material derived from these trials if a line could be developed with at least some improved tolerance to OWR, then when used in conjunction with other forms of control such as DADS and *Trichoderma* etc. there could be some benefit to the onion industry.

Table 28. White Rot disease incidence recorded in 39 onion lines and varieties and the number of bulbs selected for subsequent seed production.

Line or Variety	Mean % Disease Incidence
<i>Segregating F2 populations from hybrid crosses between resistant USDA material and Early Lockyer White varieties</i>	
1	19
2	14
3	38
4	38
5	25
6	39
7	26
8	27
9	6
10	26
11	19
12	29
13	22
14	32
15	25
16	26
17	18
18	15
19	22
20	25
<i>F1 crosses between USD resistant material and Early Lockyer Brown varieties</i>	
21	43
22	33
23	34
24	41
25	29
26	35
27 Henderson's Straight Leaf	28
USDA resistant material	
28	91
29	34
30	63
31	37
32	28
33	40
34	96
35	28
Susceptible controls	
36 Early Lockyer White (ELW)	20
37 Early Lockyer Brown (ELB)	46
38 Cavalier	43
39 Wallon Brown	28

* Shaded areas represent the lines that were used for selection in 2000 season.

5. Technology Transfer

The main forms of technology transfer were through:

Local field days

Three at Gatton Research Station (GRS) and one at co-operator producer's farm at Mulgowie (location of the first DADS trial), extension bulletins distributed at these meetings.

Grower meetings

Audiovisual presentations at local agrochemical resellers grower meetings, Gatton Wesfarmers (product release of Lime Super/Folicur by Bayer), Gatton RSL (product launch for Fortress® by Crop Care); Brisbane TAFE (Brisbane shallot growers, QFVG).

Local and regional newspaper/newsletter articles

The Gatton, Lockyer and Brisbane Valley STAR,
Queensland Country Life,
Queensland Table (newsletter of the Queensland Government Department of Primary Industries),
Heavy Produce Update (quarterly newsletter of QFVG Heavy Produce Committee).

National onion industry journal articles

Onions Australia

Articles in Proceedings of International Symposia

Australasian Plant Pathology Society,
Australasian Soilborne Diseases Symposium.

Articles in Proceedings of National Onion Industry Conference

Onions 2002 Conference.

Radio interview on regional ABC station

DADS research (11 July 2000).

Industry audit

Selected growers and 100 pickers were interviewed. Pocket-sized, waterproof extension leaflets were produced and distributed to growers, pickers, harvesting contractors and agrochemical field reps. Details of the OWR pathogen and hygiene practices were mentioned. These were produced in English, Samoan and Turkish languages (1500, 750 and 750 copies respectively), representing the main language groups of pickers.

Networking with other national/international researchers in OWR

Tasmania: Dr Dean Metcalf (DPIWE) and Dr Jason Dennis (Field Fresh Tasmania),
Victoria: Dr Ian Porter and Oscar Villalta (Department of Natural Resources and Environment),

NZ: Professor Alison Stewart (Lincoln University) and Dr John Hunt (Agrimm Pty Ltd), and

USA: Associate Professor Fred Crowe (Oregon State University) and Richard Ostrowski (United Agri Products).

Presentation at Australian Onion Industry Association AGM

Update of research in 2002 and DADS registration presented to delegates on 11 November 2002.

Scientific publications and extension articles arising from project research

A. Conference Papers

1. Davis, R.D. and Mac Manus, G.P.V. (2002). Putative phytotoxicity in onion seedlings treated with Folicur® and lime super. In *Proceedings Onion 2002 Conference* (NSW Agric.), Yanco, 3-5 June, p. 58-62.
2. Mac Manus, G.P.V., Davis, R.D., Bell, K.L. and Kopittke, R.A. (2001). Sclerotial germination stimulant suppresses onion white rot. In *Proceedings 13th Biennial Plant Pathology Conference* (APPS), Cairns, 24-27 September 2001, p.198. [Poster also presented].
3. Mac Manus, G.P.V., Davis, R.D., Bell, K.L. and Kopittke, R.A. (2002). Sclerotial germination stimulant suppresses onion white rot. In *Proceedings Onion 2002 Conference* (NSW Agric.), Yanco, 3-5 June, p. 50-52. [Poster also presented].
4. Mac Manus, G.P.V., Davis, R.D., Bell, K.L. and Kopittke, R.A. (2001). Germination stimulant diallyl disulfide (DADS) suppresses onion white rot in the Lockyer Valley. In *Proceedings of the Second Australasian Soilborne Diseases Symposium*, Lorne, Victoria, 5-8 March 2001, p.117. [Poster also presented].

B. Journal Articles

1. Davis, B. (1999). White rot- going back to school. *Onions Australia* **16**: 18-19.
2. Mac Manus, G. (2000). The attack on white rot. *Onions Australia* **17**: 22-23.
3. Metcalf, D, Mac Manus, G, Dennis, J. and Davis, B. (2000). Assailing white rot from every angle. *Onions Australia* **17**: 36.
4. Diallyl disulfide induces suicide of *Sclerotium cepivorum* sclerotia, reducing white rot and increasing bulb onion yield. (*In Press*).

C. Field Days/Grower Meetings and Extension Material

1. Extension newsletters (Information Sheets 1, 2 and 3 respectively) presented at/on the following field days:
 - 1) GRS (30 September 1999), outlined current and future project research;
 - 2) GRS (24 November 1999), reported the outcomes of field trials and the industry audit of growers and pickers and their understanding of the OWR problem;
 - 3) Shane Osborne's farm (local collaborator where DADS trials were conducted) at Mulgowie (4 July 2000), results of DADS trial presented/viewed and Dr Richard Ostrowski of United Agri Products, USA (suppliers of DADS) spoke on international research experiences.
2. 'Onion white rot' (Pocket-size, waterproof extension leaflet) distributed to pickers, growers, agrochemical reseller reps and contract harvesting companies in the Lockyer Valley and Darling Downs during 2000-2002 seasons.

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3. 'Sclerotial germination stimulant suppresses onion white rot'. (Extension leaflets distributed at Gatton Wesfarmers grower meeting (8 November 2001) and GRS field day (14 November 2001).
 4. Presented talks on OWR and its management to pathology staff and final year degree students of the University of Queensland, Gatton College (12 October 1999) and to fellow researchers/industry personnel at the local Australasian Plant Pathology Society (APPS) seminars at GRS (2 February 2000).
 5. 'Onion white rot' extension leaflet distributed to Brisbane shallot growers. Meeting organised by Julia Telford (QFVG) on 28 August 2002.

D. Newspaper/Newsletter Articles

1. Onion disease research boost.
The Gatton, Lockyer and Brisbane Valley STAR, June 9, 1999.
2. Deception strategy tricks onion white rot.
Queensland Country Life, September 9, 1999.
3. DPI deception to control white rot in onions.
The Gatton, Lockyer and Brisbane Valley STAR, September 15, 1999.
4. Fungicides to manage white rot.
The Gatton, Lockyer and Brisbane Valley STAR, February 2, 2000.
5. Expert on onion white rot to visit Lockyer.
The Gatton, Lockyer and Brisbane Valley STAR, June 28, 2000.
6. Onion white rot review a success.
Heavy Produce Update September 2000.
7. Success in fungus control.
Queensland Country Life, December 21, 2000.
8. DADS & onions- nothing to cry about.
A Queensland Table, Autumn 2001.

5.1. Industry Audit/Disease Awareness Programme

The purpose of this program was to gather baseline information on the level of understanding of both producers and pickers of the disease, the pathogen, its biology and ecology and the importance of simple hygiene practices in managing the disease and preventing spread. Ultimately the livelihoods of both are a risk.

A preliminary industry audit was conducted during the mid-harvest period in 1999. in all 100 pickers and 6 growers were asked to answer and comment on a series of standard questions presented to them in the survey. A summary of these findings is presented below:

Question	Responses
1. No. of seasons experience? a) first b) one year c) 2-5 years d) > 5 years	19 13 28 40
2. Picking area(s)? a) Lockyer only b) Other	48 52
3. No. farms/season? a) 1-3 b) 4-6 c) >6	48 16 36
4. Own equipment? a) yes b) no	95 5
5. Travel to farms? a) own vehicle b) other	83 17
6. Drive on farm? a) no b) sometimes c) never	6 30 64
7. Heard of OWR? a) no (if no go to question 20) b) yes c) think so	21 77 1

8. OWR effects? a) leaves b) roots c) bulb d) all of these e) no idea	2 25 54 17 3
9. Know of what OWR looks like? a) no (if no go to question 16) b) yes c) think so	1 76 1
10. Seen OWR? a) most farms b) some farms c) never seen it	36 38 3
11. Action taken a) advise other pickers b) tell grower c) do nothing	29 37 16
12. Action taken a) pull and leave in paddock b) pull and cut into bin c) leave in ground	56 0 24
13. Do you know what causes OWR? a) yes b) no c) not sure	15 54 8
14. Do you know how OWR is spread? a) yes b) no c) not sure	37 37 3
15. Know it lives in soil? a) yes b) no	30 47
16. Ever ask grower about OWR? a) no b) sometimes c) always	53 21 4

17. Grower ever ask you about OWR? a) no b) sometimes c) always	27 34 17
18. Grower ask where you worked before? a) never b) sometimes c) always	48 25 3
19. Grower ask if you've seen OWR before? a) never b) sometimes c) always	37 35 6
20. Grower cautioning pickers? a) never b) sometimes c) always	53 24 1
21. Who is responsible for preventing spread of OWR? a) grower b) picker c) shared d) don't know	17 1 56 4
22. Pocket card useful? a) yes b) no c) not interested	96 3 1

- A pocket-size, waterproof extension card has been produced in English, Turkish and Samoan, targeting the major language groups among the picker population. Ninety-six percent of the respondents affirmed that this would be a useful extension tool.
- All growers surveyed supported production of the extension card.

A local consulting company, Margold Consulting Service, was also very supportive and was prepared to ensure their employees are issued with a card. As a condition of their employment, they would need to show they have an awareness of the risks and pathogen movement and how they would carry out their work mindful of their responsibilities.

6. Recommendations

An integrated approach, using a combination of the following successful strategies and good hygiene practices, is recommended to obtain effective disease control.

1. DADS be applied in the first week of June with a follow-up in mid-July (if necessary) in the year prior to planting. It is important that a good seal be achieved through rolling and a light irrigation immediately after application. If a single application is used then a supplementary treatment with procymidone or *Trichoderma* be used in early June.
2. Manipulation of sowing time can be an effective management tool to avoid peak infection periods. May/June plantings tend to show less disease than earlier plantings.
3. Tebuconazole (Folicur[®] 430 SC) fungicide at 1 L/ha mixed with 125 kg/ha lime super be applied at planting. Good coverage of the lime super particles is crucial. Seed and lime super can either be mixed in the same box on the drill or placed in different boxes and sown down the same tube (as per label).
4. Procymidone (Fortress[®] 500) fungicide at 4 L/ha with fertiliser as an in-furrow application at planting. Fertiliser needs to be applied in a band no more than 2 cm below seed or as a soil spray at 2 L/ha in minimum of 250 L of water immediately after sowing and a repeat application 10 weeks after sowing (as per label). Depending on sowing time we recommend a spray in the first week of June and if continued cool moist conditions prevail another application may be advisable.
5. There may be some benefit from applying *Trichoderma* products. Ensure they are well watered in if applied as a foliar spray. Applying it on cracked grain seed as an in-furrow treatment is the preferred option.
6. The use of biological amendments such as vermicomposts is encouraged, to build up organic matter and beneficial microbes, as a long-term strategy as soils in the Lockyer Valley are generally very low in organic matter.

Future research could look at developing commercial strains of endemic *Trichoderma* and further field trials to determine the most effective rates of DADS (either as single or split applications) for use in the Lockyer Valley and other onion producing states of Australia.

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- United Agri Products Pty Ltd

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