Effects of different fungicide application strategies on the control of onion white rot (*Sclerotium cepivorum* Berk.) in the Pukekohe district.

R A Fullerton, A. Stewart, R.J.Wood, J L Tyson, J. Swaminathan

April 1998

Report to The New Zealand Onion Exporters' Association.

R.A. Fullerton and Joy Tyson
MT ALBERT RESEARCH CENTRE
HortResearch
Private Bag 92169
Auckland
Telephone: 09 849 3660
Facsimile: 09 815 4201

A. Stewart and J. Swaminathan
Soil, Plant and Ecological Sciences Division
Lincoln University
PO Box 84
Canterbury
Telephone: 03 325 2811
Facsimile: 03 325 3843

R.J. Wood
Vegcon Services Ltd
Eden Road
Pukekohe
Telephone: 09 238 6595
Facsimile: 09 238 6591

HortResearch Client Report No. 98/40

This report has been prepared by The Horticulture and Food Research Institute of New Zealand Ltd (HortResearch) which has its Head Office at Batchelar Research Centre, Private Bag 11 030, Palmerston North and has been approved by:

Research Scientist

Date: 22/4/98

Science Manager

Date: 22/4/98

CONTENTS

EXECUTIVE SUMMARY

Effects of different fungicide application strategies on the control of onion white rot (*Sclerotium cepivorum* Berk.) in the Pukekohe district.

R A Fullerton, A. Stewart, R.J.Wood, J L Tyson, J. Swaminathan April 1998

A number of application strategies using the fungicides Sumisclex and Folicur were evaluated for the control of onion white rot (*Sclerotium cepivorum* Berk.) over the 1997-98 onion growing season. Three separate trials were carried out on 2 different properties in the Pukekohe district. Two of the trials were planted in June to represent an "early-planted" crop, the third was planted in July to represent a "late-planted" crop. One of the early-planted trials and the late-planted trial were located side-by-side on the same property to observe the effects of different planting dates on disease levels and efficacy of control measures. The current recommendations of applying either Sumisclex granules at planting, or a series of 3 or 4 foliar sprays of either Sumisclex or Folicur at monthly intervals during the season were included in the trials. Alternative application strategies included the use of Folicur as a concentrated (three times foliar rate) application to the soil at planting, and both Folicur and Sumisclex as single concentrated applications in the months of August, September, and October. The effect of the fungicide Shirlan on white rot when applied as a downy mildew control programme was also observed.

Key results were:

1. Sumisclex, when applied as granules to the soil surface at planting did not control the disease in either the early or the late-planted trials.

2. Sumisclex, applied as a series of foliar sprays during the growing season, or as concentrated applications at strategic times during the season, did not provide effective control of the disease.

3. Folicur, when used in the conventional manner as a series of foliar sprays during the season reduced disease levels by approximately 17% in the early-planted trials and 40% in the late-planted trial.

4. Folicur, applied once in September at treble the recommended foliar rate, provided the greatest level of control in all 3 trials. Disease levels were reduced by 48% and 31% in the 2 early-planted trials and 48% in the late-planted trial.

5. The September application coincided with the first signs of disease in the crop.

6. Comparisons of the results of the early-planted and the late-planted trials on the same property showed that the time of planting had no effect on either the timing of the disease epidemic, or on the level of control achieved by the most effective treatment on that property. Final disease levels in the early-planted and the adjacent late-planted trials were 37.8% and 37.7% respectively, while the September triple-rate application reduced disease by 48.6% and 48.5% respectively.

7. The fungicide Shirlan had an effect in reducing white rot disease levels. Further development of application strategies for this fungicide are warranted.

8. The trials suggest that there has been an overall decline in efficacy of fungicidal control in the Pukekohe district. Further development of methods which will reduce the numbers of viable sclerotia in the soil (sclerotial germination stimulants, biocontrol agents, rotations) will be essential for sustainable onion production in the district.

For further information contact:

R.A. Fullerton
HortResearch
Private Bag 92169
Auckland
Ph: (09) 849 3660
Fax: (09) 815 4201

A.Stewart
Lincoln University
P.O.Box 84
Canterbury
Ph: (03) 3252811
Fax: (03) 325 3843

INTRODUCTION

Background

An unusually high incidence of onion white rot (*Sclerotium cepivorum*) on some properties in the Pukekohe district in the 1995-96 season was followed by near catastrophic levels of the disease district-wide in 1996-97. Losses were particularly severe in early-planted crops. This apparent failure to control the disease throughout the district during that season prompted a close examination of possible contributing factors and a re-examination of control methods.

The 1996-97 season was characterised by higher than normal rainfall during the period March to September (50-100% above monthly average), a relatively dry October, and higher than average rainfall and cool conditions through November and December 1996. Previous experience has shown that the latter conditions can lead to high levels of disease late in the season. In addition, it was the opinion of many growers that Sumisclex, which had given good control of the disease for over 10 years, was not providing the usual levels of protection either when applied as granules or as foliar sprays. However, many growers who had used a Folicur programme also suffered significant losses so the relative efficacy of the fungicide control programme was in question.

A white rot working group composed of plant pathologists from HortResearch and Lincoln University, key growers, crop servicing companies and exporters was convened by vegetable consultant Richard Wood. A series of field visits and meetings were held over the latter stages of the 1996-97 season. The meetings served to pool information and experience of the disease during the season and to examine possible remedies. Key questions to emerge from the discussions were:

1. Are the fungicides Sumisclex and Folicur, as currently recommended for control of the disease, still effective?

2. Do Sumisclex granules, applied at planting, provide adequate protection especially in early-planted (late-May early-June) crops?

3. Are there more effective fungicide application strategies than the currently recommended series of "foliar spray" applications (3 or 4 applications at approximately 4-weekly intervals over the period September-November)?

4. What is the relationship between planting time and disease severity, and how does this influence the efficacy of fungicide treatments?

The New Zealand Onion Exporters Association, representing Pukekohe growers, in association with Vegfed, Bayer New Zealand Ltd., and Cropcare Holdings Ltd, contracted HortResearch to undertake a series of field trials to address the above questions. The trials programme was developed by Dr Bob Fullerton (HortResearch), Dr Alison Stewart (Lincoln University), and Mr Richard Wood (Vegcon Services Ltd, Pukekohe).

Rationale of trials programme

A series of 3 trials were planned, two to be "early-planted" (June) and a third to be "late-planted" (July). It was decided that essentially the same treatments would be applied to all of the trials to allow a comparison of treatment effects, both in different localities, and in time. The trials were designed to include the standard control recommendations and a series of alternative application strategies involving variations to the timing of fungicide applications.

Single, high-rate applications of fungicide at planting have been found to provide effective control in the past. Sumisclex granules are the most common example of this strategy but it has also been shown to be effective for Folicur (Fullerton *et al.* 1995). Grower experience in recent years has questioned whether the single applications at planting time were providing the long term protection required for early-planted crops. The rates of fungicide used in the early season treatments involved the application, in one dose at planting, of the same quantity of active ingredient as used in 3 foliar applications (Stewart & Fullerton 1991, Fullerton *et al.* 1995). The application strategies proposed for these trials involved the use of both Sumisclex and Folicur at the same rates as for soil applications at planting, but applied at various times after planting. The objective was to try to establish the application time which would provide maximum protection against the disease.

Research at Lincoln University over the past 3 years has shown that selected Biological Control Agents (BCAs) were able to reduce onion white rot in trials carried out under glasshouse conditions. One BCA was included in this series of trials to evaluate its effectiveness compared to a range of fungicide treatments.

METHODS

Three trials were conducted, Trials 1 and 2 planted in June, and Trial 3 planted in July.

1. **Trial Locations.** Two locations were used for the trials. Both were on commercial growers' properties in areas which had been severely affected by white rot (estimated as having up to 90% loss) in the 1996-97 season.

The properties were:

Trials 1 & 3.	T A Reynolds & Sons, Bollard Rd Property, Tuakau.
Trial 2.	Hira Bhana, Friedlander Rd Property, Tuakau.

Trial 3, located on the Reynolds' Tuakau property, was planted immediately alongside the earlier planted trial on that site. This provided a unique opportunity to observe and compare the effects of planting time on disease severity, and efficacy of control in a site for which the levels of soil inoculum, and therefore potential disease, were the same.

2. **Experimental Design and Layout.** Each of the 3 trials consisted of 18 treatments replicated 6 times. The lists of treatments applied in the three trials are shown in Tables 1 and 2. Details of the fungicides used, their rates and application methods are given in Appendix 1. Two different seed treatments were used. Seed for treatments to receive BCA treatments (Treatments 1-6) were treated with Captan only. Seed for treatments intended to receive fungicide treatments (Treatments 7-18) were treated with both Captan and Sumisclex. These different seed treatments effectively provided 2 "untreated controls", the former designated Control 1, the latter Control 2.

Two variations to the standard schedule of treatments used in Trials 1 and 2 were introduced in Trial 2. The first was the introduction of fluazinam (Shirlan®) to the list of treatments. Shirlan is used for control of *Botrytis* and downy mildew in grapes and potato. It also has potential for use in onions for downy mildew. In general, fungicides which control *Botrytis* also have activity against *S. cepivorum.* It was applied in Trial 3 to simulate a downy mildew control programme, and its effects on white rot evaluated (Treatments 13,14). The second variation involved the use of Folicur instead of Sumisclex as a late season supplement to Sumisclex granules (Treatment 12).

The trial was laid out on a modified row and column design with each column consisting of a single bed of onions. The trials utilized a total of 9 beds of onions. Treatments 1-6 occurred twice along each of 3 beds of onions. Treatments 7-18 occurred once along each of 6 beds of onions. The 3 beds containing treatments 1-6 were interspersed between the 6 beds containing treatments 7-18. Treatments were randomised along the beds. Each bed of onions contained 6 individual rows of onion plants. Each treatment plot consisted of 4m of bed with plots being separated from one another by 1m. Beds were 1.3m wide giving a plot size of 5.2m^2. Layout plans for the trials are attached (Appendix 2 and 3).

3. **Management schedules.** Trials 1 and 2 were planted on 15 June 1997. Trial 3 was planted on 17 July 1997. The onions were planted with a Stanhay Precision seeder set up to position seeds 48 mm apart. For each trial the soil was in excellent seedbed condition for planting. BCA pellets, Sumisclex granules and Folicur soil surface sprays were applied immediately after planting. Thereafter fungicide and BCA applications were applied as per the schedules in Tables 1 and 2. All other management operations (herbicide, pesticide,

fertilizer, irrigation) were carried out by the cooperating growers according to their standard farming practices. A high standard of husbandry was maintained throughout the growing season.

4. Data collection. Emergence counts, to provide base-level population data, were made on 13 August 1997 for Trials 1 and 2, and on 28 August 1997 for Trial 3. Thereafter the trials were inspected approximately fortnightly and the numbers of diseased plants recorded for each plot. To facilitate counting over successive visits and to confirm the presence of white rot, the diseased plants were removed on each occasion. This practice does have the effect of limiting to some extent plant-to-plant spread of the disease. Therefore data obtained on disease severity could be considered to be conservative compared with potential disease levels had the plots been undisturbed. Counts of diseased plants were made on 29 August, 10 September, 25 September, 8 October, 22 October, 5 November and 19 November.

Onions in Trial 1 were lifted on 21 January 1998 . Final counts of sound and white rot affected onions were made on 23 January 1998. Heavy weed growth over the period December 1997- January 1998 prevented the final counts of sound and diseased onions being made in Trial 3. Final population counts were made in Trial 3 on 2 February 1998, before the onions were lifted. Unfortunately diseased bulbs were discarded by the contract topping gang and final disease counts were not able to be made. Because of these misadventures and the fact that very few diseased bulbs were recorded at post-lifting assessment in Trial 1 (generally only 2-3 per plot) analyses were performed using initial populations and total diseased plants recorded during the season.

5. Analysis and presentation of data. The data were analysed using REML (Residual Maximum Likelihood), which is a generalisation of Analysis of Variance that is suitable for moderately unbalanced designs. In this series of trials, although each treatment was replicated the same number of times, the constraints imposed by the different seed treatments introduced imbalance within the row and column design.

For each of the trials, initial populations and mean percent white rot at the end of the season for each of the treatments are presented in tabular form.

For the purposes of comparing treatment effects, the analysed results are presented as line scales. Because the disease values on the line scale represent the means of arc-sine transformed percentages, the numbers differ from means of percent plant loss derived from the raw data.

Two indicators of statistically significant differences between means are shown on each of the line scales. They are:

- **Least Significant Difference (LSD)** (at 5% level). LSD is designed for pairwise comparisons of means. Differences greater than the LSD value are considered to be significantly different. However when a large number of paired comparisons are being made (as in this case), there is a chance that some of the differences found may be due to chance alone. Thus the use of LSD alone may at times indicate significant differences when in fact they do not exist.
- **Tukey's LSD.** This measure is designed for comparison of extreme values and as such is a more conservative system for detecting differences. While separations greater than the Tukey LSD value can be considered to be statistically significant, its use could conceivably lump together treatment values which are in fact different. Thus some degree of flexibility must be used in interpreting the analyses.

For each of the treatments, disease progress curves were prepared. For convenience of viewing, the disease progress curves for the Sumisclex and Folicur treatments are presented separately. Disease progress curves for the BCA treatments are presented for Trial 1 only.

Table 1 **Schedule of BCA and fungicide treatments applied to Trial 1 (Reynolds, Bollard Rd property) and Trial 2 (Hira Bhana, Friedlander Rd property) Tuakau. 1997-98.**

Trt No.	Seed Treatment	Soil application	Foliar application	Detail and timing
1	Captan	-	-	*Untreated control 1*
2	Captan	-	BCA	BCA soil spray along row (28/8/97 & 22/10/97)
3	Captan + BCA	-	-	-
4	Captan + BCA	-	BCA	BCA soil spray along row (28/8/97 & 22/10/97)
5	Captan	BCA Pellet	-	-
6	Captan	BCA Pellet	BCA	BCA soil spray along row (28/8/97 & 22/10/97)
7	Captan + Sumisclex	-	-	*Untreated control 2*
8	Captan + Sumisclex	Sumisclex Granules	-	banded over drill rows at planting (15/6/97)
9	Captan + Sumisclex	-	Sumisclex 25	triple-rate (9l product/ha) single application 17/7/97
10	Captan + Sumisclex	-	Sumisclex 25	triple-rate (9l product/ha) single application 17/8/97
11	Captan + Sumisclex	-	Sumisclex 25	triple-rate (9l product/ha) Single application in 17/9/97
12	Captan + Sumisclex	-	Sumisclex 25	single-rate (3l product/ha). 4 applications 17/7/97, 17/8/97, 17/9/97 21/10/97
13	Captan + Sumisclex	Sumisclex Granules	Sumisclex 25	single-rate, (3l product/ha) 1 application 21/10/97
14	Captan + Sumisclex	Folicur 430SC	-	soil spray over bed surface at planting. (2.626l product/ha)
15	Captan + Sumisclex	-	Folicur 430 SC.	triple-rate (2.626l product/ha) single application 17/7/97
16	Captan + Sumisclex	-	Folicur 430 SC.	triple-rate (2.626l product/ha) single application 17/8/97
17	Captan + Sumisclex	-	Folicur 430 SC.	triple-rate (2.626l product/ha) single application 17/9/97
18	Captan + Sumisclex	-	Folicur 430 SC.	standard rate, (0.875l product/ha) 4 applications 17/7/97, 17/8/97, 17/9/97 21/10/97

Shaded treatments are standard recommendations

Table 2 Schedule of BCA and fungicide treatments applied to Trial 3 (Reynolds Bollard Rd property) Tuakau. 1997-98.

Trt No.	Seed Treatment	Soil application	Foliar application	Detail and timing
1	Captan	-	-	*Untreated control 1*
2	Captan	-	BCA	BCA soil spray along row (8/10/97 & 19/11/97)
3	Captan + BCA	-	-	-
4	Captan + BCA	-	BCA	BCA soil spray along row (8/10/97 & 19/11/97)
5	Captan	BCA Pellet	-	-
6	Captan	BCA Pellet	BCA	BCA soil spray along row (8/10/97 & 19/11/97)
7	Captan + Sumisclex	-	-	*Untreated control 2*
8	Captan + Sumisclex	Sumisclex Granules	-	banded over drill rows at planting (17/7/97)
9	Captan + Sumisclex	-	Sumisclex 25	triple-rate (9l product/ha) single application 17/8/97
10	Captan + Sumisclex	-	Sumisclex 25	triple-rate (9l product/ha) Single application in 17/9/97
11	Captan + Sumisclex	-	Sumisclex 25	standard rate (3l product/ha) 3 applications 17/9/97, 21/10/97, 18/11/97
12	Captan + Sumisclex	Sumisclex Granules	Folicur 430SC	Granules at planting + Folicur single-rate (0.875l product/ha) 18/11/97
13	Captan + Sumisclex	-	Shirlan	(0.5l product/ha) 11 applications from mid-September on a 10-14 day schedule
14	Captan + Sumisclex	Sumisclex Granules	Shirlan	(0.5l product/ha) 11 applications from mid-September on a 10-14 day schedule
15	Captan + Sumisclex	Folicur 430SC	-	soil spray over bed surface at planting. (2.625l product/ha)
16	Captan + Sumisclex	-	Folicur 430 SC.	triple-rate (2.626l product/ha) single application 17/8/97
17	Captan + Sumisclex	-	Folicur 430 SC.	triple-rate(2.626l product/ha) single application in 17/9/97
18	Captan + Sumisclex	-	Folicur 430 SC.	single-rate (0.875l product/ha) 3 applications 17/9/97, 21/10/97, 18/11/97

Shaded treatments are standard recommendations

RESULTS

BCA Treatments (Treatments 1-6 all trials)

The BCA used in these trials is the subject of a programme by Lincoln University to develop formulation and applications techniques leading to the development of a commercial product. While much of the work involved is confidential to the University it was agreed to include the BCA in this series of trials not only to evaluate its efficacy against a range of fungicide treatments, but also to learn whether it might offer an option for disease control in the relatively near future. The results over all 3 trials were similar and indicated no significant reduction in disease at the end of the season compared with the untreated control (Control 1). However there was an indication of early season disease suppression by the experimental BCA pellet in Trial 1. The effect was evident until late-October after which there was a rapid increase in disease development (Figure 2). Because of the similarities of response in all 3 trials, no further data are presented here on the BCA treatments.

Fungicide Treatments (Treatments 7-18)

I. Trial 1

Initial populations and mean total % white rot for each of the treatments are provided in Table 3. Analyses of total % white rot for Treatments 7-18 are shown in Figure 1.

Only Treatment 17 (triple-rate Folicur) in September gave disease levels significantly lower than Control 2 (Tukey LSD). Using the pairwise LSD, disease levels in Treatment 17 were significantly lower than the next most effective treatment, Treatment 15 (triple-rate Folicur in July). The latter was also significantly lower than that of Control 2. Disease levels in Treatment 16, (triple-rate Folicur in August) were not significantly different from the control nor were they significantly different from that of Treatment 15 (pairwise LSD).

Disease progress curves for the different groups of treatments (BCA, Sumisclex treatments, Folicur treatments) are given in Figure 2. Low numbers of white rot infected plants (1-3 per plot) were detected in the first assessment on 29 August. Disease levels remained generally low through September with an increase in disease activity (measured by increase in cumulative percentage of diseased plants) becoming apparent during late September and early October. Thereafter there was a rapid increase in disease activity with the greatest losses occurring over the period late October to mid- November. Disease activity declined from mid-November with very few additional plants becoming diseased during December.

The triple-rate applications of Folicur made in July, August and September respectively, and the standard foliar spray regime of single-rate applications made in July, August September and October, were all equally effective in inhibiting disease development until early November. Thereafter only the September triple-rate application limited the rate of disease increase. In each of the other 3 treatments, control was lost and the disease increased at the same rate as in untreated plots.

The most effective of the Sumisclex treatments, detectable in the disease progress curves, were the triple-rate applications made in August and September. Both had the lowest rate of disease development throughout the season though the final disease percentages were not significantly less than Control 2. None of the Sumisclex treatments were particularly effective in suppressing the disease at any time during the season nor had disease levels at the end of the season which were significantly lower than that of Control 2.

Table 3. **Initial plant populations and mean total diseased plants (%). Trial 1, Reynolds property Tuakau, 1997-98.**

No.	Treatment	Initial population av/plot	Mean total diseased %	% disease reduction
7	Captan + Sumisclex seed (Control 2)	225.2	37.8	0.0
8	Sumisclex granules	237.7	31.5	16.7
9	Triple-rate Sumisclex (July)	230.3	44.2	16.9
10	Triple-rate Sumisclex (Aug)	233.7	31.5	16.7
11	Triple-rate Sumisclex (Sept)	238.8	35.6	5.8
12	Single-rate Sum. foliar (Jul. Aug. Sept. Oct.)	219.7	41.1	-8.7
13	Sumisclex gran. + single-rate Sum. (Oct)	240.8	33.6	11.1
14	Triple-rate Folicur soil (plant)	254.2	42.5	-12.4
15	Triple-rate Folicur soil (July)	252.2	28.8	23.8
16	Triple-rate Folicur soil (Aug)	214.0	31.5	16.7
17	Triple-rate Folicur soil (Sept)	233.5	19.4	48.7
18	Single-rate Folicur foliar (Jul. Aug. Sept. Oct.)	229.8	31.4	16.7

Figure 1. **Line scale analyses of total % white rot for Trial 1. Treatments 7-18.**

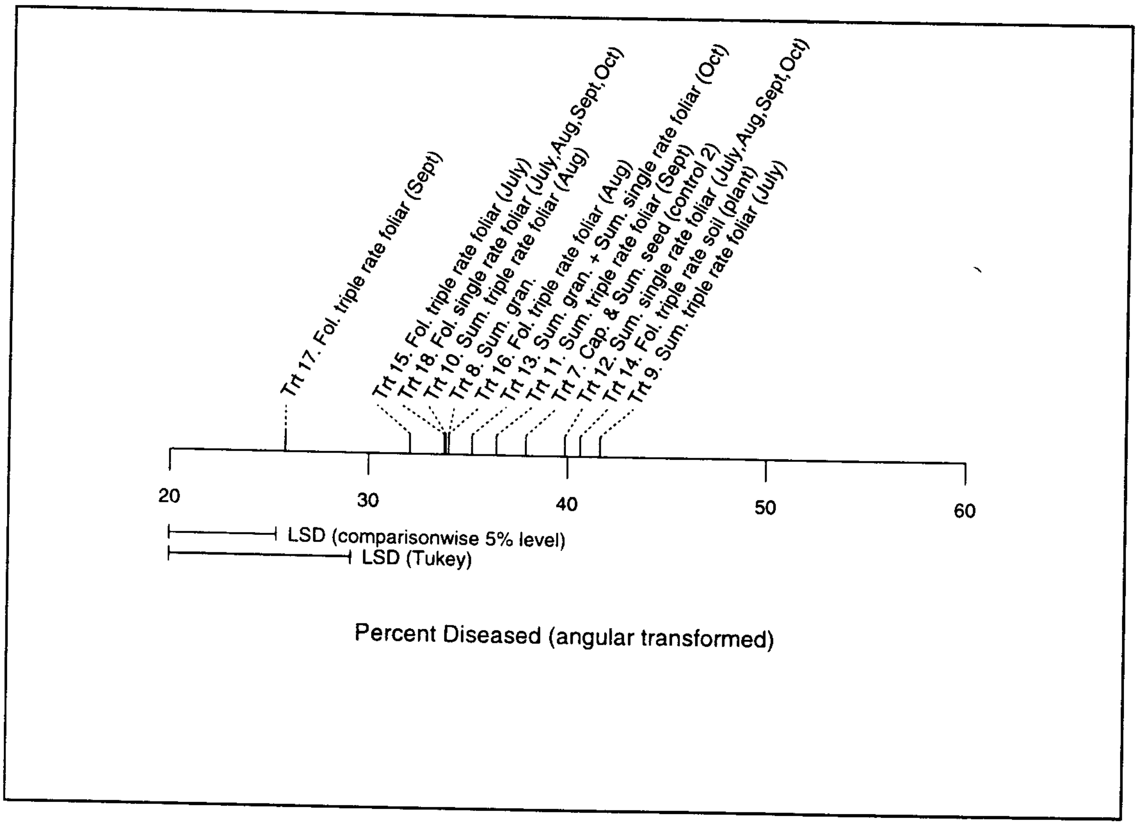
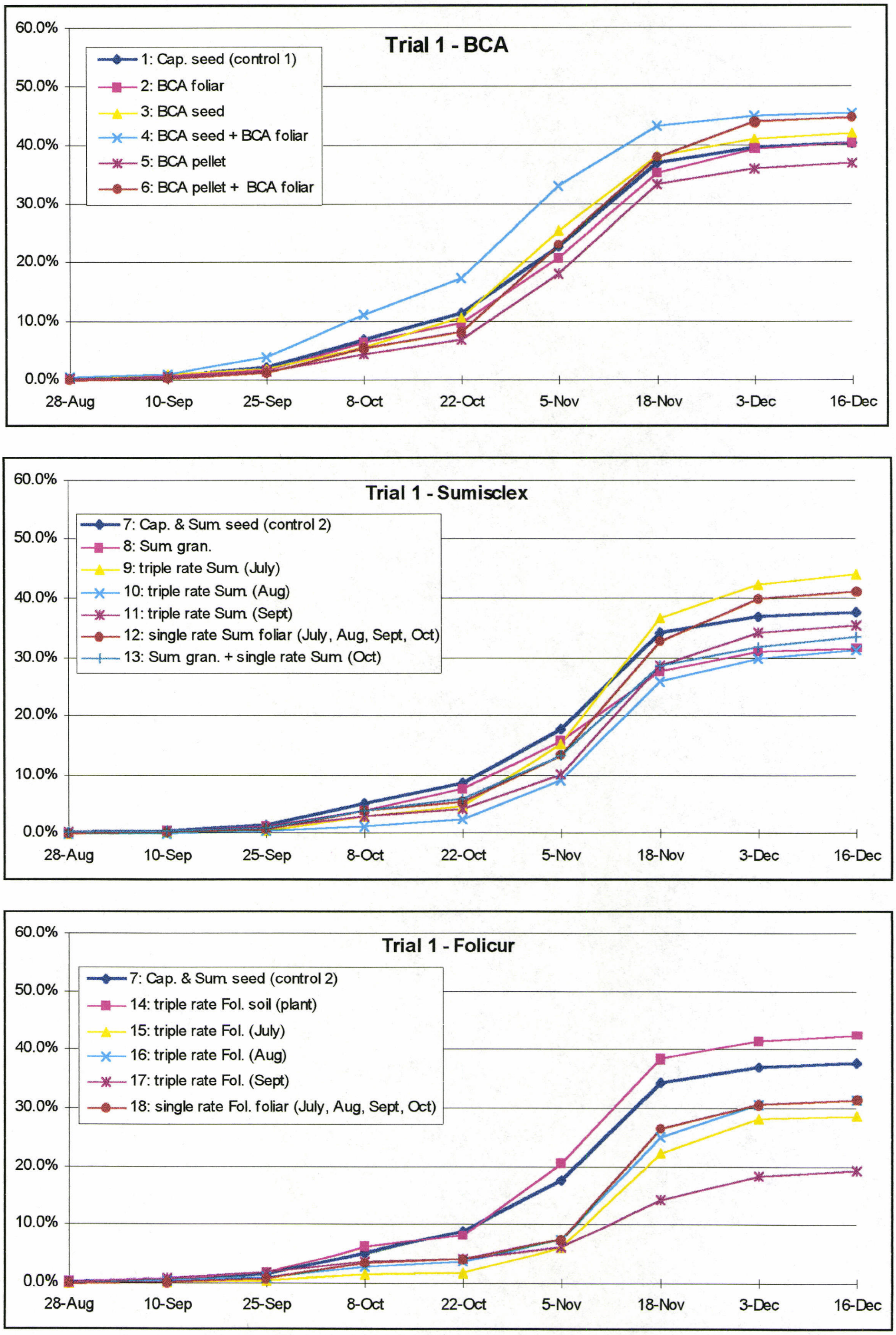


Figure 2. **Disease progress curves for Trial 1. (BCA, Sumisclex treatments, Folicur treatments).**



II. Trial 2

Initial populations and mean total % white rot for each of the treatments are provided in Table 4. Analyses are shown in Figure 3.

Only Treatment 17 (triple-rate Folicur in September), gave disease level values significantly lower (Tukey LSD) than Control 2 at the end of the season.

Disease progress curves for the different treatments are shown in Figure 4. Only a few white rot infected plants were detected at the first assessment (29 August). Overall there was a gradual rise in disease activity during September, increasing through early October, reaching its maximum rate during late October and November and declining in December. As in Trial 1, the triple-rate applications of Folicur applied in July, August and September respectively, all suppressed the disease until early November. Thereafter, the two earlier applied treatments lost their effect and the disease increased rapidly to reach a level similar to that of the untreated control by the end of the season.

The four single-rate monthly applications of Folicur over the period July-October (Treatment 18) had little detectable effect until late October. Thereafter, disease activity was reduced compared with the other treatments. However the final disease level was not significantly lower than in the control. None of the other Folicur treatments resulted in disease levels significantly lower than Control 2 (pairwise LSD).

The most effective Sumisclex treatments were the triple-rate applications made in July, August and September, and the 4 single-rate foliar applications made over the period July to October. However, none of the Sumisclex treatments significantly reduced disease compared with Control 2.

Table 4. **Initial plant populations and mean total diseased plants (%), Trial 2. Bhana property, Tuakau, 1997-98.**

No	Treatment	Initial population	Mean total diseased %	% disease reduction
7	Captan + Sumisclex seed (Control 2)	257.5	49.1	0.0
8	Sumisclex granules	247.0	52.3	-6.5
9	Triple-rate Sumisclex (July)	240.7	55.2	-12.4
10	Triple-rate Sumisclex (Aug)	252.8	47.8	2.6
11	Triple-rate Sumisclex (Sept)	230.7	47.1	4.1
12	Single-rate Sum. foliar (Jul. Aug. Sept. Oct.)	258.7	48.6	1.0
13	Sumisclex gran. + single-rate Sum. (Oct)	243.5	52.1	-6.1
14	Triple-rate Folicur soil (plant)	249.8	48.3	1.6
15	Triple-rate Folicur soil (July)	250.2	46.5	5.3
16	Triple-rate Folicur soil (Aug)	246.7	46.6	5.1
17	Triple-rate Folicur soil (Sept)	236.0	33.9	31.0
18	Single-rate Folicur foliar (Jul. Aug. Sept. Oct.)	240.2	40.9	16.7

Figure 3. **Line scale analyses of total % white rot for Trial 2. Treatments 7-18.**

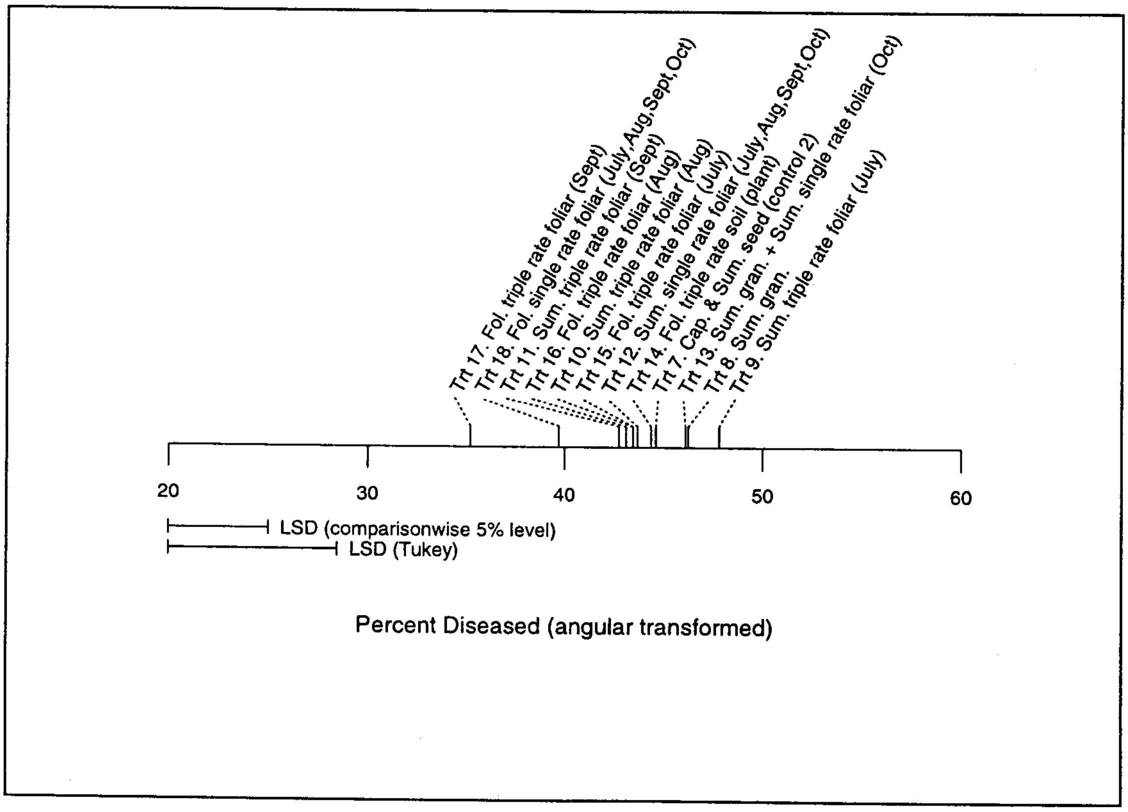
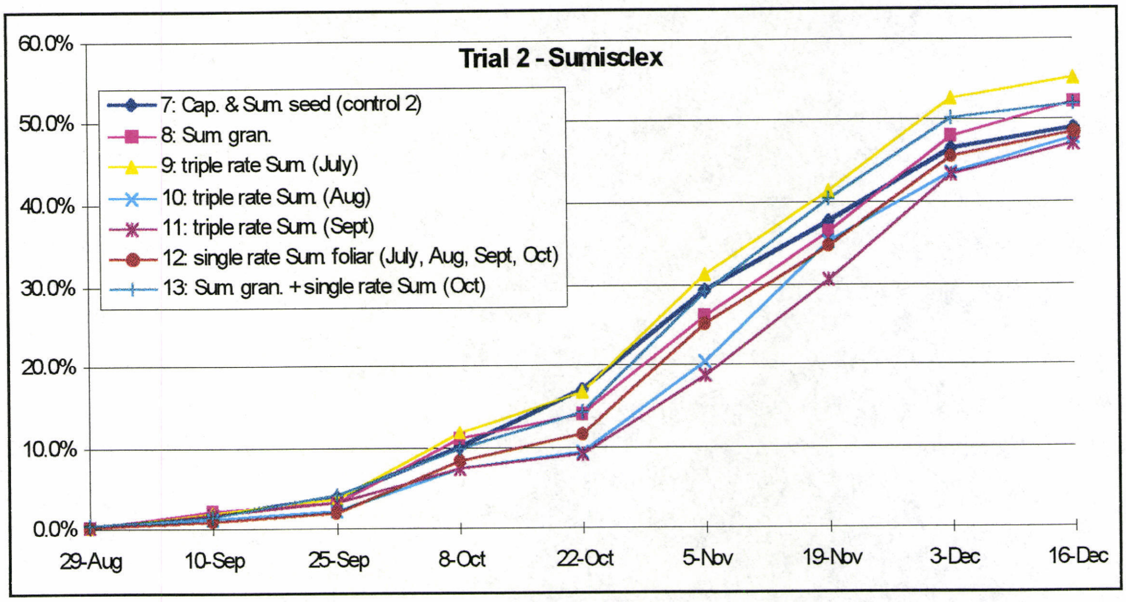
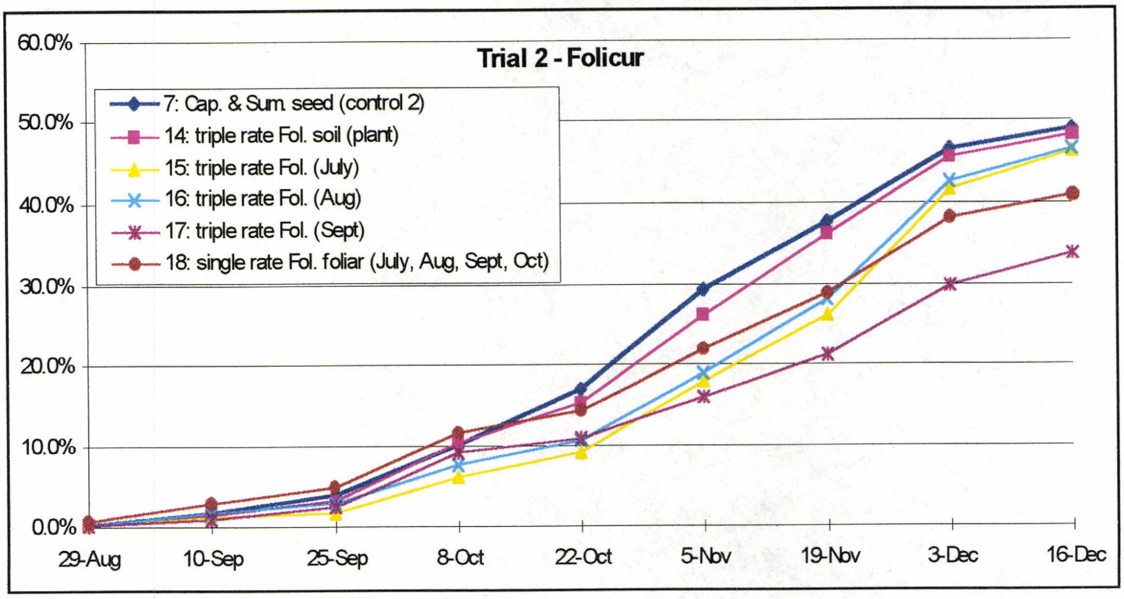


Figure 4. **Disease progress curves for Trial 2. (Sumisclex treatments, Folicur treatments).**





III. Trial 3

Initial populations and mean total % white rot for each of the treatments are provided in Table 5. Analyses are shown in Figure 5.

Treatments 16 (triple-rate Folicur in August), 17 (triple-rate Folicur in September) and 18 (3x single-rate Folicur foliar sprays) all resulted in significantly lower disease levels than Control 2 using Tukey LSD. Treatment 17 gave the greatest level of control though the results were not significantly different from Treatments 16 and 18. Using the pairwise LSD comparison none of the other treatments resulted in disease levels significantly lower than in the control.

Disease progress curves for the different groups of treatments are given in Figure 6.
White rot infected plants were first detected on 25 September. Thereafter there was a gradual increase in numbers of diseased plants until mid-October followed by period of intense disease activity over late-October and November. Disease activity began to decrease over late-November with relatively few new plants being infected in December.

Of the Folicur treatments, the triple-rate application over the bed surface at planting suppressed disease until late October after which control was lost and the final losses were of the same level as Control 2. Single triple-rate applications in August (Treatment 16) and September (Treatment 17) and the series of single-rate foliar sprays in September, October and November all maintained a high level of control until late October after which disease levels increased but at a lower rate than the untreated control.

Of the Sumisclex treatments, the granular formulation exhibited no control at any time during the season. Sumisclex granules at planting followed by a single-rate Folicur application in November had no effect in reducing disease, the majority of infections having taken place before the Folicur was applied. All of the post-plant applications suppressed the disease to some degree until late-October after which there was a dramatic increase in levels of disease. While no treatment gave final disease levels significantly lower than control, the triple-rate applications of Sumisclex in August and September, and the Shirlan treatments (foliar only, and foliar following Sumisclex granules) were the most effective of the treatments throughout the season.

Table 5. Initial plant populations and mean total diseased plants (%), Trial 3. Reynolds property Tuakau, 1997-98.

No	Treatment	Initial population av/plot	Mean total diseased %	% disease reduction
7	Captan + Sumisclex seed (Control 2)	297.3	37.7	0.0
8	Sumisclex granules	275.8	42.5	12.7
9	Triple-rate Sumisclex (Aug)	304.5	33.4	11.4
10	Triple-rate Sumisclex (Sept)	289.3	35.2	6.6
11	Single-rate Sumisclex (Sept. Oct. Nov)	276.7	38.7	2.7
12	Sum. gran. + single-rate Folicur (Nov)	299.8	38.5	2.1
13	Shirlan foliar	291.5	33.9	10.1
14	Sum. granules + Shirlan foliar	283.0	31.4	16.7
15	Triple-rate Folicur soil (planting)	305.3	38.1	1.1
16	Triple-rate Folicur soil (Aug)	284.2	27.1	28.1
17	Triple-rate Folicur soil (Sept)	303.5	19.4	48.5
18	Single-rate Folicur foliar (Sept. Oct. Nov.)	274.8	22.2	41.1

Figure 5. Line scale analyses of total % white rot for Trial 3. Treatments 7-18.

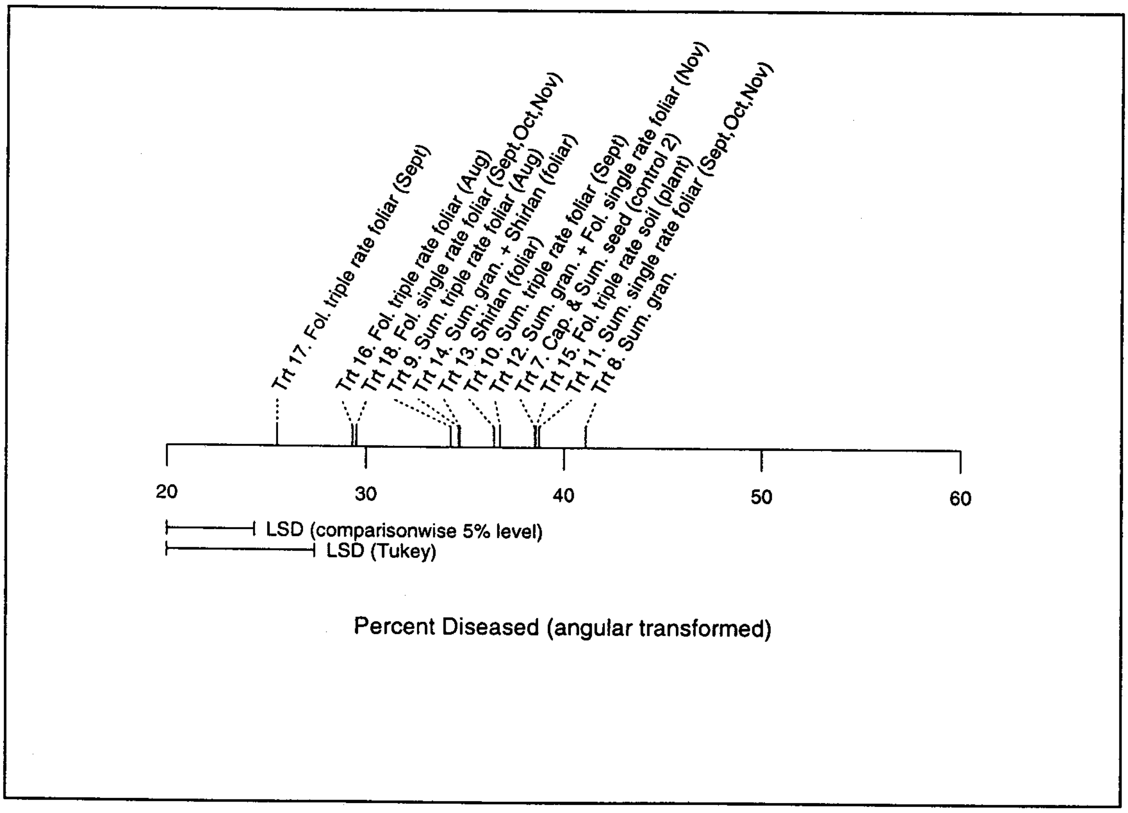
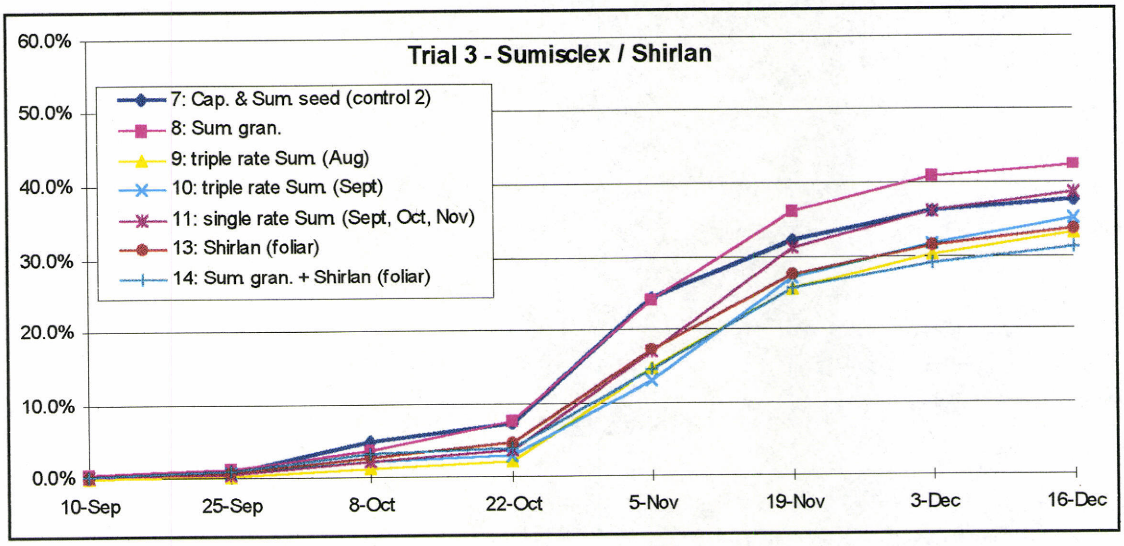
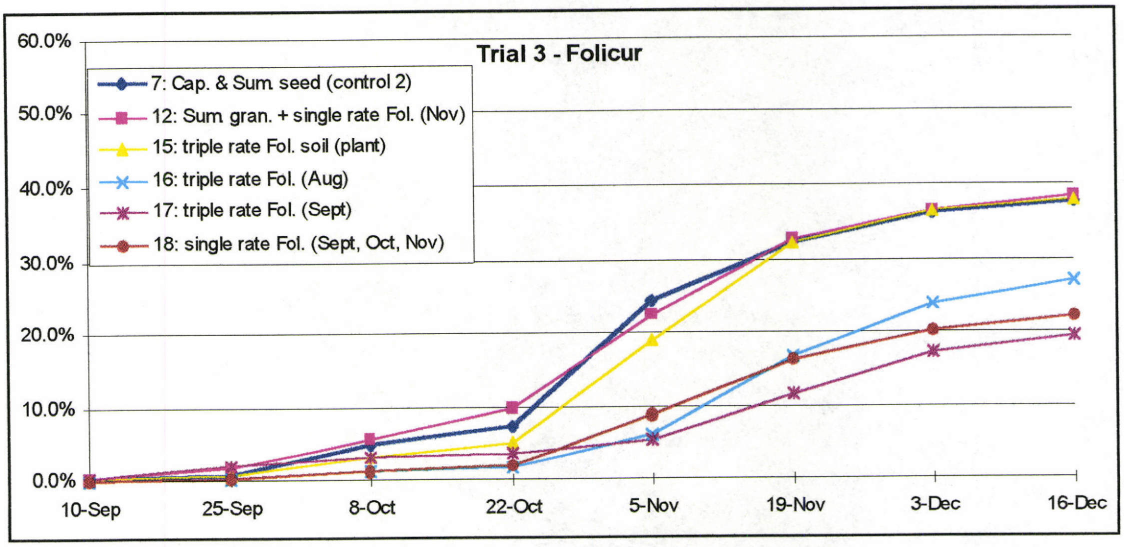


Figure 6. **Disease progress curves for Trial 3. (Sumisclex /Shirlan treatments, Folicur treatments).**





IV. Effect of time of planting on disease severity and efficacy of treatments

In order to compare patterns of disease development and efficacy of treatments on onions at different planting times, disease progress curves for selected treatments in Trials 1 and 3 have been plotted on the same time scale (September - December) in Figure 7.

In each trial, the disease progress curves for the untreated controls (Control 2) follow essentially the same pattern and have the same final total % diseased plants. Similarly the progress curves for like treatments in each of the trials follow almost identical paths and have essentially the same final levels of disease.

V. Effect of site on disease severity and efficacy of control

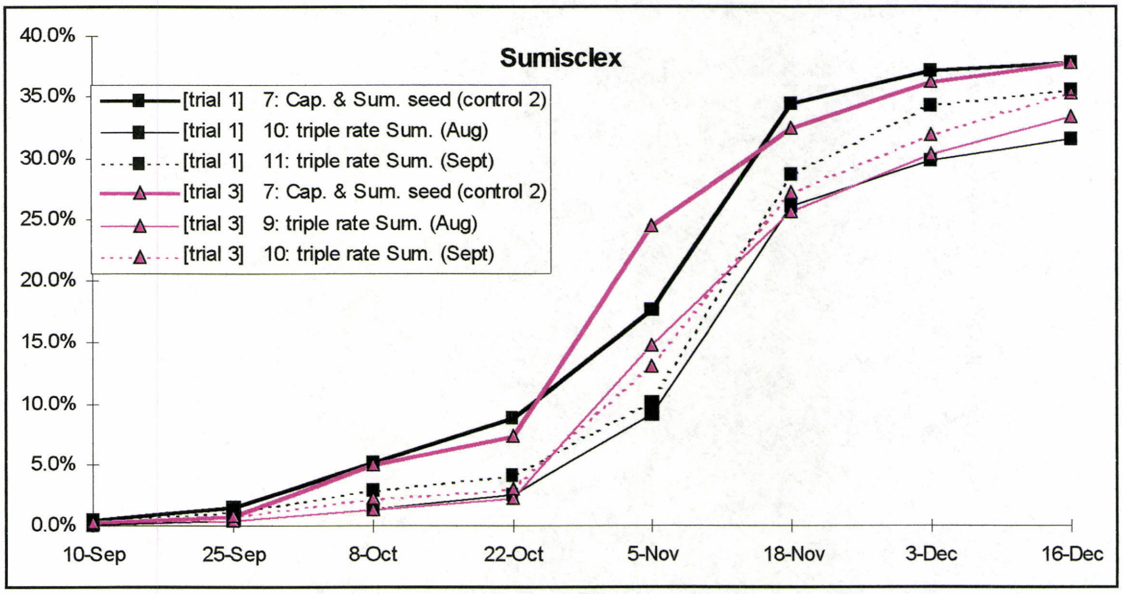
To compare disease levels and efficacy of control at the different sites, the final % diseased plants for the untreated controls (Control 2) for each site and the final % disease for the most effective treatment in each case (triple-rate Folicur in September) are shown in Table 6. The % reduction in disease is also shown.

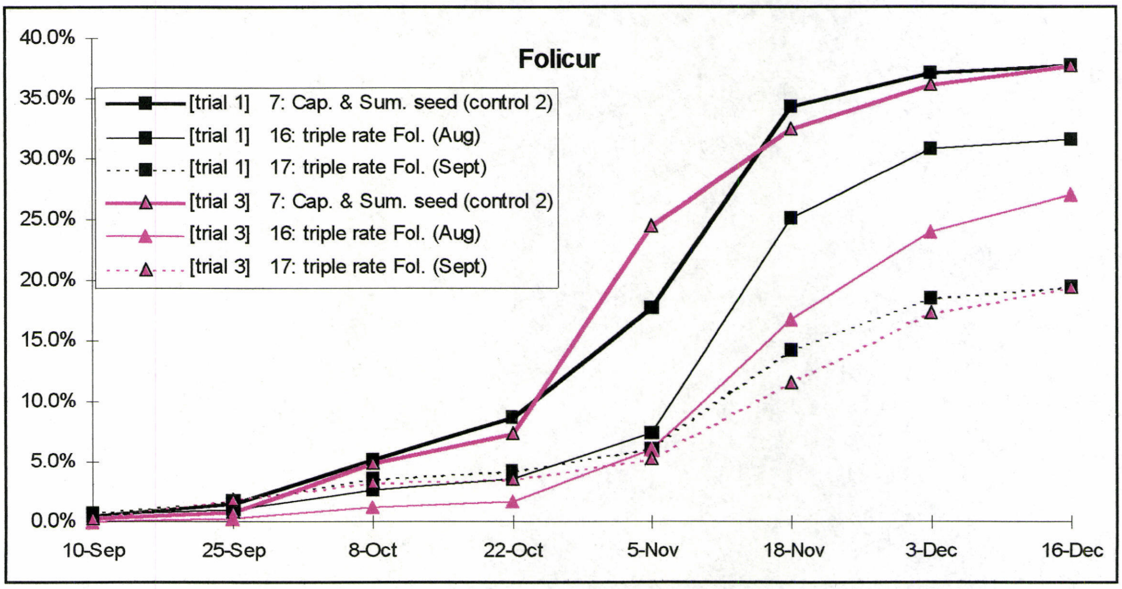
On the Reynolds site (Trial 1 - June planted and Trial 3 - July planted), levels of disease in untreated control plots were essentially the same for both trials (37.8% and 37.7% respectively) as were the levels of disease following the September triple-rate Folicur applications (19.4% in each case). The September treatment achieved a similar level of disease reduction in both trials (48.7% and 48.5%) on the Reynolds site and a 31% reduction in the trial in the Bhana site.

Table 6. Mean total % diseased plants for Control 2 and Treatment 17 for Trials 1, 2, and 3 and % reduction in disease, Reynolds and Bhana properties, Tuakau, 1997-98.

	Mean % diseased plants		% reduction in disease
	Control 2	Treatment 17	
Trial 1 (early-planted)	37.8%	19.4%	48.7%
Trial 2 (early-planted)	49.1%	33.9%	31.0%
Trial 3 (late-planted)	37.7%	19.4%	48.5%

Figure 7. **Disease progress curves for untreated controls and selected Sumisclex and Folicur treatments in Trial 1(June planted) and Trial 3 (July planted), Reynolds property, Tuakau, 1997-98.**





DISCUSSION

Overall, the levels of the disease in all trials were quite high, with untreated plots suffering approximately 40% loss and 50% loss in the Reynolds and Bhana sites respectively. The level of control achieved overall was lower than might have been expected from the range of different treatments applied. The best control, achieved in Trials 1 & 3, gave only a 48% reduction in disease levels. The best treatment in Trial 2 achieved only a 31% reduction in disease. The lower level of control in Trial 2 possibly reflects the higher disease pressure existing at that site.

Performance of Folicur. The only treatment to give a consistent significant reduction in disease across all trials was the triple-rate application of Folicur in September. Triple-rate applications of Folicur in July and August in the early-planted trials and the August application in the later planted trial also consistently reduced disease and were generally superior to other fungicides and application strategies. In the late-planted trial, the standard application regime for Folicur (3 single-rate foliar sprays) was also relatively effective in controlling the disease, but the level of control was inferior to the September triple-rate application. In 3 field trials over the period 1989 -1992, levels of control obtained with Folicur ranged from 83% to 98% for both foliar spray and soil applications (Fullerton *et al.* 1995, plus unpublished commercial reports). With the best control achieved in these trials (triple-rate application in September) at approximately 50% reduction in disease, and with the conventional foliar spray programmes achieving only 16%-41% reduction in disease, the performance of Folicur in these trials was substantially lower than that observed previously. It is too soon to conclude that there is a general loss of efficacy by Folicur, but its performance does need to be critically evaluated in further trials.

Performance of Sumisclex. None of the currently recommended Sumisclex treatments, either as granules at planting or as foliar sprays, provided an acceptable level of control. The result tends to confirm grower impressions over recent years that Sumisclex was not providing the expected levels of control. Sumisclex granules applied at planting had no effect in reducing disease in any of the trials. This is a somewhat surprising outcome given the high level of control achieved by this fungicide in the past. Over the period 1984-1992, Sumisclex was used in 6 different field trials. Disease reductions compared with untreated controls were consistently in the range of 60% to 90+% for foliar spray applications and in the range of 70 to 90% for granules (Fullerton & Stewart 1991; Stewart & Fullerton 1991; Fullerton *et al.* 1995, plus unpublished data). The only conditions under which there was a detectable effect of the granules in this trial was when they were supplemented with multiple applications of Shirlan. The application of either foliar Sumisclex (Trials 1, 2) or Folicur as late-season supplements to granules had no effect.

Potential of Shirlan. Shirlan is currently registered for control of *Botrytis* and downy mildew in grapes and potato, and is being examined for use against these diseases in onion. The fungicide has been shown to significantly reduce white rot when applied as pre-plant drenches and post-plant stem basal spray to module raised onions in UK (Davies *et al.* 1997). The fungicide has also been shown to have a strong effect against the sclerotia of *Ciborinia camelliae* Kohn, a related fungus causing a serious disease of camellia (Fullerton, unpublished data). When applied in Trial 3 here, in a regime suitable for downy mildew control, both alone and following granules at planting, there was a clear trend to a reduction in disease levels. With further development of appropriate rates and application strategies there is a possibility that Shirlan may have a place in a white rot control programme.

Effects of timing of fungicides on disease control. The results of these trials show that in order to control the disease, it is necessary to use a fungicide with a high level of activity against the disease and to introduce it at an appropriate concentration to the soil at the appropriate time. Comparisons of the timing of the most effective treatments in these trials with the patterns of disease development indicate that a high concentration of the fungicide applied immediately prior to the onset of the epidemic had the greatest effect. In each case the triple-rate applications of Folicur in September were more effective than the conventional multiple applications of single-rate concentrations. The results also suggest that when a series of single-rate applications are used, most of the effect is probably derived from the earlier of the applications.

Folicur has a significant penetrative action when applied to plant leaves. The interception and absorption of the fungicide by the dense foliage cover later in the season may be a significant factor in preventing the later-applied fungicides from reaching the site of action in the soil. Applications of Folicur to the soil at planting in these trials failed to control the disease. This is in contrast to earlier experience when soil applications at planting had a season-long effect in controlling the disease (Fullerton & Stewart, 1995). In those trials, the fungicide was applied in a narrow band immediately above the drill row. In the current series of trials, the fungicide was applied evenly over the full surface of the bed. The concentration of the fungicide in the soil in the immediate vicinity of the young plants would be substantially greater under the former application regime than under the latter. This observation further reinforces the principle that the concentration of fungicide in the immediate vicinity of the onion plant is critical for effective control.

In these trials, Folicur has emerged as the only fungicide with reliable activity against white rot. The critical time for its application in this particular series of trials has been shown to be mid-September. A single September application of Folicur at a concentration 3 times that recommended for foliar sprays was consistently superior to all other treatments. In the early-planted trials particularly this strategy not only provided control superior to the conventional programme of 4 foliar sprays, but it was achieved by the use of 25% less product.

Effect of time of planting on disease severity and efficacy of treatments. It is generally considered that later planted crops either suffer less damage from white rot, or that the disease is easier to control. Comparison of disease levels in the 2 trials planted side by side, but a month apart, on the Reynolds property showed that both the timing of the epidemic, the rate of disease development and the final proportion of plants affected was almost identical in both cases. Furthermore, the most effective treatment (Treatment 17) reduced disease levels by precisely the same proportion in each trial.

Overall the time of planting did not greatly affect the response of the disease to the different fungicide treatments. Although the September triple-rate Folicur treatment was still the most effective, there was a tendency for the August triple-rate application and the conventional series of foliar sprays to be more effective in the later-planted trial than in the earlier trial.

CONCLUSIONS

In response to the questions posed at the outset by the working group, the following conclusions are drawn:

1. Are the fungicides Sumisclex and Folicur, as currently recommended for control of the disease, still effective?

Sumisclex, when applied as granules to the soil surface at planting, as a series of foliar sprays during the growing season, or as concentrated applications at strategic times during the season, was unable to provide effective control of the disease. Folicur remains effective against the disease but the conventional application strategy of a series of foliar sprays was only marginally effective and only then in the July planted trial.

2. Do Sumisclex granules, applied at planting, provide adequate protection especially in early-planted (late-May early-June) crops?

Sumisclex granules did not provide adequate protection in the either early-planted or the late-planted trials.

3. Are there fungicide application strategies which might be more effective alternatives to the currently recommended series of "foliar spray" applications (3 or 4 applications at approximately 4-weekly intervals over the period September-November)?

Folicur, as a single application at treble the recommended foliar rate applied in September was consistently superior to all other treatments.

4. What is the relationship between planting time and disease severity, and how does this influence the efficacy of fungicide treatments?

The timing of the disease epidemic in July-planted onions was the same as in an adjacent plot of June-planted onions. The final plant losses (about 40%) and the proportional reduction in disease levels (about 50%) were virtually identical in both the early-planted and late-planted trials.

FUTURE CONSIDERATIONS

This series of trials has clarified a number of issues relating to the efficacy of currently available fungicides and has shown that the use of "single shot" high concentration application strategies offers a superior and possibly more economical control option than the current recommendations. The trials have also provided a better insight into the behaviour of the disease during the season, particularly in relation to disease epidemics in early and late-planted crops.

In order to build on this progress, the following directions for future study are proposed:

1. Further development of single-application strategies to obtain a better understanding of the critical timing under different seasonal conditions.

2. Development of disease prediction systems in order to predict onset of epidemics for timing of key fungicide application. A knowledge of when the disease is likely to enter its active phase, and the anticipated duration of activity, would be of considerable benefit in determining the most appropriate application time.

3. Epidemiological studies to assist in prediction of disease. Reliable disease prediction systems for white rot will depend on an understanding of the relationship between inoculum potential in the soil, stage of host development, prevailing environmental conditions and disease. The relationship between inoculum density in the soil and disease severity is currently under investigation a part of a PhD programme being funded by the Onion Exporters Association. Optimum soil conditions for sclerotial germination and disease development need to be determined.

4. Further assessment of Shirlan as an alternative to Sumisclex. With Sumisclex apparently no longer effectual in the Pukekohe district, Folicur is the only effective fungicide currently available. An alternative is urgently required to decrease selection pressure for resistance development to Folicur.

5. These trials have shown that in cases of high disease pressure, even the most effective fungicide treatments may not provide commercially acceptable levels of control. To ensure sustainable onion production in the district alternative strategies must be employed to reduce sclerotial numbers in the soil (and hence potential disease) to levels at which conventional fungicides will be able to control the disease. These will include the use of germination stimulants such as the diallyl disulphide (DADS), biocontrol agents and appropriate crop rotations. Further development of BCAs will be continued by Lincoln University in association with Agrimm Technologies Ltd., Christchurch, to maximise the early season disease suppression and to maintain it throughout the season.

6. Critical fungicide evaluation trials need to be conducted in Canterbury to determine the efficacy of the different fungicides and application strategies under the environmental conditions encountered there.

ACKNOWLEDGEMENT

The successful conduct of field trials of the kind reported here are totally dependent on the willing cooperation of growers. This series of trials represents one of the most intensive programmes of field research carried out on Onion White Rot in New Zealand in recent times. The work would not have been possible without the support of Peter Reynolds (T.A.Reynolds Ltd), and Dinesh Bhana. In each case the grower devoted valuable land, time, equipment and materials to the trials. All trials were planted by the Reynolds brothers who also provided labour for harvesting the 2 trials on their property. It is appreciated that trials of this type have a certain "nuisance value" to growers particularly at critical times for normal farming activities. Yet at all times assistance was willingly provided. The authors, the New Zealand Onion Exporters Association and the industry in general owe a debt of gratitude to those growers for their direct contribution to this work.

REFERENCES

Davies, J.M.Li.; Watling, M.; Savinelli, C. 1997. Control of *Allium* white rot (*Sclerotium cepivorum*) in module-raised onions with fluazinam. ANNP - Fifth International Conference on Plant Diseases Tours 3-4-5 December 1997.

Fullerton, R.A.; Stewart, A. 1991. Chemical control of onion white rot (*Sclerotium cepivorum* Berk.) in New Zealand. New Zealand Journal of Crop and Horticultural Science. 19: 121-127.

Fullerton, R.A.; Stewart, A.; Slade, E.A. 1995. Use of the demethylation inhibiting fungicides (DMIs) for the control of onion white rot (*Sclerotium cepivorum* Berk.) in New Zealand. New Zealand Journal of Crop and Horticultural Science. 23: 121-125.

Stewart, A.; Fullerton, R.A. 1991. Additional studies on the control of onion white rot (*Sclerotium cepivorum* Berk.) in New Zealand. New Zealand Journal of Crop and Horticultural Science. 19: 129-134.

APPENDIX 1.

Details of fungicides, rates, and methods of application in Trials 1, 2 and 3.

Fungicides used

The fungicides used were:

captan	as Orthocide® 80W	for seed treatments
procymidone	as Sumisclex® WP (50%ai)	for seed treatments
	as Sumisclex Granules (10%ai)	for soil surface applications
	as Sumisclex® 25 (flowable)	for foliar sprays
tebuconazole	as Folicur® 430SC	for soil sprays and foliar sprays
fluazinam	as Shirlan®	for foliar sprays.

Seed Treatments

Seed for untreated control plots and plots to receive biocontrol treatments were treated with Orthocide (10g product/kg of seed) only to provide protection from damping off fungi. Seed for all other treatments were treated with both Orthocide (10g product/kg of seed) and Sumisclex (10g product/kg of seed), the standard commercial treatment for onion seed.

Soil treatments

Sumisclex Granules. Granules were applied to the soil surface above each drill row immediately after planting at the rate of 0.55g/metre of drill row. The appropriate quantity of granules for each individual plot row was weighed into small packets and sprinkled by hand along each row.

Folicur. Folicur soil treatments were applied as spray on the soil over the bed surface immediately after planting at the rate of 2.625 l product in 500 l water per hectare. The fungicide was applied using a precalibrated timed application of known pressure and nozzle output.

Foliar Sprays

Sumisclex - Single-rate. Based on label recommendation of 3.0 l product/ha. The rate of water was reduced from the label recommendation of 1000 l/ha to 500 l/ha, to more closely simulate common commercial practice.

Sumisclex - Triple-rate. A single application of 9 l product in 500 l/ha water, providing the same amount of product as 3 foliar sprays at normal recommended label rates.

Folicur 430SC - Single-rate. Based on label recommendation of 0.875 l product/ha. The rate of water was reduced from the label recommendation of 1000 l/ha to 500 l/ha, to more closely resemble common commercial practice.

Folicur 430SC - Triple-rate. A single application of 2.625 l product in 500 l/ha water, providing the same amount of product as 3 foliar sprays at normal recommended label rates.

Shirlan 11 applications of Shirlan were made at the rate of 0.5 l of product in 500 l/ha. Application dates were as follows: 13/9/97, 26/9/97, 9/10/97, 21/10/97, 3/11/97, 14/11/97, 25/11/97, 5/12/97, 17/12/97, 28/12/97 and 14/1/98.

All foliar sprays of Sumisclex and soil and foliar sprays of Folicur were applied by hand-operated knapsack using a timed application of known pressure and nozzle output. Shirlan was applied by means of a hand-held, compressed air boom sprayer calibrated for a known output using a constant walking speed.

APPENDIX 2.

Trial Layout 1 and 3 : Reynolds property, Bollard Rd, Tuakau 1997-98

	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	
12	8	6	12	13	1	14	15	5	17	*12*
11	7	5	11	12	6	13	14	4	16	*11*
10	17	2	9	10	3	11	12	1	14	*10*
9	16	4	8	9	5	10	11	3	13	*9*
8	12	3	16	17	4	18	7	2	9	*8*
7	15	1	7	8	2	9	10	6	12	*7*
6	18	4	10	11	1	12	13	3	15	*6*
5	14	1	18	7	4	8	9	6	11	*5*
4	13	3	17	18	6	7	8	2	10	*4*
3	11	5	15	16	2	17	18	4	8	*3*
2	9	2	13	14	5	15	16	1	18	*2*
1	10	6	14	15	3	16	17	5	7	*1*
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	

Headland ↑ N

APPENDIX 3.

Trial Layout : Bhana property, Friedlander Rd, Tuakau 1997-98

	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	
12	15	1	7	8	2	9	10	6	12	*12*
11	12	3	16	17	4	18	7	2	9	*11*
10	7	5	11	12	6	13	14	4	16	*10*
9	16	4	8	9	5	10	11	3	13	*9*
8	17	2	9	10	3	11	12	1	14	*8*
7	8	6	12	13	1	14	15	5	17	*7*
6	11	5	15	16	2	17	18	4	8	*6*
5	10	6	14	15	3	16	17	5	7	*5*
4	18	4	10	11	1	12	9	3	15	*4*
3	13	3	17	18	6	7	13	2	10	*3*
2	14	1	18	7	4	8	8	6	11	*2*
1	9	2	13	14	5	15	16	1	18	*1*
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	

S
↑