This report has been prepared by The Horticulture & 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 19/4/99.

Portfolio Manager

Date 19/4/99

A Study of the Strategic Application of Fungicides for the Control of Onion White Rot (*Sclerotium cepivorum*) and Observations on the Development of the Disease in Relation to Soil Moisture and Temperature

R.A. Fullerton and J.L. Tyson

February 1999

Confidential report to the New Zealand Onion Exporters' Association

R.A. Fullerton and J.L. Tyson
The Horticulture and Food Research
Institute of New Zealand Ltd
MT ALBERT RESEARCH CENTRE
Private Bag 92169
Auckland
Telephone: (09) 815 4200
Facsimile: (09) 815 4201

HortResearch Client Report No. 1999/203
Contract No. 4519

CONTENTS

EXECUTIVE SUMMARY

Strategic application of fungicides for the control of Onion White Rot (*Sclerotium cepivorum*) and observations on the development of the disease in relation to soil moisture and temperature.

R.A. Fullerton and J.L. Tyson March 1999

HortResearch was commissioned by the Onion Exporters Association of New Zealand Ltd to undertake a research programme on the control of onion white rot in the Pukekohe district in the 1998-1999 onion cropping season. The principal aims of the programme were:

1. To further refine single application strategies for the use of fungicides to control the disease.

2. To carry out epidemiological studies of the disease with the aim of developing a system for predicting the onset, potential severity and duration of the epidemic. This would potentially be used as a guide to the timing of fungicide applications.

The principal findings were:

1. Sumisclex, applied as a seed treatment, is effective in slowing the onset of the disease for up to 8 weeks.

2. Sumisclex, applied as 3 foliar sprays at label rates during the course of the season, had no effect in controlling the disease.

3. Folicur, applied at label recommendations and as single triple rate applications at different times over the period July to October, significantly reduced losses from disease.

4. The control provided by Folicur was not outstanding with the best treatment (Folicur at label rates) reducing disease by only 31.6%.

4. Single applications of Folicur, applied at triple the normal rate, can be as effective as the current label recommendations.

5. The most appropriate time to apply triple rate treatments for the 1998-99 season was from early to late-September.

6. Plant-to-plant spread is a factor in epidemic development and is reduced by fungicide applications. Low plant numbers and irregular plant spacing in the trial limited the quality of information able to be obtained. The exercise has shown that the methods for mapping the incidence of disease in the trial plots, and the computer programmes developed for handling and analysing the mapping data are effective.

7. Rainfall during the growing season does not seem to be directly correlated with disease development.

8. Soil moisture data for the trial was limited by the late installation of the equipment and its loss by theft several months later. No correlation could be made from the data available.

9. Soil temperature is an important factor in the initiation of the epidemic. Higher than average soil temperatures in 1998 resulted in disease activity commencing in July and increasing rapidly through the period September to December.

Future research in this area should aim to develop a better understanding of the relationships between environmental factors, the timing, severity and duration of the epidemic and the efficacy of fungicides when used in different application strategies. In particular, emphasis should be given to activities that will allow the development of a method for predicting the timing of the disease epidemic. Such knowledge will allow growers to adopt the most effective application strategy for fungicides.

There is a need to find alternative fungicides to Folicur for the control of white rot.

INTRODUCTION

Background

A comprehensive programme of fungicide trials was carried out on behalf of the New Zealand Onion Exporters Association over the 1997-98 growing season (Fullerton *et al* 1998). The main findings were:

1. Sumisclex, applied either 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.
2. Folicur provided effective control of 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.
3. Folicur, as a single application at treble the recommended foliar rate applied in September, was consistently superior to all other treatments.
4. The time of planting (June vs. July) did not affect the timing of the disease epidemic in adjacent June and July planted crops nor the efficacy of the fungicides used.

In order to improve the efficiency of fungicidal control, the most effective time for application of fungicides must be identified. This requires an understanding of how the activity of the fungus and the subsequent disease epidemic are related to soil conditions.

Aims of trial programme for 1998-99

1. To further refine "single-shot" strategies for the application of fungicides in order to better understand the critical timing for applications.

2. To carry out epidemiological studies of the disease with the aim of developing a system for predicting the onset, potential severity and duration of the epidemic. This would potentially be used as a guide to the timing of fungicide applications.

METHODS

Location: The trial was located on the property of T.A. Reynolds and Sons, Bollard Rd, Tuakau. The area had been severely affected by white rot in the 1996-97 season. Potatoes were grown on the site during 1997. The soil type is Patumahoe clay loam, rolling phase.

Experimental details: The trial consisted of 16 treatments each replicated 6 times. The trial was laid out on a modified row and column design with each column consisting of a single bed of onions. Each column comprised one replicate and contained each of the treatments once. Each bed contained six rows of onion plants. The layout of the trial is attached (Appendix 1).

Plots were 4m of bed and separated from one another by 1m of bed. Beds were 1.3m wide, giving a plot size of 5.2m^2. The variety used was May and Ryan Pukekohe Longkeeper. The trial was planted on 22 June 1998 using a Stanhay precision belt seeder. Apart from the trial treatments, all management operations (herbicide, pesticide, fertiliser and irrigation) were carried out by the participating grower according to his standard farming practice. A high standard of husbandry was maintained throughout the growing season.

Treatments: The list of treatments applied is shown in Table 1. Details of fungicides and application methods are shown in Appendix 2. All fungicide treatments were applied by Alpha Research Limited, Pukekohe. Application details are provided in Appendix 3.

Data collection: Emergence counts, to provide base-level populations, were performed on 29 July 1998. The plots were thereafter inspected in detail for the presence of white rot at fortnightly intervals during the season.

Counts of diseased plants were made on 12 August, 25 August, 9 September, 23 September, 7 October, 21 October, 4 November, 18 November and 2 December. The proportion of plants lost from disease was determined from initial populations and the cumulative numbers of diseased plants recorded during the season. Diseased plants in plots were handled in three different ways according to the protocol.

Count and pull = diseased plants counted and removed from plot.
Count and peg = diseased plants counted, marked with a toothpick and left in plot.
Count, peg and map = diseased plants counted, marked as above and the positions of diseased plants recorded on a map for each plot.

Rainfall was measured at the Pukekohe Research station of the New Zealand Institute for Crop and Food Research. Temperature was measured by continuous data logging of soil temperature at a depth of 10 cm in the trial site. Soil moisture was measured by means of Enviroscan automatic soil moisture monitoring equipment, also located on the site. Unfortunately, the Enviroscan equipment was stolen from the site in October 1998, leaving soil moisture data incomplete.

Table 1. Schedule of treatments 1998-99 Crop Year

Trt No.	Seed Treatment	Foliar applications of fungicides	Timing	Recording
1	Captan	Untreated control 1	-	count pull
2	Captan	Untreated control 1	-	count peg and map
3	Captan + Sumisclex	Untreated control 2	-	count pull
4	Captan + Sumisclex	Untreated control 2	-	count peg
5	Captan + Sumisclex	Sumisclex 25 Standard rate (3*l* product/ha)	3x applications from 6 weeks after planting	count pull
6	Captan + Sumisclex	Folicur 430 SC Standard rate (0.875*l* product/ha)	3x monthly from 6 weeks after planting	count pull
7	Captan + Sumisclex	Folicur 430 SC Standard rate (0.875*l* product/ha)	3x monthly from 6 weeks after planting	count peg and map
8	Captan + Sumisclex	Folicur 430 SC Triple rate (2.626*l* product/ha)	single mid-July	count pull
9	Captan + Sumisclex	Folicur 430 SC Triple rate (2.626*l* product/ha)	single mid-July	count peg
10	Captan + Sumisclex	Folicur 430 SC Triple rate (2.626*l* product/ha)	single early-August	count pull
11	Captan + Sumisclex	Folicur 430 SC Triple rate (2.626*l* product/ha)	single mid-August	count pull
12	Captan + Sumisclex	Folicur 430 SC Triple rate (2.626*l* product/ha)	single mid-August	count peg and map
13	Captan + Sumisclex	Folicur 430 SC Triple rate (2.626*l* product/ha)	single early-September	count pull
14	Captan + Sumisclex	Folicur 430 SC Triple rate (2.626*l* product/ha)	single mid-September	count pull
15	Captan + Sumisclex	Folicur 430 SC Triple rate (2.626*l* product/ha)	single mid-September	count peg and map
16	Captan + Sumisclex	Folicur 430 SC Triple rate (2.626*l* product/ha)	single early-October	count pull

Analysis of results: The total number of plants with onion white rot were expressed as a percentage of the number of plants counted at emergence. The percentages were transformed to the arc-sine scale before analysis to stabilise variance. A REML (residual maximum likelihood) analysis was carried out using the GENSTAT statistical package.

The results from the "mapped" plots were entered fortnightly into an Excel spreadsheet. An Excel program was written to recognise the number of new infections occurring adjacent to previously infected plants ("actual") at each assessment date and to calculate the number of these new infections which would have occurred next to previously infected plants had infection occurred completely at random ("expected"). "Actual" versus "expected" comparisons were made for each of the mapped treatments. If the "actual" number is consistently greater than the "expected" number then it could be presumed that plant-to-plant, or secondary infection is occurring.

The environmental data (temperature, rainfall and soil moisture) was all converted to Excel spreadsheets for manipulation and presentation.

RESULTS

Emergence, establishment and disease distribution

The plants in the trial area emerged evenly, but plant populations were considerably lower than the anticipated 250 plants per plot derived from the planter settings. The distribution of plants within the rows was also irregular with numerous doubles and large gaps (up to 10cm) between plants. This effect was attributed to uneven planting, possibly caused by worn seeding belts in the seeder.

Upon examination of final percentages of disease it was found that the disease was unevenly distributed throughout the trial site, being much more severe towards one end of the block (Appendix 4). As the variability amongst results of the same treatment increases, there must be a greater difference between treatment means in order for differences to be recognised as statistically significant. In this trial the variability has possibly masked some differences between treatments but this is not considered to have materially affected the overall results.

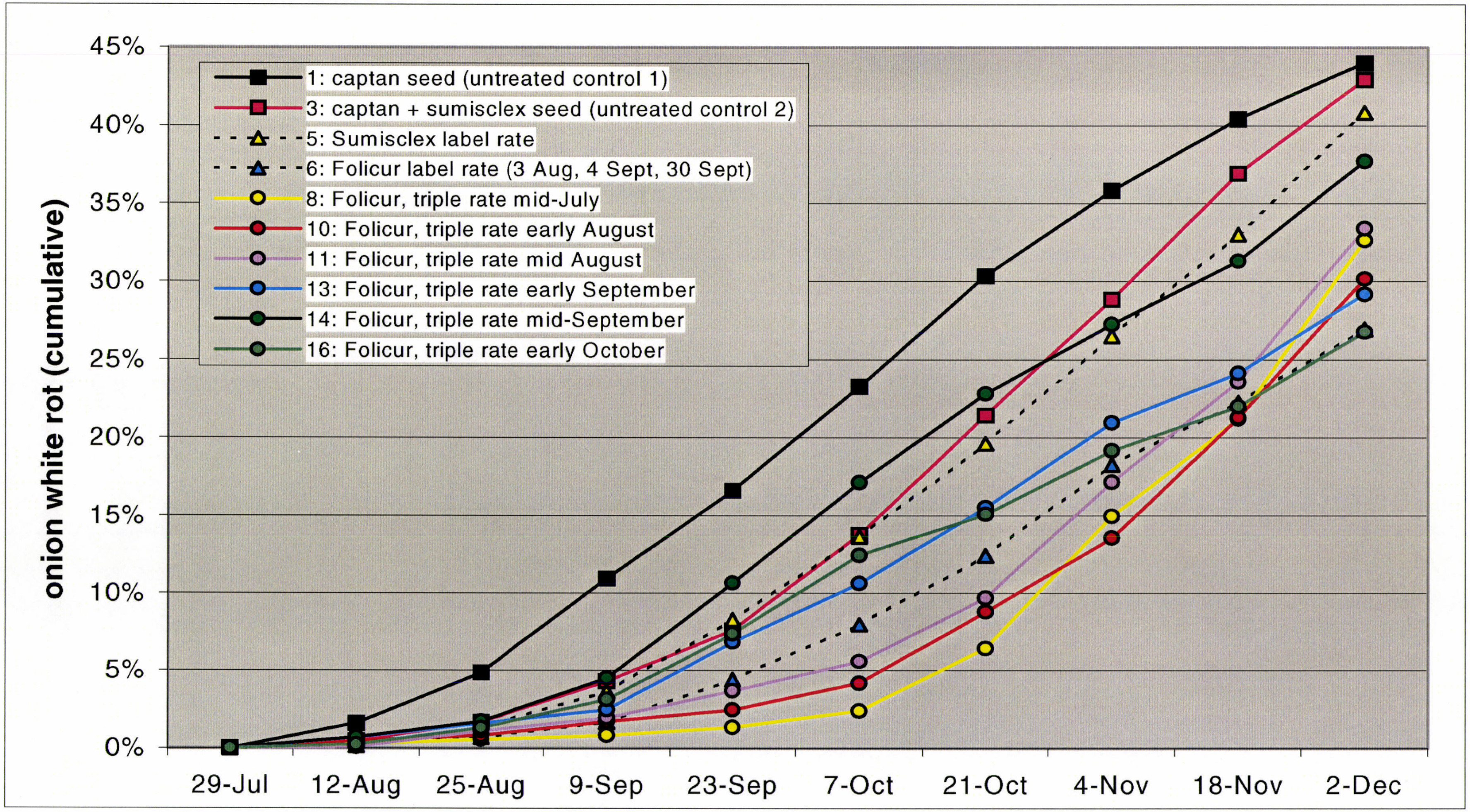
Treatments recorded by counting and removing diseased plants (Trts 1, 3, 5, 6, 8, 10, 11, 13, 14, 16).

The mean initial plant populations, arc-sine transformed mean of total percent white rot, back transformed means of percent disease incidence and the relative reduction in disease compared with the untreated control are presented in Table 2. The cumulative percentages of disease for each treatment regime throughout the growing season are shown as a series of disease progress curves (Figure 1). The disease percentages used in developing the disease progress curves are treatment means calculated directly from field data and will therefore differ slightly from the back-transformed means of white rot incidence shown in Table 2.

Table 2. REML analysis of arc-sine transformed results, initial populations and percentage increase in control in treatments in which diseased plants were removed.

No	Treatment	Average emergence	Arc-sine transformed percentages	% incidence onion white rot	% disease reduction
1	Untreated control 1 – captan seed	193	41.6	44.0	
3	Untreated control – captan and Sumisclex seed	212	39.2	39.9	0.0
5	Sumisclex label rate	220	39.0	39.7	0.5
8	Folicur triple rate mid July	216	37.1	36.3	9.0
10	Folicur triple rate early August	214	35.9	34.4	13.8
11	Folicur triple rate mid August	201	34.1	31.5	21.1
14	Folicur triple rate mid September	200	33.7	30.8	22.8
16	Folicur triple rate early October	203	33.3	30.2	24.3
13	Folicur triple rate early September	199	32.4	28.8	27.8
6	Folicur label rate	212	31.5	27.3	31.6
	SED		1.4		

Figure 1. **Disease progress curves for treatments in which diseased plants had been removed from the plots. T.A Reynolds Ltd, Bollard Rd, Tuakau 1998-99.**



Disease was first observed during the initial assessment, six weeks after planting (12 August 1998). The number of diseased plants in the untreated control plots increased rapidly from August through to the final counts in mid-December. Plant losses from white rot in the untreated plots were in the range of 32-50%.

Comparisons of efficacy for the different fungicide treatments should be made with values in Treatment 3 (untreated control - Captan and Sumisclex treated seed). This is the industry standard treatment and was applied to seed for all the subsequent fungicide treatments. The principal features were:

1. Comparison of the disease progress curves for seed treated with Captan alone and seed treated with Captan and Sumisclex shows that the addition of Sumisclex significantly delayed the onset of the epidemic but the final percentages of disease were similar.
2. Sumisclex applied at label rates had no effect in controlling the disease, with the disease progress curve for that treatment closely paralleling that of the equivalent untreated control (Trt 3).
3. All Folicur treatments had some control.
4. While the differences between Folicur treatments were not large it may be concluded that for this years trial later applications of single, triple rate applications were more effective than earlier applications.
5. Folicur applied at the label rate had the greatest control in this trial, but even this treatment only reduced final disease levels by 31.6% in comparison to the untreated control.

Treatments recorded by counting and pegging diseased plants.

The cumulative percentages of disease in the two treatments (Trts 4 & 9), recorded by counting and pegging diseased plants are shown in Table 3. The differences in percent disease between the two treatments were not statistically significant. The percentages of diseased plants recorded were less than in comparable treatments assessed by counting and removing diseased plants (Table 2). This was considered to be the direct result of the difficulty in differentiating new infections from previously pegged plants.

Table 3. Average emergence and final percent disease in treatments assessed by counting and pegging diseased plants and the comparable treatments assessed by counting and removing diseased plants.

Trt	Treatment	Method of assessment	Average emergence	% disease incidence
3	Untreated control	Count and pull	212	39.9%
4	"	Count and peg	209	31.5%
8	Folicur triple-rate mid-July	Count and pull	216	36.3%
9	"	Count and peg	213	27.1%

Treatments recorded by counting, pegging and mapping diseased plants.

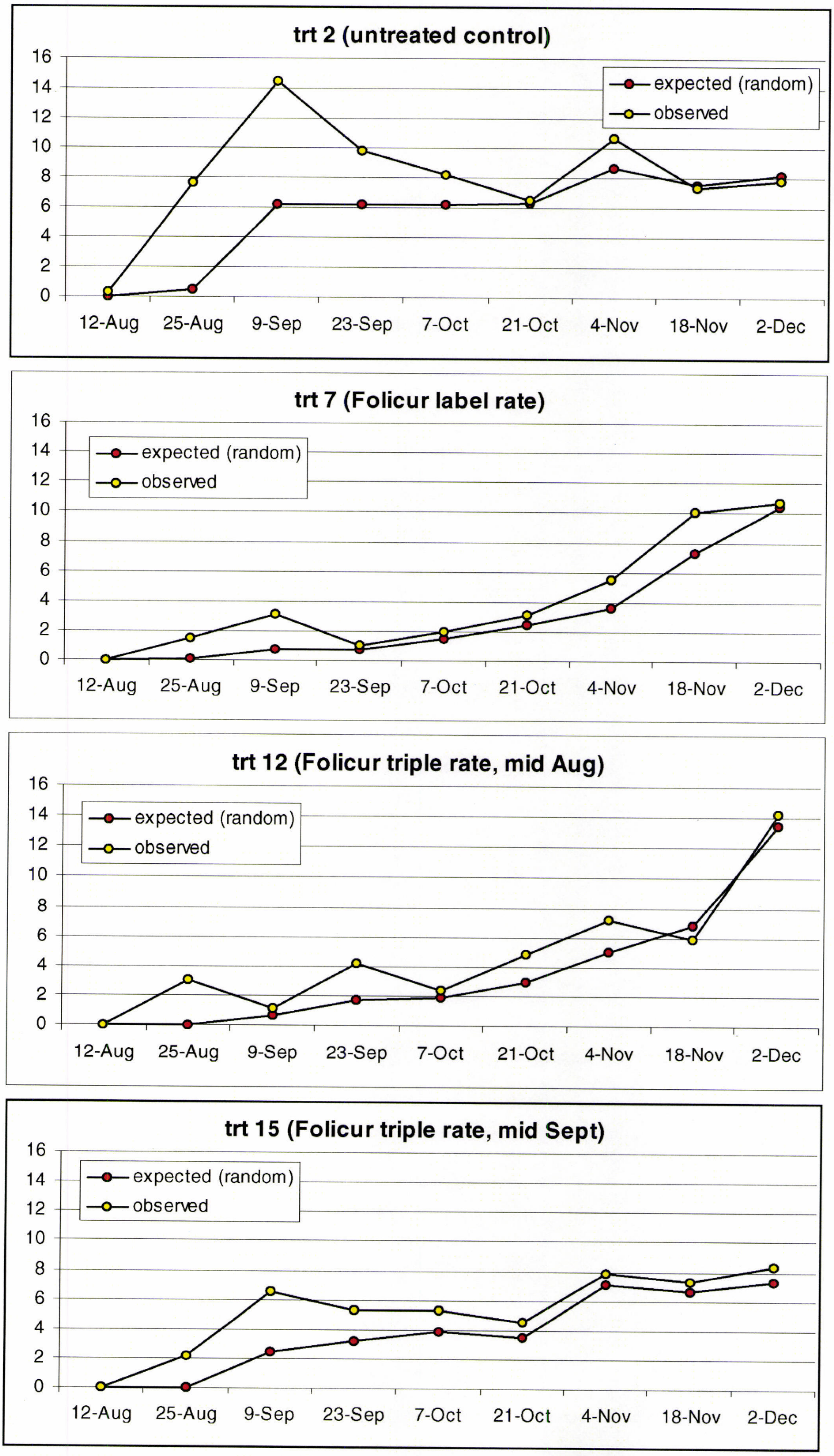
The cumulative disease percentages for four treatments recorded by counting, pegging and mapping diseased plants (Treatments 2, 7, 12 and 15) are shown in Table 4. Each of the treatments had higher levels of final infection than comparable treatments assessed by the "traditional" recording method of counting and pulling. This was due to the more stringent inspection required for mapping as every plant was individually identified and checked at each assessment date. The final percentages of disease in the three fungicide treatments were statistically lower than that of the untreated control. The results for the three fungicide treatments were not different from one another.

Table 4. Average emergence and final percent disease in treatments assessed by counting, pegging and mapping diseased plants and the comparable treatments assessed by counting and removing diseased plants.

Trt	Treatment	Method of assessment	Average emergence	% disease incidence
1	Untreated control	Count and pull	193	44.0%
2	"	Count, peg and map	197	58.9%
6	Folicur label rate	Count and pull	212	27.3%
7	"	Count, peg and map	197	35.6%
11	Folicur triple rate mid-August	Count and pull	201	31.5%
12	"	Count, peg and map	193	39.6%
14	Folicur triple rate mid-September	Count and pull	200	30.8%
15	"	Count, peg and map	205	42.3%

An example of a recording (mapping) sheet is shown in Appendix 5. The results of the Excel-based program used to analyse the mapped data are summarised as a series of graphs (Figure 2). In all treatments the observed number of diseased plants occurring adjacent to previously diseased plants were slightly greater than would have been expected had the infections taken place purely at random. The results show that the fungicide treatments reduced plant-to-plant spread of the disease, but that the differences were not great.

Figure 2. Mean number of newly diseased plants that would have randomly occurred next to previously diseased plants, compared to the actual number at each assessment.



Observations on the development of the disease in relation to rainfall, soil moisture and temperature.

The relationships between disease progress and soil temperature, and disease progress and rainfall are shown in Figures 3 and 4 respectively. The relationship between soil moisture and disease progress is shown in Figure 5. The Enviroscan soil moisture monitoring equipment located at Bollard Rd was stolen in early November. Soil moisture data from a nearby site (Parker Lane Rd, Tuakau) has been included in Figure 5 to determine whether it could be used as an alternative source of soil moisture data.

Figure 3 Cumulative percentages white rot and average fortnightly soil temperature at a depth of 10cm

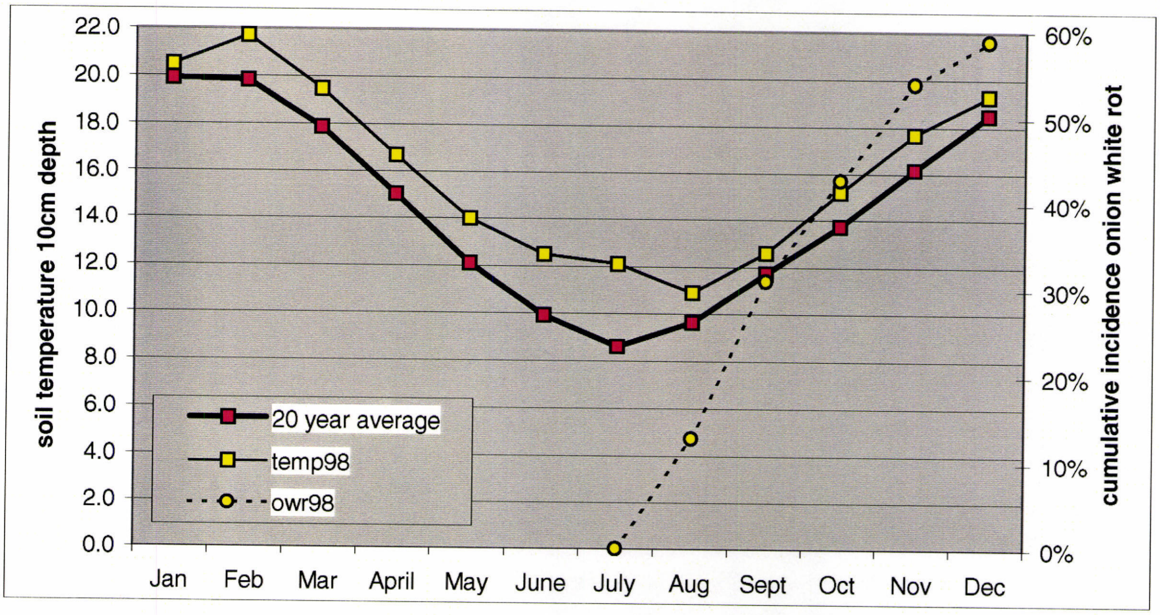


Figure 4 Comparison of cumulative percentage white rot, fortnightly percentage new infections and monthly rainfall (ex Pukekohe Research Station)

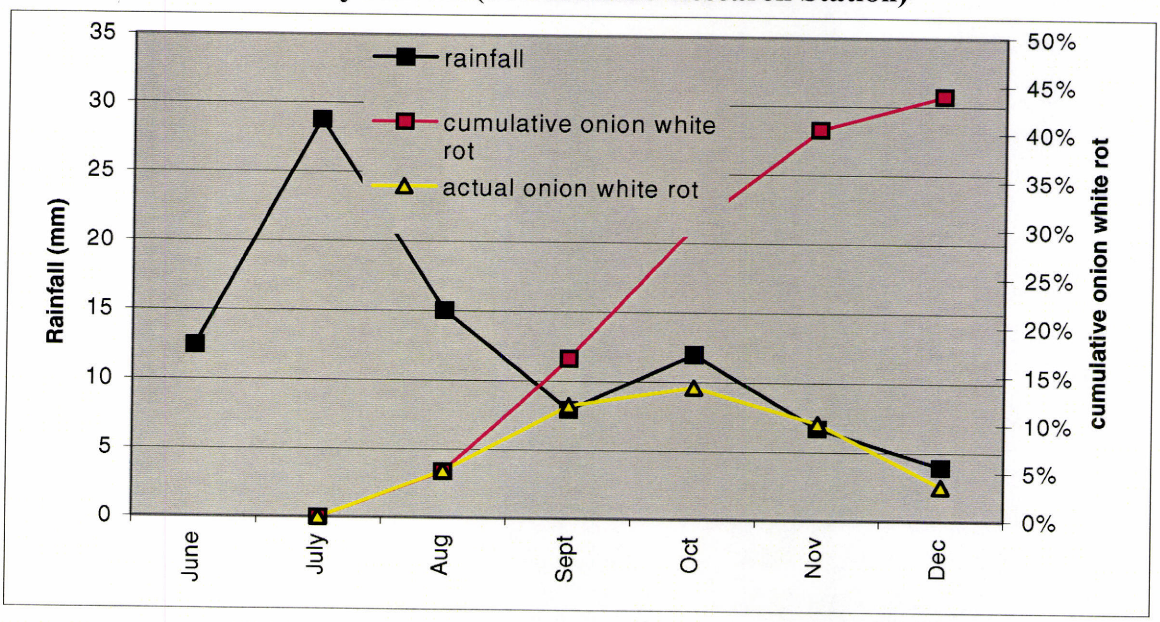
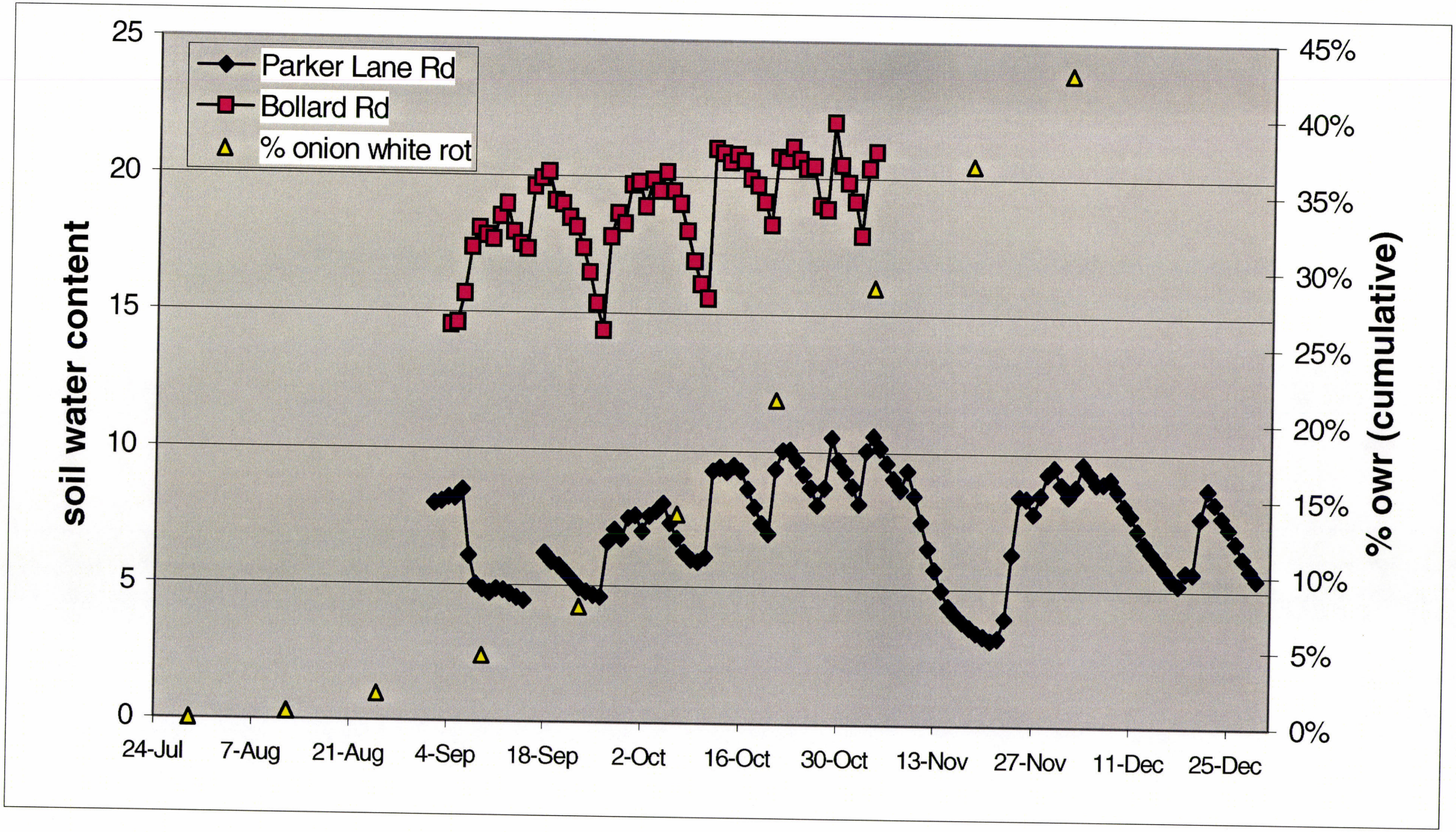


Figure 5 Relationship between average monthly soil moisture and disease progress



DISCUSSION AND CONCLUSIONS

Disease control.

The results have once again demonstrated the effect of the Sumisclex seed treatment in delaying the onset of the epidemic by up to 8 weeks. The activity of Sumisclex as a seed treatment is in contrast to that of the later foliar applications of the same fungicide, which had no effect in providing further control of the disease.

While all Folicur treatments resulted in statistically significant reductions in disease, the extent of control was not outstanding. The best treatment (three foliar applications of Folicur as per label recommendation) reduced disease by only 31.6%.

When applied as single, triple-rate treatments, the later applications (September to early-October) were the most effective. The earliest of the triple rate applications, made in mid-July, provided strong suppression of the disease until early October, after which the disease increased rapidly to become one of the least effective of the triple rate treatments. The most effective triple rate applications were those applied in September and early-October. This result is similar to that obtained in trials in 1997-98 in which triple rate applications made in mid-September were the most effective in controlling the disease (Fullerton *et al.* 1998).

Similar results from triple rate application strategies over two successive years suggest that the timing of the fungicide application(s) are a compromise between early application to suppress the onset of the epidemic and the length of time the application is able to protect the crop. Too early, and the activity of the fungicide may decline before the end of the season. With later applications (e.g. mid-October) the fungicides are being applied during the period of maximum disease activity. There will also be interception of fungicide by the crop canopy and possibly a lack of rain to wash the fungicide into the soil.

Effect of fungicides on plant-to-plant spread.

Field observations suggest that during epidemics when the plants are well bulbed, plant-to-plant spread (secondary infection) is an important component of the epidemic. An attempt was made in the current trial programme to determine the effects of fungicide applications on plant-to-plant spread. Data from plots in which the distribution of diseased plants was mapped showed that there were consistently more diseased plants in adjacent positions than would be expected by chance. The difference was greatest in untreated plots indicating that the fungicide applications were limiting the growth of hyphae through the soil. The extent of plant-to-plant spread occurring in the trial was somewhat less than anticipated from previous general experience. This is attributed to the relatively uneven stands of plants in the plots and in particular the greater than normal spacing between many plants within the rows. This has been the first attempt to quantify the effects of fungicides on plant-to-plant spread and has been a valuable exercise in how to monitor disease activity in a detailed way. In general the methodology worked very well. In future higher populations of evenly spaced plants will be used for these studies.

Environmental factors influencing onion white rot.

Analysis of rainfall data over the growing season indicates that rainfall does not seem to be directly correlated with timing of the disease epidemic, although it will effect soil moisture.

Soil moisture has long been considered to be an important factor in disease development, particularly in relation to the duration of the epidemic, but has never been monitored in association with a closely watched disease situation. An Enviroscan soil moisture monitoring system was installed at the test site. As the system was not obtained and installed until September, and was then stolen in early November, the minimal data obtained is of limited value in determining relationships with disease activity. Soil moisture data obtained from a nearby site (Parker Lane Rd, Tuakau) could not be related to the development of the epidemic in the trial as the Parker Lane site was considerably drier than the trial site. Data will need to be obtained over several seasons in order to identify possible relationships.

Soil temperature appears to be the major factor influencing disease development. The 1998-99 years trial has confirmed impressions gained from earlier trials that the onset and pattern of white rot epidemics are influenced by winter and spring temperatures (Fullerton *et al.* 1998). The unseasonably high winter soil temperatures in 1998 (July 20-year average = 8.6°C; July 1998 = 12.1°C) resulted in the early onset of the epidemic (late July) and a rapid rise in the severity of disease from August to December.

The shape of the disease progress curves in Figure 1 indicate that the epidemic in the untreated control plots tended to slow in December 1988 (possibly due to the reduced numbers of plants available for infection). However, the curves for most of the fungicide treated plots indicated continuing disease activity at the time of the final assessment. The results suggest that while minimum soil temperature may be important in the onset of the epidemic, the disease is still active in soil temperatures of 19.3°C. It is possible that soil moisture may be more important than temperature in slowing the activity of the fungus in the late-spring early summer-months. Future studies should monitor both soil temperature and moisture in order to elucidate their effects on disease epidemics.

Conclusions and Recommendations

1. Sumisclex, applied as a seed treatment, is effective in slowing the onset of the disease up to 8 weeks after planting.

2. Sumisclex, applied as 3 foliar sprays at label rates during the course of the season, had no effect in controlling the disease.

3. Folicur, applied at label recommendations and as single triple rate applications at different times over the period July to October, all significantly reduced losses from disease.

4. The control provided by Folicur was not outstanding with the best treatment (Folicur at label rates) reducing disease by only 31.6%.

4. Single applications of Folicur, applied at triple the normal rate, are as effective as the current label recommendations.

5. The most appropriate time to apply triple rate treatments for the 1998-99 season was from early to late-September.

6. Plant-to-plant spread is a factor in epidemic development and is reduced by fungicide applications. Low plant numbers and irregular plant spacing in the trial limited the quality of information able to be obtained on these factors.

7. Rainfall during the growing season does not seem to be directly correlated with disease development.

8. Soil moisture data for the trial was limited by the late installation of the equipment and its loss by theft several months later. No correlation could be made from the data available.

9. Soil temperature is an important factor in the initiation of the epidemic. Higher than average soil temperatures in 1998 resulted in disease activity commencing in July and increasing rapidly through the period September to December.

FUTURE RESEARCH

Five trials over the past two seasons (3 OEA, 2 Bayer) have examined the optimum timing for single, triple rate applications of fungicide. These trials collectively have begun to provide a picture of the response of the disease to the timing of the fungicide. The results suggest that the control of onion white rot by fungicides could be improved by a better understanding of the epidemiology of the disease. The ability to predict the likely onset, severity and duration of the epidemic would allow growers to utilise the most appropriate options for fungicide application.

Research should aim at relating easy-to-measure parameters such as rainfall, soil moisture and soil temperature to the characteristics of the epidemic. The relationship between inoculum levels and disease severity is being studied as part of a Lincoln University research programme. Collectively the information could allow the development of a system for predicting onion white rot, covering both the weather driven aspects (timing, severity) on a district basis and, using the inoculum/disease severity relationships, levels of risk on a field-by-field basis.

Specific activities would include:

- Review and analysis of data from all trials over the period 1984 to the present to determine relationships between soil temperature, rainfall and the characteristics of the disease epidemic each year.
- Continuation (on a smaller scale) of trials on the relationship between timing of fungicide applications and efficacy of control.
- Repeat of observations on the measurement of plant-to-plant spread, its importance in the development of the epidemic, and the extent to which it is reduced by fungicide applications.

It is recommended that a small technical working group (representing industry, chemical companies and researchers) be established to review the current state of knowledge of the disease, and to develop the framework of the research programme.

ACKNOWLEDGEMENTS

This work could not have been possible without the co-operation and support of Peter Reynolds of T.A. Reynolds Ltd, by making available, the trial site, assisting with the planting and undertaking all husbandry activities on the trial during the course of the season. The authors, the client and the onion industry are indebted to Peter for this contribution.

REFERENCES

Fullerton R.A.; Harris F.M.; Stewart A. 1998. Chemical control and seasonal incidence of onion white rot in New Zealand. Proceedings of the Sixth International Workshop on Allium White Rot, 2-5 March, Guanajuato, Mexico.

Fullerton R.A.; Stewart A.; Wood R.J.; Tyson J.L.; Swaminanthan J. 1998. Effects of different fungicide application strategies on the control of onion white rot (*Sclerotium cepivorum* Berk.) in the Pukekohe district. Report to the New Zealand Onion Exporters' Association, April 1998. HortResearch Client Report No. 98/40. Session 5: 11-15.

APPENDIX 1

Layout of OEA onion white rot trial 1998-99

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

APPENDIX 2

Details of fungicides, rates, and methods of application

Fungicides used:

Active ingredient	*product*	*use*
captan	as Orthocide® 80W	for seed treatments
procymidone	as Sumisclex® WP (50%ai)	for seed treatments
	as Sumisclex® 25 (flowable)	for foliar sprays
tebuconazole 430 g/l	as Folicur® 430SC	for soil sprays and foliar sprays

Seed Treatments:

Seed for untreated control plots was treated with Orthocide (10gm product/kg of seed) only to provide protection from damping off fungi.

Seed for all other treatments was treated with both Orthocide (10gm product/kg of seed) and Sumisclex (10gm product/kg of seed), the standard commercial treatment for onion seed.

Foliar Sprays:

Sumisclex - single rate. Used at label recommendation of 3.0*l* product/ha.

Folicur 430SC - single rate. Used at label recommendation of 0.875*l* product/ha.

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

Methods of application:

For all applications the rate of water was reduced from the label recommendation of 1000*l*/ha to 500*l*/ha, to more closely approximate with common commercial practice. All foliar applications of Folicur were applied by means of a CO2 powered plot sprayer, with 4 x 8003 fan nozzles at 260kPa and 3.6km/hr delivering 500*l*/ha.

APPENDIX 3

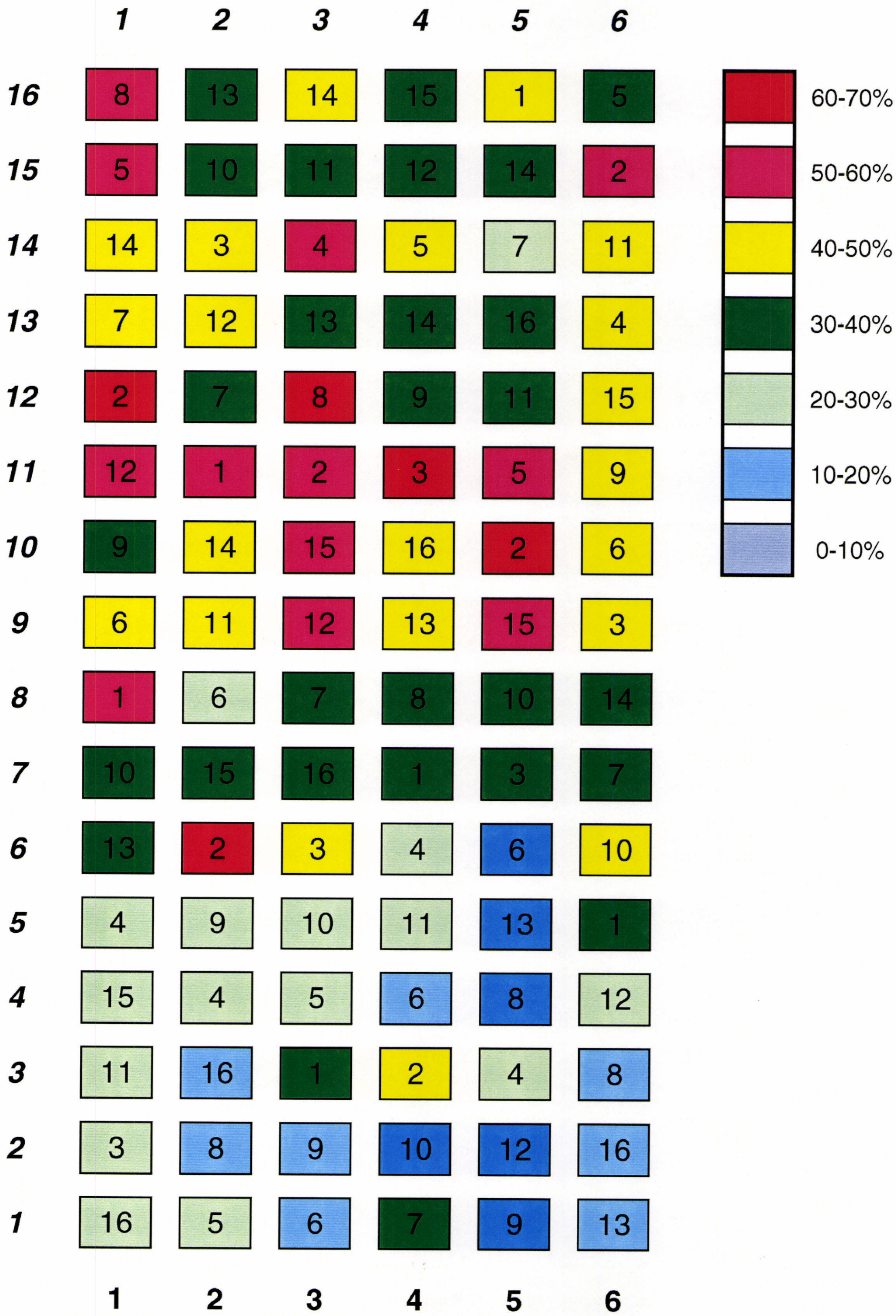
Treatment application details

(as provided by Paul Munro of Alpha Research Limited)

Application Number	*1*	*2*	*3*	*4*	*5*	*6*
Date	16.07.98	03.08.98	14.08.98	04.09.98	15.09.98	30.09.98
Interval (days)	-	18	11	21	11	15
Growth Stage	1-2 leaf	2-3 leaf	3 leaf	3 leaf (200mm)	3-4 leaf (250mm)	4 leaf (350mm)
Foliage (wet/dry)	Dry	Dry	Dry	dry	wet	wet
Air Temperature (°C)	16	15	16	13	16	15
Relative Humidity (%)	-	58	69	66	89	94
Soil Temperature (°C)	-	15	14	12	14	15
Soil Moisture	Wet	Wet	Wet	moist	moist	wet
Wind (km/hr)	NE 0-3	S 5	0	SW 5	N 5	SE 3
Cloud Cover (%)	90	40	40	10	100	100
Rainfall (mm) between sprays	MTD 220	66	77	40	22	34
Treatments applied	8,9	5,6,7,10	11,12	5,6,7,13	14,15	5,6,7,16

APPENDIX 4

Distribution of disease throughout the trial site.



APPENDIX 5

Plot 1.12 (Treatment 2)

Row 1	Row 2	Row 3	Row 4	Row 5	Row 6
	x				
	x				
	25-Aug				
	4-Nov				
	18-Nov				
9-Sep	7-Oct				
x	9-Sep				
9-Sep	23-Sep				
x	x				
7-Oct	x				
9-Sep	23-Sep				
9-Sep	18-Nov				
23-Sep	x				
x	25-Aug				
7-Oct	21-Oct				
23-Sep	25-Aug				
23-Sep	9-Sep				
x	18-Nov				
9-Sep	25-Aug				
25-Aug	25-Aug		x	25-Aug	23-Sep
x	23-Sep		21-Oct	21-Oct	x
x	25-Aug		12-Aug	x	18-Nov
4-Nov	21-Oct		x	9-Sep	x
21-Oct	21-Oct	x	21-Oct	9-Sep	9-Sep
25-Aug	21-Oct	x	x	9-Sep	9-Sep
21-Oct	x	x	7-Oct	23-Sep	21-Oct
4-Nov	x	25-Aug	x	23-Sep	x
25-Aug	2-Dec	9-Sep	x	x	4-Nov
23-Sep	x	9-Sep	x	x	x
x	18-Nov	7-Oct	x	9-Sep	25-Aug
x	2-Dec	18-Nov	9-Sep	25-Aug	23-Sep
x	21-Oct	x	23-Sep	x	18-Nov
9-Sep	2-Dec	x	x	x	23-Sep
25-Aug	x	23-Sep	4-Nov	9-Sep	x
25-Aug	18-Nov	23-Sep	18-Nov	x	21-Oct
25-Aug	x	25-Aug	12-Aug	2-Dec	23-Sep
x	2-Dec	x	x	x	x
7-Oct	23-Sep	x	21-Oct	21-Oct	12-Aug
7-Oct	9-Sep	7-Oct	23-Sep	x	x
x	9-Sep	x	21-Oct	9-Sep	x
9-Sep	x	18-Nov	x	25-Aug	23-Sep
x	x	21-Oct	4-Nov	25-Aug	4-Nov
x	9-Sep	21-Oct	x	23-Sep	23-Sep
25-Aug	25-Aug	21-Oct	25-Aug	x	9-Sep
25-Aug	25-Aug	25-Aug	25-Aug	x	25-Aug
9-Sep	x	4-Nov	9-Sep	7-Oct	21-Oct
7-Oct	x	4-Nov	18-Nov	x	4-Nov
Row 1	Row 2	Row 3	Row 4	Row 5	Row 6