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Disease management strategies for the production of bunching vegetables

Dr. Elizabeth Minchinton
VIC Department of Primary Industries

Project Number: VG01045

VG01045

This report is published by Horticulture Australia Ltd to pass on information concerning horticultural research and development undertaken for the vegetable industry.

The research contained in this report was funded by Horticulture Australia Ltd with the financial support of the vegetable industry.

ISBN 0 7341 1088 X

Published and distributed by:
Horticultural Australia Ltd
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Sydney NSW 2000
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Know-how for Horticulture™

DEPARTMENT OF
PRIMARY INDUSTRIES

Disease management strategies for downy mildew on spring onions and white blister on radish

HAL VG01045

(February 2005)

Dr Elizabeth Minchinton *et al*

Department of Primary Industries Knoxfield Centre

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Purpose of project:
This project details the outcomes of a 3 year study on developing integrated management strategies for control of downy mildew on spring onions and white blister on bunching brassicas.

Report completed: February 2005

Funding acknowledgments:
The researchers acknowledge the financial support for this project from Horticulture Australia Limited (HAL), AUSVEG, the Federal Government and the Department of Primary Industries, Victoria.

Acknowledgments:
The authors thank the members of the steering committee, Craig Arnott, Peter Cochrane, Geoff Foster, Tony Lamattina, Rocky Lamattina and Karl Riedel for their valuable contribution to this project. The authors thank the growers whom supplied their crops for field trials, reported in this report. The authors also thank the Vegetable Industry Development Officers for their assistance with the project.

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Media Summary

Downing downy mildew in spring onions and white blister on radish

Research has identified new and improved methods for controlling damaging diseases of spring onion and radish crops in Australia. The total national value of the two industries in Australia is estimated at $85 million annually and economic consequences for growers can be considerable.

The diseases, known as downy mildew and white blister, are caused by two different microscopic fungi that infect and kill leaves. The problem is significant because it has curtailed winter production of spring onions and, in many cases, totally prevented growing of radish crops.

The research by scientists at DPI's Knoxfield Centre was supported by funds from the Vegetable Industry, Horticulture Australia and the Department of Primary Industries Victoria.

Three improved control strategies have been developed for downy mildew and offered to growers of spring onions:

1. The use of decision support systems linked to computer models that analyse prevailing temperature, rainfall, relative humidity and predict the need to apply control treatments.

2. New foliar spray schedules have been designed which incorporate the combination of new and old fungicides. When used correctly these can reduce disease to negligible levels and minimise the risk of resistance to fungicides.

3. The use of early morning overhead irrigation as a supplementary control measure, suppresses spore production by the fungus and can be integrated with foliar spray programs.

Research showed some varieties were less susceptible to downy mildew than others. It also found the disease could not be controlled by modification of nutrient treatments, despite nutrient amendments producing a better quality onion.

One specific control strategy was developed for white blister and offered to growers of radish crops:

1. New foliar spray schedules have been designed which incorporate combinations of new and old fungicides. These effectively control disease and minimise the risk of resistance to fungicides.

Limited surveys did not demonstrate seed borne infection by the white blister fungus. The implications are that it is unlikely that epidemics of white blister are caused by planting infected seed. It is more likely that these originate from resistant spores, which survive in soils or from the carry-over of spores from other radish crops. The consequence is that, on the basis of current data, seed treatment by heat or fungicides is not considered a high priority.

Much of the information from the research is presented in a booklet "*A guide to diseases and disorders of bunching vegetables in Australia*" which has been distributed nationally to industry through the Industry Development Officer network.

Technical Summary

Downy mildew and white blister are the main foliage diseases of spring onions and radish respectively. Growers report that these diseases can cause up to 50 –100% losses in a national industry worth an estimated $85 million annually. Some growers have ceased production of spring onion and radish crops because of disease pressure from the two causal fungi – *Peronospora destructor (Berkeley) Caspary and Albugo candida (Pers.) Kuntze,* respectively.

This three year study on downy mildew in spring onions evaluated prospects for the development of Integrated Management Strategies. This involved research on: computer models and decision support systems, fungicides and irrigation scheduling, resistant varieties and nutrition. An economic analysis also appraised the cost effectiveness of proposed treatments for use by growers.

Studies on white blister were more restricted. They targeted the evaluation of fungicides and the risk of transmission of *A candida* in seed.

Recommendations
Three improved control strategies have been developed for downy mildew and offered to growers of spring onions.

1. The use of decision support systems linked to computer models that analyse prevailing temperature, rainfall, relative humidity and predict the need to apply control treatments.

2. New foliar spray schedules have been designed which incorporate the combination of new and old fungicides. When used correctly these can reduce disease to negligible levels and minimise the risk of resistance to fungicides.

3. The use of night time overhead irrigation as a supplementary control measure suppresses spore production by the fungus and can be integrated with foliar spray programs

One specific control strategy has been developed for white blister and offered to growers of radish crops

1. New foliar spray schedules have been designed which incorporate combinations of new and old fungicides. These effectively control disease and minimise the risk of resistance to fungicides.

Spring Onion
Available models were tested for their effectiveness in predicting periods of sporulation and infection by *P destructor* as affected by temperature, moisture and relative humidity. Interpretation of output data from models was used to generate decision support guidelines on when sprays are required in relation to predicted disease risk. In summary these specified that risk was highest when irrigation occurred in the evening prior to midnight.

Complementary experiments evaluated which combinations of new systemic and/or conventional protectant fungicides provided the most effective control of disease while minimising the risk of acquired resistance to fungicides. All treatments controlled disease and some of the most effective were metalaxyl+mancozeb, dimethomorph+mancozeb and azoxystrobin. These reduced damage by up to 99%.

Information derived from models on factors which favour sporulation also provided the basis for experiments on irrigation scheduling, comparing overhead and drip irrigation as potential management practices for disease control. Data showed the potential of overhead irrigation in suppressing sporulation. However the treatment needs to be used with care because its application in autumn and winter can cause saturation of soils.

Experiments on varietal susceptibility, nutrition and adjuvants indicated that none could be used to effectively suppress disease.

An economic analysis compared the costs and effectiveness of calendar spraying operations with strategic spraying based on decision support systems from models. Surprisingly the analysis did not confirm reduced costs associated with strategic spraying, even though between 2 to 5 fewer sprays were used. The use of only the sporulation component and not the infection component of the DOWNCAST model, under drought conditions, when no dowmy mildew was present in the field, may have contributed to lack of an economic benefit. This result needs further consideration especially in the context of environmental issues and the potential problems of residues in produce.

Radish
Evaluation of fungicides confirmed that protectant (chlorothalonil, mancozeb, dichorfluanid) and systemic (metalaxyl) fungicides reduced damage from white blister by up to 80%. Azoxystrobin, metalaxyl/mancozeb, dimethomorph/mancozeb, were more effective and reduced damage by up to 100%.

Limited surveys did not demonstrate seed borne infection by the white blister fungus. The implications are that it is unlikely that epidemics of white blister are caused by planting infected seed. It is more likely that these originate from resistant spores, which survive in soils or from surrounding infected radish crops. The consequence is that, on the basis of current data, seed treatment for white blister, by either heat or fungicides, is not considered a high priority.

Recommendations for future work

- The DOWNCAST model needs to be evaluated on a number of different sites over several seasons to remove site effects and determine its efficacy in a non-drought season.
- Evaluate the infection component of the DOWNCAST model to improve the accuracy of the model under drought conditions.
- Evaluate cheaper chemicals. In a spray program dimethylmorph could be replaced with the cheaper azoxystrobin. Also trial phosphonic acid (new formulation) + mancozeb as this combination had efficacy for downy mildew on *Brassica* seedlings (HRDC, NY506).
- Evaluate fungicides with longer with-holding-periods, such as F5161f (BASF) identified in HAL VG02118. It may be useful as a first spray on 6-week-old spring onions, to reduce the number of fungicide applications.
- Establish a formula to put an economic cost or benefit on fewer sprays applied to crops to reduce exposure of the environment, farmers and consumers to pesticides.

Technical Report

Chapter 1 Introduction

Summary

This chapter reports on the Bunchline Vegetable Industry, production of spring onions and radish and the main foliage diseases on these crops, downy mildew on spring onions and white blister on radish and their respective life cycles. In 2000 the Bunchline Vegetables Industry was estimated to be worth about $85 million. The industry is labour intensive and most crops are hand harvested. Crops produced by bunching vegetable growers are spring onions (shallots), parsley, radish, silverbeet, beetroot, spinach, Dutch carrots, turnips, swedes, endive, bok choi and pak choi.

1.1 The industry

Crops produced by bunching vegetable growers are spring onions (shallots), parsley, radish, silverbeet, beetroot, spinach, Dutch carrots, turnips, swedes, endive, bok choi and pak choi. The industry is labour intensive with most crops being hand harvested. In 2000 the industry was estimated to be worth about $85 million, with Coles holding 20% of the market share, Woolworths 25%, Franklins 10%, fruit shops 25% and food services 20%.

In Victoria the main production area is south east of Melbourne, Devon Meadows, Clyde, Heatherton, Lang Lang and Pearcedale. In New South Wales (NSW) production is predominantly located in the Sydney basin. Production in South Australia (SA) is located mostly on the north Adelaide plains around Virginia with a few growers in the Adelaide hills. Wanneroo and Gingin north of Perth and Hopeland south of Perth are the main production areas in Western Australia (WA). In Tasmania growers are located south of Devonport, Hobart and south east of Burnie. The main production areas in Queensland are the Lockyer Valley and south of Brisbane. Foliage diseases affecting the main crops in the industry are downy mildew on spring onions and white blister on radish.

1.2 Spring onions

Spring onions are probably the major line grown by the bunch-line growers. The most recent estimates of production are in Table 1.1. During 2000 and 2001 Queensland was the major producer of spring onions, followed by Victoria. Nationally in 2000, one major supermarket chain was thought to hold 33% of the market share of spring onions, which was estimated to be worth $10,765,465. From this the value of the national spring onion production could be estimated at $32.3 million.

Spring onions are sold at retail outlets in bunches with no defined number of plants per bunch, although supermarkets have a weight range for bunches. At the farm gate they are sold in bundles, decks, plastic bags, cartons, crates, bins or as per customer requirements. A bundle consists of 5 bunches and a deck consists of 10 bunches. Plastic bags, cartons and crates consists of about 10, 20, and 20-25 bunches, respectively. Bins hold about 400 bunches. Recently in Queensland there has been a move to selling a bunch of spring onions in a plastic sleeve. At the farm gate spring onions are worth about $4-$6 per deck.

The major diseases affecting spring onions are downy mildew and bacterial spot on the foliage and white rot on the roots. At the commencement of this project downy mildew was reported to cause 50-100% crop losses in Victorian spring onion crops.

Table 1.1 Production of spring onions in Australia (ABS 2000, 2001, ABS for DPI/DSE 2001-02)

State	2000			2001			2002
	Ha	Kg	Production (%)	Ha	Kg	Production (%)	value ($)
Queensland	174.5	2,426,188.20	54.4	246.74	2,399,516.56	49	12,232,749 [a]
Victoria	145.1	1,181,332.20	26.5	212.16	920,294.11	19	4,743,311
New South Wales	48.9	192,550.20	4.3	77.37	406,700.92	8	1,997,183 [a]
South Australia	20.6	337,767.40	7.6	17.77	171,899.22	4	998,591 [a]
Tasmania	17.7	319,037.00	7.2	21.95	565,734.19	12	2,995,775 [a]
Western Australia	-	-	-	10.65	-	-	-
Total	406.8	4,456,875.00		586.63	4,856,221.58		22,967,609

[a], estimated from Victorian data based on the percentage of production in 2001.

1.3 Radish

It is very difficult to obtain production estimates for radish, either red or white, as there are no ABS figures on this crop. In 2000, one major supermarket chain estimated they held 33% of the national market share of vegetables and valued radish at $1,137,690 (all types). The national value of radish is therefore estimated at $3.4 million.

At retail outlets red radishes are sold with their foliage attached in bunches, or less commonly with their foliage not attached in bags. A bunch or bag is made up of an indeterminate number of plants. At the farm gate red radish is sold in decks consisting of 10 bunches. They can also be sold in 10kg bags, cartons or crates. At least 2 growers were producing the white radish (daikon) in Victoria. The main foliage disease, affecting both red and white radish is white blister. It causes unsightly white blisters on the foliage reducing the aesthetic quality of the bunch. At the commencement of the project some growers reported that they had ceased growing the crop due to disease pressure from white blister.

1.4 Downy mildew on spring onions

The fungus *Peronospora destructor* (Berkeley) Caspary ex Berlely causes the downy mildew disease on onions, *Allium cepa* L.. *P. destructor* is an obligate parasite, which means it can only survive on living plant tissue. It is host specific to *Allium* species (Palti, 1989) and distributed world-wide (Viranyi, 1981). It was first reported on onions in Australia in 1894 (Plant Disease Herbarium, DPI, Knoxfield, Victoria). There is no conclusive evidence of seed transmission (Viranyi, 1981).

Symptoms

Symptoms of downy mildew on spring onions first appear as a pale green to yellowish lesion usually a third of the way downy the outer leaves. Infected leaves may curl downwards. Under humid conditions a violet to grey 'down' appears on these lesions, which consists of sporangiospores (airborne spores) and sporangiophores (spore producing structures). Over successive days the colour of the 'down' changes to black as unreleased spores die and other fungi invade the lesion. Leaf tips shrivel and leaves may die.

Life-cycle

Two types of spores are produced, the thin walled sporangiospores on the leaf lesions and thick walled oospores, internally. The latter were not detected in spring onions in this study. There are 4 phases in the life cycle of *P. destructor*, associated with the sporangiospores: sporulation, dispersal, germination and infection (Figure 1.1). The sporangiospores are produced from 0100 hrs to 0600 hrs, under specific conditions (Figure 1.2): (i) Relative humidity must be greater than 95% between 0200 – 0600 hrs; (ii) No rain after 0100 hrs; (iii) Mean night temperatures between 4 – 24ºC; and (iv)

Mean temperatures during the preceding day are less than 24ºC (Sutton and Hilderbrand, 1985). Rain or heavy dew can injure sporangiospores and sporangiophores and impair sporulation, whilst light dews do not (Hilderbrand and Sutton, 1982).

The sporangiospore release commences 1.5 hrs after sunrise and ends 7 hrs afterwards (Friedrich *et al*., 2003). Dispersal of sporangiospores coincides with a reduction in atmospheric relative humidity, drying of leaves and a rise in wind speed. It usually peaks between 1000 hrs and 1200 hrs (Hilderbrand and Sutton, 1982). Sporangiospores are disseminated by wind, by rain splash from rain or by irrigation water (Hughes, 1970). The sporangiospores can survive on leaf surfaces for up to 2 days (Populer, 1981).

The optimum temperature range for germination is 10-13ºC, with a range of 1-28ºC. Germination commences within 2-4 hours of spores arriving on the leaf, provided that water or a relative humidity greater than 95% are present (Develash and Sugha, 1996). Within 3 hrs of spores germinating their germtubes can infect the leaf via the stomata (Viranyi, 1974). The incubation period is 9-16 days, but it can be prolonged with high temperatures of 25-30ºC (Viranyi, 1981).

Figure 1.1 Life-cycle of *P. destructor* (Ryley, 1989) (Conidia = sporangiospores).

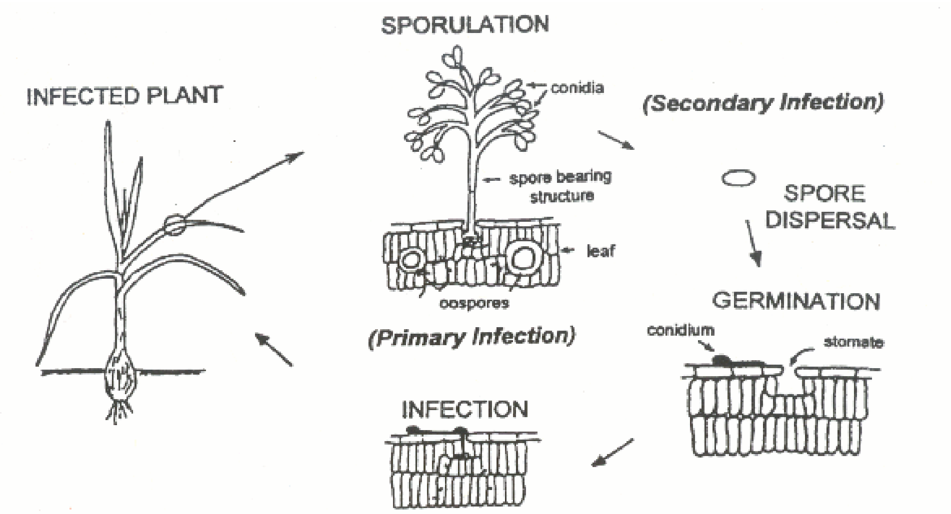
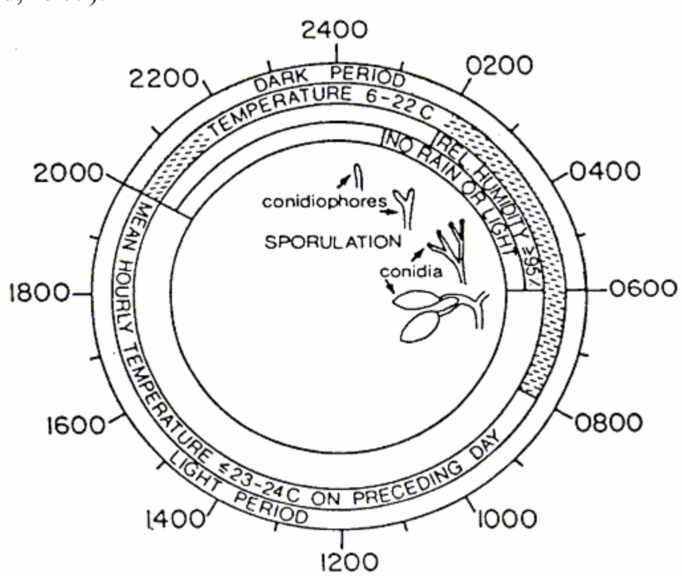


Figure 1.2 Environmental requirements of sporulation of *P. destructor* on onion leaves (Sutton and Hilderbrand, 1985).



1.5 White blister on radish

The fungus *Albugo candida* (Pers. Ex. Lev.) Kuntze, Race 1 (Pound and Williams (1963) causes the white blister disease on radish (*Raphanus sativus* L.). *A. candida* is an obligate parasite, first recorded in Victoria, Australia in 1903 (Plant Disease Herbarium, DPI, Knoxfield, Victoria). It is distributed worldwide (Mukerji, 1975). At the commencement of the project growers reported that white blister had been causing problems in their radish crops for at least 30 years.

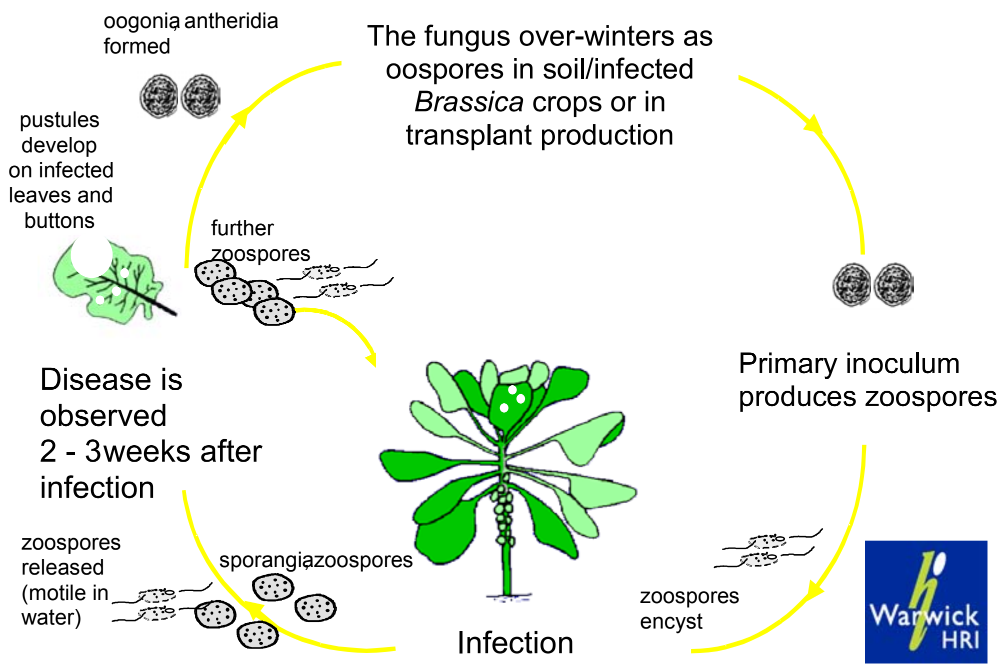
Symptoms

The fungus can form either localised or systemic infections, with the former being the more common in radish. Localised infections form on aerial parts of the plant and consist of white chalky pustules up to a centimetre in diameter, which are most common on the undersurfaces of leaves. The pustules contain the sporangiospores. The systemic phase of the disease is associated with distortion and hypertrophy of plant parts and formation of oospores, especially in the inflorescence and in galls on roots (Mukerji, 1975). Infections of the inflorescence may display stagheads and seed is often aborted. Radish seed can carry oospores of *A. candida* (Petrie, 1986).

Life-cycle

The sporangiospores can be produced and released at any time of the day or night. They are dispersed by wind, rain or insects (Cerkauskas, 1994). Zoospore release from sporangiospores requires a film of water on the leaf surface (Lakra *et al*., 1989). The temperature for zoospore release has not been reported for Race 1 on radish, but for the *A. candida* races infecting Brussels sprouts and mustards the temperature range is 2-25ºC with an optimum of 12-14ºC (Gilijames *et al*., 1998; Lakra *et al*., 1989). Zoospore release is reduced with temperatures above 25ºC (Howard *et al*., 1994). Zoospores encyst on leaf surfaces, germinate and germ tubes directly penetrate the stomata to form intercellular mycelium and knob-like haustoria in plant cells (Verma *et al*., 1975). The optimum conditions for infection are 3 hours of leaf wetness at 20ºC (Gilijames *et al*., 1998). On radish plants white blister developed over a temperature range of 12-21ºC with an optimum of 16-18ºC (Sempio, 1938; Sempio, 1939; Sempio, 1940; cited in Saharan and Verma, 1992). The incubation period is 8-10 hrs on radish but may vary with temperature (Petrie, 1986).

Figure 1.3 Disease cycle of *Albugo candida* on Brussels sprouts (Roy Kennedy, HRI, UK)



1.6 Similarities between downy mildews and white blister

P. destructor and *A. candida* are members of the Peronosporales (Oomycota) (Alexopolous *et al*., 1996). In recent phylogenetic research, *Albugo* and *Peronospora* have been shown to constitute a distinct group within the oomycetes, which includes other plant pathogenic genera such as *Pythium* and *Phytophthora* (Riethmuller *et al*., 2002). Theoretically, due to the similarity of *P. destructor* and *A. candida*, chemicals, which control one disease should control the other. Both downy mildew and white blister are polycyclic or multicyclic diseases, as new generations of inoculum (sporangiospores) are continually produced during the growing season, enabling infection to continue (Schumann, 1991).

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Chapter 2 Survey of the bunching vegetable industry with emphasis on downy mildew of spring onions and white blister of radish

Summary

In Victoria, over a two-year period, spring onion and radish crops were monitored for downy mildew and white blister, respectively, to identify management practices, which may contribute to these diseases. These surveys showed that crops irrigated in the evening (8-12pm) had higher levels of disease. A national survey of spring onions for downy mildew in Queensland, NSW, SA and Victoria found that SA and Brisbane (QLD) had the highest levels of the downy mildew whilst Victoria and the Lockyer Valley (QLD) had the lowest levels of the disease.

2.1 Introduction

Little is documented about the bunching vegetable industry in Australia or their main crop, spring onions. Telephone conversations with a few Victorian growers revealed that downy mildew on spring onions and white blister on radish were the main foliage diseases affecting crops in the industry.

The fungus *Peronospora destructor* (Berk) causes downy mildew on spring onions (*Allium cepa* L.). Casp. Ex Berk. In Victoria the first herbarium collection of *P. destructor* on *A. cepa* dates back to 1894 (Plant Disease Herbarium, DPI, Knoxfield, Victoria). Much information is available on this disease in bulb onions (Mac Manus, 2002), but little information is available on spring onion crops grown in Australia. Victorian growers of spring onions reported that downy mildew is more severe during autumn fogs and in spring. A few growers reported not producing spring onions in winter due to disease pressure.

White blister on radish (*Raphanus sativus* L.) is caused by the fungus *Albugo candida* (Pers. Ex. Lev.) Kuntze. Growers reported that it has been a problem in their radish crops for about 30 years. The first Victorian herbarium collection of *A. candida* on *R. sativus* dates back to 1903 (Plant Disease Herbarium, DPI, Knoxfield, Victoria). Some growers with crops located close to the coast reported they had ceased growing the crop, due to disease pressure from the white blister.

Queensland and Victoria are the largest produces of spring onions and have the most hectares under cultivation (ABS 2000, 2001). In 2002 Queensland produced 49% of the spring onion crop, followed by Victoria 19%, Tasmania 12%, New South Wales 8% and South Australia 4% (ABS, 2001). No figures were available for Western Australia. Little is known of spring onion cultivation in Australia or of the cultivars grown.

This chapter reports on surveys of spring onions crops for downy mildew, on radish crops for white blister, the effects of management practices on the levels of these diseases over a two-year period and lists other diseases observed on crops in the industry during the survey period in Victoria. It also reports on a national survey of spring onions for downy mildew.

2.2 Materials and Methods

Victorian surveys for downy mildew on spring onions and white blister on radish

At the commencement of the project in market garden areas south east of Melbourne, Victoria, a survey of grower practices was conducted prior to surveying their crops for downy mildew on spring onions and white blister on radish (Appendix 2.1). The downy mildew survey commenced in the spring of 2001 and finish in the summer of 2003. The white blister survey was conducted from summer 2001-02 till summer 2003.

Assessment of spring onions for downy mildew and radish for white blister

Spring onions were assessed by a 'two stage sampling method' (Nam Ky Nguyen, pers. comm.). The area to be assessed was determined by counting the number of beds per bay (area between sprinkler lines). This was then divided in half across the bay, which doubled the number of assessment units. The new total number of units were then divided by 3 and this number was halved and each assigned equally to each half of the bay. This number determined how many beds to select for assessment of downy mildew across each half of the bay. Beds to assess were randomly selected. In each of the selected beds two sections, each of a 20cm length, were randomly selected to assess for the incidence of downy mildew (number of plants affected divided by total number of plants, multiplied by 100). A bed of spring onions usually consists of three rows of spring onions. The age and cultivar of the spring onions in each bay were also recorded. Where there was more than one bay of spring onions of the same cultivar and age, bays were combined and treated as one. Where large crops of spring onions were grown, every second planting (age) of spring onions were assessed for downy mildew. Spring onions less than 6 weeks of age were omitted from the calculations, as they showed no symptoms of downy mildew. White blister on radish was assessed similarly except those crops of all ages were surveyed.

The times of the surveys and number of growers participating are given in Table 2.1. For the analysis of the effect of irrigation timing on incidence of downy mildew or white blister, growers who watered their crops at variable times were omitted from the calculation.

Table 2.1 Surveys conducted in spring onion and radish crops from spring 2001 to summer 2003

Year	Season	Month	Date	Growers participated Spring onion	Radish
2001	Spring	August	14, 15, 20, 21		
		September	4, 6, 7, 13, 17	14	Nil
2001-02	Summer	February (2002)	7, 12, 14, 15, 19, 20, 21, 23, 26		
		March(2002)	2, 15, 23	17	11
2002	Autumn	May	6, 7, 9, 13, 14, 17	15	12
2002	Winter	July	31		
		August	1, 2, 5, 6	14	11
2002	Spring	October	16, 17, 21, 22		
		November	13, 19, 27, 28	17	12
2002-03	Summer	February (2003)	7, 12, 14, 19, 20, 26	15	11
2003	Autumn	March	4, 5, 6, 7, 11		
		May	15, 19, 20, 21, 22	14	12
2003	Winter	August	16, 18, 20	13	11
2003-04	Summer	December	1, 2, 4, 12, 15, 17	16	12

National survey for downy mildew on spring onions

Systematic surveys of spring onion crops for the incidence of downy mildew and cultivars grown was undertaken during August 2002 in New South Wales, South Australia and Queensland and during September in Victoria. The number of growers participating in the survey in New South Wales was 5, in Queensland 6, in South Australia 8 and in Victoria 14. The data was accessed as previously described. The incidence of downy mildew on spring onions in the Lockyer Valley of Queensland was treated as separate data, as it differed from the incidence of the disease on spring onion crops south of Brisbane (Brisbane). The data was analysed using the non-parametric Kruskal-Wallis Test.

Assessment of Victoria data

The data consisted of the number of affected plants out of the total number of plants assessed. Due to the binary nature of the data, logistic regression was successfully used to analyse the results. Crop age, irrigation timing and cultivar significantly affected the incidence of both diseases with the exception of irrigation timing in radish data from summer 2003. This was because there were only two categories of irrigation timing instead of three.

The tables of data contain the expected proportion of disease expressed as a percentage. Where possible, significant differences are indicated. The tables should be interpreted with care. For example, when considering regional differences in the incidence of a disease, it must be remembered that these regional differences may simply be due to the fact that the cultivars that are grown in a particular region may be cultivars that are more (or less) susceptible than those grown in another region.

2.3 Results

The industry in Victoria

The area of bunching vegetable production in Victoria is located south-east of Melbourne, in an area bounded by Heatherton, Devon Meadows, Pearcedale, Clyde and Lang Lang. One grower is located at Meerlieu near Bairnsdale. The project located 22 growers in the industry and up to 17 were consistently surveyed during the project. During the course of the project two growers left the industry. The industry in Victoria uses fixed overhead sprinklers to irrigate crops, which are grown on raised beds. The number of beds in a bay, which is the area between sprinkler lines, ranges from 6 – 10 with the most common being 6 or 8. Nutrient analysis of crops is generally only under taken when a problem is noticed. At the commencement of the project 82% of growers sprayed crops with a boom whilst the rest used a boom with droppers. Spray records were kept by 81% of growers, however, this may have changed during the course of the project. Crops are hand-harvested.

Of the growers surveyed, 100% grew spring onions and parsley, both Italian and curly leaf varieties. Commonly grown crops were red radishes grown by 94% of growers, Dutch carrots by 78%, and coriander by 72%. Other crops grown in the industry were beetroot, silver beet, spinach, turnip, swede, endive, white radish, leeks, salad onions, chives, basil, dill, rosemary, oregano, mint, sage, thyme, chervil, bok choy, pak choy, shanghai, Chinese cabbage, fancy lettuce, rocket and radicchio. Crops were fertilised by Rustica™ (Blue and or Gold), fowl manure, potassium, calcium nitrate, Nitrophoska™ and macroelements. Up to 65% of growers regularly scout their crops and 18% of these employed a crop scout.

Spring onions

Spring onion cultivars

Spring onions in Victoria are generally grown 3 rows per bed. In winter the crops are harvested at 14 to 16 weeks, whilst in summer these may be harvested in 10 to 12 weeks. Over the course of the survey, 10 cultivars were recorded as being grown by the industry. Paragon was generally the most common followed by either Javelin or Straight Leaf (Table 2.2).

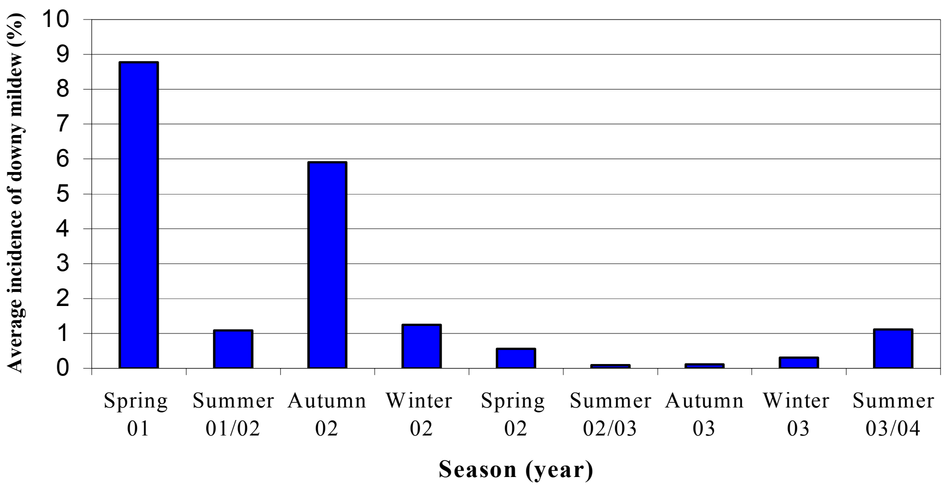
Table 2.2 Percentage of market gardeners who grow spring onion cultivars during various seasons

	Percentage of market gardeners growing spring onion cultivars								
Cultivar	Spring 2001	Summer 2001-02	Autumn 2002	Winter 2002	Spring 2002	Summer 2002-03	Autumn 2003	Winter 2003	Summer 2003-04
Alaska	7.1	-	4.3	-	-	5.9	11.8	-	
Javelin	35.8	35.3	17.4	26.7	33.3	47.1	23.5	27.3	29.4
Electra	-	-	4.3	6.6	3.7	-	-	-	-
KinChu	-	-	8.7	-	3.7	-	-	-	-
Paradox	-	-	8.7	6.6	3.7	11.8	5.9	27.3	-
Paragon	50.0	29.4	30.4	40.0	25.9	17.6	29.4	45.4	41.2
Polaris	-	-	-	6.6	3.7	-	-	-	-
Straight Leaf	-	29.4	21.7	13.4	18.5	17.6	29.4	-	29.4
Winter King	7.1	5.9	-	-	3.7	-	-	-	-
Zelda	-	-	4.3	-	3.7	-		-	-

Incidence of downy mildew on spring onions seasonally

The mean disease incidence of downy mildew on spring onions in Victoria declined over the 3 years of the survey (Figure 2.1). In the summer of 2002 downy mildew was only observed on the property of one grower. A comparison of the average incidence of downy mildew in spring 2001 compared with spring 2002 indicated a drop of 94% in the disease. A similar comparison between autumn 2002 and autumn 2003, indicated a 98% drop in the average incidence of downy mildew in the industry.

Figure 2.1 Average incidence of downy mildew surveyed on spring onions from spring 2001 to summer 2003



Incidence of downy mildew on spring onion cultivars from 2001 to 2003

The data from spring 2001 and autumn 2002 had the highest incidence of downy mildew (Table 2.3). Winter King was very susceptible in the former and Paragon in the latter. During the drier condition of Spring 2002 Winter King and Paragon were much more tolerant of downy mildew. Kin Chu, Electra, Zelda, Paradox and Polaris were generally tolerant over the whole assessment period. The analysis of data does not take into account the effect of irrigation or age on incidence of downy mildew on spring onions.

Table 2.3 Mean proportion of assessed plants with downy mildew percentage on different spring onion cultivars over three years and several seasons

Spring onion cultivar	Mean percentage of the proportion of assessed plants with downy mildew[1]									
	Spring 2001	Summer 2001-02	Autumn 2002	Winter 2002	Spring 2002	Summer 2002-03[3]	Autumn 2003[3]	Winter 2003	Spring 2003[4]	Summer 2003-04
Kin Chu	-	-	0.0 d	-	0.0 c	-	-	-	-	-
Javelin	9.5 c[2]	0.2 a	1.2 c	1.3 c	0.6 a	0.0	0.0	0.4 a	-	0.1 b
Electra	-	-	0.0 d	0.2d	0.0 c	-	-	-	-	-
Alaska	8.5 c	-	0.0 d	-	-	6.4	0.0	-	-	-
Paragon	12.3 b	1.1 b	11.5 a	1.9 b	0.3 b	0.0	7.3	0.1 b	-	0.1 b
Zelda	-	-	2.2 c	-	0.0 c	-	-	-	-	-
Winter King	44.6 a	0.6 a	-	-	0.0 c	-	-	-	-	-
Paradox	-	-	0.0 d	-	0.0 c	0.0	0.0	0.8 c	-	-
Straight Leaf	-	1.5 b	5.5 b	4.8 a	1.0 a	0.0	38	-	-	4.4 a
Polaris	-	-	-	0.0 c	0.0 c	-	-	-	-	-

[1], Data analysed over all irrigation times , [2], Several cultivars with different letters are significantly different from each other at 5% level
[3], Insufficient disease to analyse data and no data for summer 2002-03 and autumn 2003, [4], Not assessed

Effect of irrigation timing on levels of downy mildew in spring onions

Irrigating spring onion crops during the evening (8-12 midnight) in spring (2001), autumn and winter (2002) produced the highest levels of downy mildew in crops (Table 2.4). During these periods the best times to irrigate to significantly reduce downy mildew levels were either pre-dawn or morning. In the summer of 2001-02 there was little disease in the crops and from spring 2002 through summer 2002-03 and autumn 2003 to winter 2003 probably due to the drought.

Table 2.4 Effect of irrigation time on levels of downy mildew on spring onions by years and seasons

Irrigation time	Mean percentage of assessed plants with disease[2]					
	Spring 2001	Summer 2001-02	Autumn 2002	Winter 2002	Spring 2002	Winter 2003
Evening (8-12pm)	15.4 a[1]	0.3 b	11.3 a	3.9 a	0.3 b	0.3 a
Pre-dawn (before 6.00am)	11.0 a	0.0 c	2.6 b	0.2 c	0.6 a	0.4 a
Morning (9-12am)	7.5 b	1.0 a	0.6 b	0.9 b	0.7 a	0.0 a

[1], For each season, effect of irrigation times with different letters are significantly different from each other at 5% level
[2],Data analysed over all cultivars

Susceptibility of spring onion cultivars to downy mildew under evening irrigation
Irrigating spring onions in the evening makes them more susceptible to downy mildew especially in winter (Table 2.4). A comparison of the susceptibility of spring onion cultivars to downy mildew under conditions of high disease pressure in winter, indicated that Javelin and Straight Leaf were significantly the most susceptible to the disease and Electra and Polaris were significantly the least susceptible to downy mildew (Table 2.5).

Table 2.5 Susceptibility of spring onion cultivars to downy mildew under evening irrigation (8-12 midnight) during winter 2002

Spring onion cultivar	Mean percentage proportion of plants with disease
Electra	1.9 c[1]
Polaris	0.0 c
Paragon	2.6 b
Straight Leaf	4.8 a
Javelin	5.8 a

[1], Those cultivars with different letters are significantly different from each other at 5% level.

Regional differences in downy mildew incidence
Spring onion crops grown closest to the coast (Pearcedale) generally had the highest levels of downy mildew throughout the survey period (Table 2.6). Levels of downy mildew were low during summer 2001 and during the spring of 2002. Over the survey period the disease declined.

Table 2.6 Effect of location on proportion of spring onion plants with downy mildew.

Season	Proportion of plant with disease (%)[1]			
	Cranbourne	Heatherton	Pearcedale	Lang Lang
Spring 2001	6.7	2.0	20.7	8.1
Summer 2001-02	0.6	0.2	1.1	0.7
Autumn 2002	0.9	0.8	7.6	3.5
Winter 2002	1.1	0.6	5.4	0.2
Spring 2002	0.3	0.1	0.9	0.3

[1], Data adjusted for cultivar effect

Radish

Radish cultivars
Radish, are generally grown at 6 rows per bed in Victoria. In winter radish crops are harvested at 6 to 8 weeks of age, whilst in summer they may be harvested at 4 to 6 weeks of age. The industry in Victoria grows up to 5 cultivars. The cultivar Radio is the most commonly grown followed by Fireball and this order did not change over the survey period (Table 2.7).

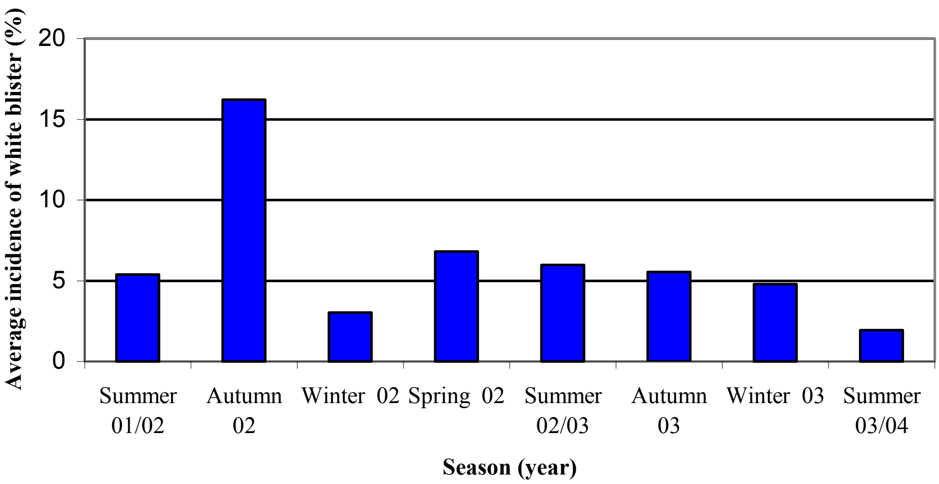
Table 2.7 Percentage of market gardeners growing radish cultivars during various seasons

Cultivar	Season							
	Summer 2001-02	Autumn 2002	Winter 2002	Spring 2002	Summer 2002-03	Autumn 2003	Winter 2003	Summer 2003-04
Fireball	27.3	30.8	27.3	40.0	33.3	30.7	25.0	33.3
Primex	9.1	7.7	18.2	13.3	16.7	15.4	16.7	8.3
Radio	54.5	53.8	45.4	40.0	41.7	46.2	50.0	50.0
Red Planet	9.1	7.7	9.1	6.7	8.3	7.7	8.3	8.3

Incidence of white blister on radish seasonally from summer 2001 to summer 2003

The incidence of white blister was highest in the autumn of 2002 and lowest in the summer of 2003 (Figure 2.2). The white blister incidence dropped by 66% from the autumn of 2002 to the autumn of 2003. In the summers of 2001 and 2002 the incidence of white blister was very similar 5-6%, but by the summer of 2003 it had fallen to 2%. No surveys were conducted in spring 2003 due to staffing issues.

Figure 2.2 Mean incidence of white blister on radish from summer 2001-02 to summer 2003-04



Incidence of white blister on radish cultivars over several seasons

The cultivar Radio was the least susceptible to white blister during summer, autumn and winter of 2002, while Red Planet was the most susceptible during this period (Table 2.8). Interestingly the situation was reversed in the spring of 2002.

Table 2.8 Incidence of white blister on radish cultivars for three years and several seasons

Cultivar	Incidence of white blister on red radish (%)							
	Summer 2002-03	Autumn 2002	Winter 2002	Spring 2002	Summer 2002-03	Autumn 2003	Winter 2003	Summer 2003-04
Radio	2.2	8.0	0.6	12.8	0.2	0.9	1.1	2.3
Fireball	2.5	15.1	1.8	1.4	7.7	4.2	5.1	0.6
Primex	0.0	14.9	2.6	0.7	13.4	22.2	17.2	0.0
Red Planet	17.3	40.7	10.3	0.2	0.0	1.8	0.0	0.2

Effect of the age of radish plants on their susceptibility to white blister

The susceptibility of radish plants to white blister appears to increase with age of the crop, irrespective of season (Table 2.9). The appearance of white blister appears to be delayed in winter and spring crops.

Table 2.9 Incidence of white blister on radish crops of different age.

	Incidence of white blister (%)							
Age (weeks)	Summer 2001-02	Autumn 2002	Winter 2002	Spring 2002	Summer 2002-03	Autumn 2003	Winter 2003	Summer 2003-04
2	0.0	-	0.0	0.0	0.0	-	-	0.0
3	0.8	0.0	0.0	0.0	0.0	3.1	0.0	1.5
4	3.8	7.9	0.0	0.0	2.0	0.0	0.0	1.3
5	2.1	7.2	0.0	0.0	8.4	13.1	0.7	3.6
6	16.7	29.9	0.0	8.6	5.9	1.4	0.3	0.0
7	-	6.0	0.8	21.4	0.0	29.2	0.0	0.0
8	-	82.8	1.8	0.8	-	2.0	10.9	13.8
9	-	-	8.1	7.8	-	-	0.0	-
10	-	-	2.5	18.9	-	-	10.2	-
11	-	-	23.9	0.0	-	-	-	-
12	-	-	-	-	-	-	10.5	-

-, no data

Effect of time of irrigation on the levels of white blister on radish crops.

Radish cops that were irrigated in the evening consistently showed a significantly higher level of white blister (Table 2.10). The best time to irrigate radish to reduce the incidence of white blister was generally pre-dawn.

Table 2.10 Effect of irrigation time on the incidence of white blister on radish

	Incidence of white blister (%)						
Time of irrigation	Summer 2001-02	Autumn 2002	Winter 2002	Spring 2002	Summer 2002-03	Autumn 2003	Winter 2003
Evening (8-12pm)	7.9a[1]	23.0a	4.8a	12.5a	1.3a	0.5a	9.7a
Morning (9-12am)	0.8b	12.1b	0.4b	4.9b	17.4b	4.7b	3.6b
Pre-dawn (After 6.00 am)	0.8b	3.4c	1.7c	1.5c	0.4c	1.8c	1.6c

[1], Within each column (season), different letters against the properties means that the numbers are significantly different at 5% level.

Regional difference in the incidence of white blister on radish

The incidence of white blister on red radish was consistently low at Lang Lang and Heatherton compared with the other two locations during 2002 (Table 2.11).

Table 2.11 Effect of location on the incidence of white blister on red radish during spring 2002

	Incidence of white blister on red radish during 2002 (%)			
Location	Autumn	Winter	Spring	Summer
Cranbourne	17.1	3.5	4.6	2.6
Heatherton	2.8	0.5	0.9	0.5
Lang Lang	4.1	0.7	1.0	0.5
Pearcedale	31.0	0.0	11.7	5.3

Diseases recorded

During the course of the surveys for downy mildew on spring onions and white blister on radish a number of diseases were observed on bunch-line crops, which were identified by Crop Health Services, Department of Primary Industries, Knoxfield, Victoria (Table 2.12). The commonly observed diseases were downy mildew on spring onions, white blister on radish, white rot and bacterial leaf spot on spring onions, leaf blight and damping off in parsley and collar and root rot of coriander.

Table 2.12 List of diseases and their causal agent observed on bunch-line crops during the three years of surveys.

Crop	Disease	Causal agent
Bok choy, pak choy	Phoma leaf spot	*Phoma lingam*
	White blister (rust)	*Albugo candida.*
Beet (beetroot)	Bacterial leaf spot	*Pseudomonas syringae*
	Phoma leaf spot	*Phoma beta*
Beet (silver beet)	Cercospora leaf spot	*Cercospora beticola*
Coriander	Collar and root rot	Mycocentrospora acerina
Dutch carrots	Alternaria leaf blight	*Alternaria dauci*
Parsley	Celery mosaic virus	*Celery mosaic virus (CeMV)*
	Leaf blight (rust)	*Septoria petroselini*
	Damping off	*Pythium spp.*
Radish	White blister (rust)	*Albugo candida*
Spinach	Downy mildew	*Peronospora farinosa f. sp. Spinaciae*
Spring onions	Bacterial spot	*Pseudomonas syringae*
	Downy mildew	*Peronospora destructor*
	Leaf blight	*Stemphylium vesicarium*
	Purple blotch	*Alternaria porri*
	Rust	*Puccina allii*
	White rot	*Sclerotium cepivorum*

Downy mildew on spring onions nationally

Cultivation

There are two main spring onion (shallots) production areas in Queensland, the Lockyer Valley and south of Brisbane. In Queensland there is little or no bed formation for spring onion cultivation. They are direct seeded at 10 rows of spring onions per bed. Bed length can be over 100m long. Irrigation is generally by moving set sprinklers. One grower in Brisbane grew spring onions in Lannan trays with 6-10 seedlings per cell. Cells of seedlings were planted, spaced, and at 3 rows per bed. There is no production over summer (the wet season).

The main production area for spring onions in New South Wales is the Sydney basin. Most growers were of Asian origin, cultivating on about 10 ha of leased land. Irrigation was by fixed overhead sprinklers with above ground lateral lines. There was little bed formation and up to 14 rows of spring onions planted either side of the irrigation line. Some crops appeared to be planted by hand.

Spring onion production in South Australia is mainly located on the north Adelaide plains around Virginia. One grower produced spring onions in the Adelaide Hills. Seed is direct sown at 4 rows per bed on raised or slightly raised beds, which can be over 100m long. Crops are overhead irrigated either by fixed or moving set sprinklers.

Refer to 1.3.1 for the characteristics of spring onion production in Victoria. Spring onion crops were observed in Tasmania (Spalford) during February 2004 and in Western Australia during August 2004 at Gingin, north of Perth and Hopeland, south of Perth. Downy mildew was only observed on spring onion at the latter site.

Cultivars of spring onions grown nationally

During the survey of the 4 states, Queensland, New South Wales, South Australia and Victoria, 9 cultivars of spring onions were recorded (Table 2.13). The most common was Paragon. The cultivar Legend was grown in New South Wales, but was never found in the other states. There was no difference in the levels of downy mildew on cultivars within states.

Table 2.13 Popularity of spring onion cultivars in the eastern Australian states

Cultivar of spring onion	Percentage of growers planting the cultivar
Paragon	54.17
Javelin	13.54
Straight Leaf	7.29
Zelda	7.29
Electra	6.25
Winter King	5.21
Legend	3.13
Paradox	2.08
Polaris	1.04

Incidence of downy mildew nationally
During spring 2002 the incidence of downy mildew on spring onions was highest in South Australia and Brisbane, Queensland (Table 2.14). It was lowest in Victoria and the Lockyer Valley of Queensland.

Table 2.14 Incidence of downy mildew nationally on spring onions

Location	Incidence of downy mildew ***(Z values)***
South Australia	2.47
Queensland - Brisbane	2.42
New South Wales	0.74
Victoria	-2.21
Queensland – Lockyer Valley	-3.14

Values of 0 are the average level of downy mildew at the time of assessment. Values greater than or equal to 2 indicate a significantly higher level of downy mildew than the average level. Values of greater than or equal to –2 indicate levels of downy mildew are significantly less than the average level.

2.4 Discussion

The Victorian industry
This is the first systematic survey of the bunching vegetable industry in Victoria. It showed that irrigating spring onions and radish in the evenings appears to increase the levels of these diseases in crops. There is a range of spring onion and radish cultivars grown. Paragon is the most commonly grown spring onion cultivar and Radio is the most commonly grown radish cultivar. There is a general consensus in the industry that these diseases are worst in autumn and spring and our data tends to support this, however, the drought impacted on the incidence of these diseases in the latter half of the project. The surveys literally evolved into monitoring the effect of drought on the incidence of white blister on radish and downy mildew on spring onions.

Effect of irrigation timing on levels of white blister on radish and downy mildew on spring onions.
In general the best time to irrigate radish to reduce their susceptibility to white blister is pre-dawn and the worst time to irrigate them is in the evening. *A. candida* zoosporangia require 3 hours of leaf wetness for infection (Gilijamse *et al*., 1998; Lakra *et al*., 1989). So irrigating between 8.00-12.00pm will only increase the number of hours leaves are wet and make conditions favourable for infection.

The surveys suggest that generally irrigating spring onions in the evening increased the incidence of downy mildew. Generally the best time to irrigate spring onions to reduce the incidence of the disease is pre-dawn. It is possible that the pre-dawn irrigation has coincided with the sporangiospore formation of *P. destructor*, which takes place between 1.00am and 6.00am (Sutton and Hilderbrand, 1985). Water in the form of rain or heavy dew can inhibit sporulation by injuring the sporophores (Sutton and Hilderbrand, 1985).

Incidences of diseases
Growers reported that downy mildew on spring onions and white blister on radish, are worst during the fogs in autumn and during spring. There was a decline in the incidence of downy mildew on spring onions over the 3 years of surveys, which may have been influenced by drought from mid 2002 onwards. In 2004 when rainfall was more consistent one grower reported that downy mildew levels were epidemic again. The incidence of white blister on radish remained fairly consistent throughout

the survey and an autumn peak was observed only early in the survey period. Perhaps the lack of a second peak the following autumn may have been due to the drought.

The only other diseases of major concern were white rot and bacterial leaf spot. White rot was a major issue for some growers due to its persistence in cropping areas. It is suggested that market gardeners without the disease should consider disinfestation procedures for personnel moving between infected and non-infected properties. Bacterial leaf spot had been a major problem for at least one grower in the past. Leeks are also a host of this bacterium, consequently avoiding the planting of adjacent crops of leeks and spring onions may help to reduce its spread.

Cultivars

The diversity of spring onion and radish cultivars grown should be a healthy situation for an industry. There have been instances where the reliance on one cultivar in an industry can have devastating consequences. Southern corn leaf blight was an unimportant disease of corn in the USA until a new hybrid variety was released which was very susceptible and resulted in losses of more than a billion dollars in one year in the USA (Agrios, 1988). The fresh trellis tomato industry in northern Victoria predominantly grew one cultivar of tomato and when a bacterial canker epidemic broke-out on tomatoes during 1997-98; this cultivar was very susceptible to the disease. The impact on the trellis tomato industry was devastating (Bill Ashcroft, pers. comm.).

Cultivar and season

The survey suggested that the cultivars Straight Leaf, Paragon and Winter King were very susceptible while Javelin and Kin Chu were very tolerant during autumn when downy mildew is a major problem. However, timing of irrigation influences the levels of downy mildew in a crop. So when susceptibility of cultivars to downy mildew is compared under conditions which should promote higher levels of disease Javelin and Straight Leaf were more susceptible, while Electra and Polaris were significantly less susceptible. Survey data of this nature needs to be viewed with caution when dealing with diseases where irrigation timing can affect incidence.

The radish cultivar Red Planet was consistently significantly susceptible to white blister in the early surveys through to winter 2002 and the cultivar Radio was consistently significantly tolerant of the disease. However in the spring of 2002, the situation was reversed when Radio showed higher levels of the disease. The drought may have contributed to the observation.

Regional differences

Regional differences were examined for the 2002 surveys. Pearcedale generally had the highest levels of downy mildew on spring onions. Of all the market garden areas surveyed it is the one closest to the coast. One grower in the area reported that since moving there he had given up growing radish due to disease pressure from white blister and no longer grew spring onions in winter due to high levels of down mildew. White blister on *Brassica* crops was worst in cropping areas close to the coast in the UK (Roy Kennedy pers. comm). It is possible that there is more moisture in the coastal areas and perhaps fogs are more frequent or last for longer periods of time.

Effect of age on levels of disease

White blister became more severe on radish crops as they aged suggesting that control strategies, such as chemical spray programs, were not very successful. It is possible that the older crops, which are probably passed their use by date, could be acting as sources of inoculum for younger crops. It may be good practice to remove these crops. The most commonly used fungicide for white blister control on radish was chlorothalonil. It has a registration for Botrytis on radish. A systemic fungicide azoxystrobin has since been registered for white blister on radish, through the 'Ausveg Minor Use of Pesticides in Vegetables Program" (Peter Dal Santo). Although we could not demonstrate a significant increase in downy mildew on spring onions with increased crop age, we never found it on spring onions less than 6 weeks of age in the survey. Its incidence was found to progressively increase with crop age in more intensively monitored crops in Chapter 7.

Downy mildew on spring onions nationally

Paragon was the most commonly grown spring onion cultivar in the eastern mainland states of Australia. Over 50% of growers planted this cultivar. Its share of the market suggests it has excellent qualities for a spring onion cultivar. There was no significant difference in levels of downy mildew on cultivars in each state, however, cultivar trials reported in Chapter 4 did find difference in the susceptibility of cultivars to downy mildew. The cultivar Paragon in these trials was mid way between susceptible and tolerant to downy mildew. The low levels of downy mildew on spring onions in Victoria and the Lockyer Valley of Queensland may be associated with a drought in both areas.

2.5 References

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Appendix 2.1

Survey of Bunching Vegetable Growers

Date:	Response		
Grower Name:			
Location			
Total acerage			
Crop - spring onions			
cv			
density			
Irrigation type			
No beds between spray lines			
Distance between heads			
Time of watering crops			
Area planted to spring onions			
Frequency of planting			
Time to harvest	summer	winter	
Production (decks)			
Set rotation			
Chemicals			
Are spray records kept?	Yes	No	
Type of spray unit	boom	dropper	air-assist
Fertilizers			
Rates			
Diseases			
Pests			
QA	Yes	No	
Crops scouted	Yes	No	
Nutrient analysis - soil	Yes	No	
Nutrient analysis - foliage	Yes	No	
Residue tests	Yes	No	
Crops grown (list)			
Best time to contact			
Overseas/interstate/local work visits?			
Comments			

Chapter 3 Review and development of prediction systems for onion downy mildew

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Summary

This chapter reviews the various versions of the DOWNCAST model and the development of the model as a computer program. It identified that one component of the model (rainfall) could be manipulated by management practices to reduce the incidence of downy mildew. The model states that rainfall, ie 2mm of irrigation, between midnight to 4.00pm prevents the fungus sporulating. A grower and crop consultant successfully evaluated the model in commercial spring onion crops.

3.1 Predictive models

Predicting or forecasting plant disease is an attempt to estimate the future state of that disease based on microclimate measurements. The measurements are made on the farm or within the crop (Parry 1990) and are usually interpreted through a model. A plant disease model is a mathematical description of the interaction of these variables (such as temperature, relative humidity, leaf wetness etc.) that can result in disease. Such models are based on the actual understanding of how the disease-causing pathogen reproduces and infects in the field.

Benefits of Plant Disease Prediction Systems

There are three key reasons for the development of plant disease prediction systems (Fry and Fohner 1985):

1. To increase income by more efficient allocation of disease management resources. The strategic use of fungicides is seen as a key issue.
2. To decrease the risk of large losses in crop value, in terms of yield and/or quality as a result of un-predicted disease outbreaks.
3. To decrease the amount of pesticide applied to crops and thus reduce the potentially harmful effects on human health and the environment.

Disease prediction systems may assist in the management of fungicide resistance strategies by assisting the grower to identify the most appropriate timing for the application of systemic (curative) compounds.

Requirements of a Successful Plant Disease Prediction System

For a prediction system to be successful, it needs to be adopted and implemented by growers. There are a number of factors that contribute to adoption (Kable 1991; Maloy 1993; Polley 1983).

1. There must be significant economic losses in terms of yield and/or quality associated with the crop disease.
2. Economically viable control measures must be available.
3. Seasonal variability in the time of initial infections and the subsequent rate of disease progress may make the appearance of this disease difficult to predict.
4. There must be validation of the model under local field conditions.
5. The system must be readily available to end-users.

To ensure this happens, growers must be confident that specific, tangible benefits can be expected from using the system. The attributes that will ensure its success include: (1) reliability, (2) cost effectiveness, (3) simplicity, (4) importance to the industry, (5) usefulness and (6) availability (Campbell and Madden 1990).

3.2 Review of Onion Downy Mildew Prediction Systems

The onion downy mildew prediction system is based on a Canadian predictive system called "DOWNCAST" (Jesperson and Sutton 1987). This system, which was developed specifically for bulb onions (*Allium cepa*) has formed the basis of a handful of variant systems resulting from attempts to fine tune this original model to suit localised conditions. The following tables define both components of the DOWNCAST model which predict sporulation (Table 3.1) and the subsequent infection (Table 3.2) of the crop by the pathogen *Peronospora destructor*. Variations of this scheme by various authors are also indicated.

Infection of the crop is the result of a two stage process. (1) Sporulation (the production and release of infective spores) occurs from already infected plants in the crop or in neighbouring crops, when all four sporulation criteria are met (Table 3.1). Should any one or more of these criteria not be satisfied, it is assumed that sporulation failed to occur on that night. (2) Infection of the crop by viable spores is possible immediately after sporulation (the same night / following morning) or on any (but only one) of the following three nights according to the requirements set out in (Table 3.2). Although infection is possible up to the third night following sporulation, this only happens when conditions for infection have not previously been met (i.e. lack of sufficient dew) for that particular batch of spores. On the first night when conditions are found to be suitable for infection, it is assumed that the majority of spores germinate. Beyond this point, remaining spores are considered non-viable, and are no longer available for infection on subsequent nights, regardless of climatic conditions.

Fitz Gerald and O'Brien (1994) modified the DOWNCAST parameters to better suit local conditions by taking account of diurnal variations between the different growing seasons (Canadian summer and Lockyer Valley winter). This model has been further evaluated for use in bulb onions in Queensland (Lockyer Valley) by MacManus (2002) and extended as a prediction service to onion growers by the QDPI in S.E. Queensland (Harper *et al*. 1999).

The interpretation by Fitz Gerald and O'Brien (1994) is most useful, as it allows for calculation of criteria 1, 2 and 4 (Table 3.1) of the sporulation component of the model in relation to sunrise and sunset times, rather than by the use of specified (set) times of day. This is most important when translating such a scheme to other locations where the crop may be grown in a different season, and the influence of latitude and longitude with respect to the local time zone may affect the sensitivity of the model. The use of sunrise / sunset times also considers the gradual shift in photoperiod which occurs across a growing season, this is particularly important for a model which is based on the calculation of mean values over set (hourly) periods.

Friedrich *et al.* (2003) developed a mathematical model (ZWIPERO) to describe the activity of *P. destructor*, enabling true forecasting of sporulation and infection events based on actual meteorological data provided by the German weather service. This model uses hourly values of temperature, relative humidity, leaf wetness, precipitation as well as local times for sunrise and sunset. Their model was adjusted to use predicted weather conditions to retrospectively and prognostically predict crop disease on a regional basis. Actual parameter values within the crop are estimated from the data generated by the German weather service.

Although it is generally agreed that a rainfall event on the night of sporulation will disrupt this process (criteria 3), the authors (Table 3.1) show some variance in the minimum rainfall amount (and the time frame in which it occurs), which they consider necessary to prevent spore production.

Interpretation of the second (infection) component of this model also varies among authors (Table 3.2). While most authors related this process to actual times of day (Jesperson and Sutton 1987, Whiteman and Beresford 1998, Wright *et al.* 2002, de Visser 1998), Fitz Gerald and O'Brien continued to base their calculations on hours after sunrise allowing closer approximation of this model to the influence that daylight has on the infection process by this pathogen.

Friedrich *et al* (2003) developed a better understanding of the relationship between temperature, leaf wetness and time with respect to the infection process of *P. destructor*. They developed an equation, which describes the rate of infection as a progressive function of temperature. Infection can only occur if leaf wetness is sufficient for a minimum of 3h, otherwise the equation is re-set to zero and calculations re-commence. This equation is based on the re-interpretation of results of earlier workers.

The work of Friedrich *et al*. (2003) provides an excellent opportunity to re-focus the way we look at the model for onion downy mildew prediction. Interpretation of their model and how it functions is not straight forward, and there appear to be some difficulties in understanding its exact operation. These difficulties are in part due to the translation of their work, which was carried out in Germany, into an English language journal.

Table 3.1 The sporulation component (and subsequent variations) of the prediction model for *P. destructor*

Author	**Jesperson and Sutton (1987)**	**Fitz Gerald and O'Brien (1994)**	**Whiteman and Beresford (1998), Wright *et al.* (2002)**	**de Visser (1998)**	**Galea and Minchinton Current Project**	**Friedrich *et al.* (2003)**
Model	Downcast	Modified Downcast	Modified Downcast	Modified Downcast	Modified Downcast	ZWIPERO
Sporulation Component of Model						
Criteria 1	Mean hourly temp between 0800 (sunrise + 2h) and 2000 h (sunset) EST of preceding day was ≤ 24ºC. If the temperature exceeded 24º C, it must not be > 27º C for more than 8 h; >28º C for more than 4 h; or > 29º C for more than 2 h.	Mean hourly temp during the previous day is ≤ 24ºC. If the temperature exceeded 24º C, it must not be > 27º C for more than 8 h; >28º C for more than 4 h; or > 29º C for more than 2 h.	Mean temperature between 0800 and 2000 h during the previous day < 24ºC.	Mean hourly temp between 0800 and 2000 h of preceding day was ≤ 24ºC. If the temperature exceeded 24º C, it must not be > 27º C for more than 8 h; >28º C for more than 4 h; or > 29º C for more than 2 h.	As per Jesperson & Sutton (1987) – however previous day determined from actual sunrise to actual sunset as measured by daylight sensor.	Estimated crop canopy temp during previous day (sunrise to sunset) must not exceed 29º C for more than 7 h; >31º C for more than 4 h; or > 33º C for more than 1 h. Crop canopy data predicted not actual.
2	The mean hourly temperature at night was between 4ºC and 24ºC.	The mean hourly temperature at night was between 4ºC and 24ºC.	Mean hourly temperature at night (2000 – 0500 h) between 4 and 24ºC.	The mean hourly temperature at night was between 4ºC and 24ºC.	As per Jesperson & Sutton – based on actual night period (sunset to sunrise).	Sporulation at night (sunset to sunrise) expressed as a proportional value dependent on a temperature x time equation. A certain threshold must be achieved for sporulation to occur. Sporulation prevented by VPD values > 1 hPa.
3	No rain occurred after 0100 h EST.	There is no rainfall (<1 mm) between 2300 and 0400 h EST. *(equivalent to 000 to 0500 h Daylight Saving Time)*	<0.2 mm rain between 0100 and 0500 h.	No rain (Author suggested this be changed to 0.3 mm) occurred after 000 h (author suggest a change to 0100 h).	As per FitzGerald and O'Brien (1994).	Rainfall exceeding 2 mm from sunset + 5h to sunrise + 1h will totally inhibit sporulation. An injury factor can be determined for rainfalls < 2mm according to an equation.
4	Relative humidity was ≥ 95% at or before 0200 h and persisted without interruption until 0600 h.	Relative humidity is ≥ 95% for a continuous 4 h between the time when 6 h of darkness has accumulated and sunrise.	Relative humidity >95% continuously between 0100 and 0500.	Relative humidity was ≥ 95% at or before 0200 h and persisted without interruption until 0600h.	As per FitzGerald and O'Brien (1994).	Relative sporulation rate from sunset to sunrise measured as a function of humidity (measured as VPD). Sporulation prevented by VPD values > 1 hPa.
Analysis	Correctly predicted sporulation on 111 of 119 nights.	5 out of 7 infection periods predicted.	Prediction system resulted in 40% reduction in fungicide applications.	Sporulation model accurate on 25 of 40 occasions.		Model accurately predicted spore production as measured using spore traps in the field.

Table 3.2 The infection component (and subsequent variations) of the prediction model for *P. destructor*

Author	**Jesperson and Sutton (1987)**	**Fitz Gerald and O'Brien (1994)**	**Whiteman and Beresford (1998), Wright *et al.* (2002)**	**de Visser (1998)**	**Friedrich *et al*. (2003)**
Model	Downcast	Modified Downcast	Modified Downcast	Modified Downcast	ZWIPERO
Infection Component of Model					
Infection on same night / morning of sporulation.	Leaf wetness continues until 0900 h or later at 6-22^{o}C or until 1000 h at 23-26^{o}C.	Leaf wetness persists until 3 h after sunrise at 6-22^{o}C or 4 h after sunrise at 23-26^{o}C.	Leaf surface wetness between 0500 and 0800 immediately following the sporulation event.	Leaf surface wet between 0600 and 0800 (or 0900 h) when temp range 6-16^{o}C or between 0600 and 1100 h when temp range 16-20^{o}C or between 0600 and 1200 h when temp range 20-24^{o}C immediately following the sporulation event.	Infection can occur from time of spore dispersal (sunrise + 1.5 hours) to sunrise + 7 h. Relative rate of germination and infection is calculated by a temp x time function. Infection can only occur if leaf wetness is sufficient.
Infection on first succeeding night.	Dew deposition in first 5 h of leaf wetness is rapid and wetness lasted at least 3 h at 6-22^{o}C.	Dew deposition is rapid and wetness lasted at least 3 h at 6-22^{o}C.	Leaf surface remains wet for 3 hours between 1900 and 2400 on the evening following the sporulation event.	As per Jesperson and Sutton (1987).	Infection possible if conditions on previous night not suitable – 50% of sporangia will survive.
Infection on second succeeding night.	Little or no dew on previous night. Dew deposition in first 5 h of leaf wetness is rapid and wetness lasted at least 3 h at 6-22^{o}C.	Little or no dew on previous night and dew deposition is rapid and wetness lasted at least 3 h at 6-22^{o}C.	Leaf surface remains wet for 3 hours between 1900 and 2400 on the second evening following the sporulation event.	As per Jesperson and Sutton (1987).	Infection possible if conditions on previous 2 nights not suitable – 25% of sporangia will survive.
Infection on third succeeding night.	Little or no dew on previous 2 nights. Dew deposition in first 5 h of leaf wetness is rapid and wetness lasted at least 3 h at 6-22^{o}C.	Little or no dew on previous 2 nights and dew deposition is rapid and wetness lasted at least 3 h at 6-22^{o}C.	Not included in this model.	As per Jesperson and Sutton (1987).	Infection possible if conditions on previous 3 nights not suitable – 12.5% of sporangia will survive.

3.3 Development of the model as a computer program

A complex routine was written as a macro within the spreadsheet program Microsoft Excel (Microsoft Corporation USA) using the language Visual Basic. The purpose of this program was to enable the processing of meteorological data collected from the various weather stations used in this project. The standardised formatting of data sets from these weather stations allowed for a uniform method of data treatment irrespective of the type of weather station used. All examples of downy mildew prediction systems found in the literature are based on hourly calculations of metrological data. The model reported here in this work was based on half hourly time periods allowing for more accurate pinpointing of time periods where the various criteria cross their threshold values.

Sporulation Component

For this project, the following criteria were selected for the sporulation component of the model. Conditions favouring dispersal are assumed to occur each day. Thus, sporulation is determined to occur during the pre-dawn hours when all the four following criteria are met:

1. Mean hourly temperature during the previous day was $\leq 24^{o}$ C.
   If the temperature exceeded 24^{o} C, it must not be > 27^{o} C for more than 8 h; >28^{o} C for more than 4 h; or > 29^{o} C for more than 2 h;

   This calculation is made by measuring the mean hourly temperature from first light the previous day to last light on the evening of the same day. Calculations are based on half hourly steps.

2. Night temperatures were within the range 4-24^{o} C;

   This calculation is made by measuring the mean temperature from last light of the previous evening to first light of the current morning. Calculations are based on half hourly steps.

3. There was no significant rainfall or irrigation (< 1 mm) between 2300 and 0400 hours;

4. Relative humidity (RH) was > 95 % for a continuous 4 h period between the time when 6 h of darkness had accumulated and sunrise (typically a 4 h period between 0000 and 0600 hours).

   This calculation is made by determining the numbers of hours which have elapsed since sunset on the previous evening and determining the number of hours during which RH exceeds 95% before sunrise occurs. Calculations are based on half hourly steps.

Calculations of criteria 1, 2 and 4 were based on 30-minute steps instead of 1 hourly periods as described in Table 3.1. This was done to improve accuracy of the model, particularly to allow capture of data where the influence of day period is migratory as seasonal shifts in sunrise and sunset occur.

Temperature sensors within the crop provided the information required for criterion 1 and 2. Rainfall data collected by tipping bucket rain gauge provided data for criterion 3. Relative humidity sensors placed within the crop enabled criterion 4 to be determined. Day length data measured by light sensors also contributed to the calculation of criteria 1, 2 and 4.

Meteorological data from the various weather stations (Figures 3.1 and 3.2) were imported into Microsoft Excel and merged into single spreadsheets for each field experiment. The complex routine (Appendix 3.1) examined the meteorological data applying the four key criteria of the modified DOWNCAST model in sequence. This routine was applied individually for each daily data set in each trial. Outcomes for the data set appear on the spreadsheet adjacent to the daily data set (Table 3.3).

Figure 3.1 Example of a weather station used in this project

Table 3.3 Output of the modified DOWNCAST model for August 2003
(A positive forecast event is shown, after having satisfied the conditions for each of the four microclimate criteria or factors).

Date	Time	RH(%)	T dry	T soil	WSPD	L wet	Total rain	Total solar
			°C	°C	KPH	%	mm	MJ/m
6/08/2003	6:00:00	90	7.8	8.6	16.7	0	0	0
6/08/2003	6:30:00	93	7.7	8.6	15.1	0	0	0
6/08/2003	7:00:00	97	7.7	8.6	13	0	0	0
6/08/2003	7:30:00	95	8	8.6	14.4	0	0	0.1
6/08/2003	8:00:00	98	7.8	8.6	14	0	0	0.023
6/08/2003	8:30:00	98	8.1	8.6	13.4	0	0	0.09
6/08/2003	9:00:00	100	8	8.7	11.5	29	0.2	0.089
6/08/2003	9:30:00	102	8.6	8.7	13.5	24	0.2	0.234
6/08/2003	10:00:00	98	9.2	8.8	14.4	0	0	0.232
6/08/2003	10:30:00	95	9.6	9	15.7	0	0	0.251
6/08/2003	11:00:00	96	10	9.1	16.3	0	0	0.361
6/08/2003	11:30:00	91	11.7	9.3	15.3	0	0	0.803
6/08/2003	12:00:00	86	12.4	9.6	16.6	0	0	0.697
6/08/2003	12:30:00	86	12.4	10	17.8	0	0	0.771
6/08/2003	13:00:00	83	12.9	10.4	18.6	0	0	0.772
6/08/2003	13:30:00	83	12.5	10.7	16.4	0	0	0.521
6/08/2003	14:00:00	82	12.4	10.9	17.1	0	0	0.506
6/08/2003	14:30:00	79	13.1	11.1	16.7	0	0	0.619
6/08/2003	15:00:00	78	12.6	11.2	14.7	0	0	0.316
6/08/2003	15:30:00	78	12.9	11.3	12.3	0	0	0.351
6/08/2003	16:00:00	72	12.8	11.4	14.3	0	0	0.291
6/08/2003	16:30:00	73	12.4	11.3	9.9	0	0	0.148
6/08/2003	17:00:00	73	12.1	11.2	10.9	0	0	0.083
6/08/2003	17:30:00	73	11.4	11.1	8.8	0	0	0.013
6/08/2003	18:00:00	81	10.2	10.9	6.7	0	0	0
6/08/2003	18:30:00	87	9.4	10.8	7.5	0	0	0
6/08/2003	19:00:00	90	8.7	10.6	5.9	0	0	0
6/08/2003	19:30:00	93	8.5	10.4	6.9	0	0	0
6/08/2003	20:00:00	92	8.1	10.2	5.5	0	0	0
6/08/2003	20:30:00	94	8	10.1	8.8	0	0	0
6/08/2003	21:00:00	94	8.2	9.9	10.3	0	0	0
6/08/2003	21:30:00	95	8	9.7	10.1	0	0	0
6/08/2003	22:00:00	96	8.5	9.6	9.2	0	0	0
6/08/2003	22:30:00	95	8.9	9.6	9	0	0	0
6/08/2003	23:00:00	96	8.5	9.5	8.1	0	0	0
6/08/2003	23:30:00	98	8.7	9.5	6.6	0	0	0
7/08/2003	0:00:00	99	8.9	9.5	7	0	0	0
7/08/2003	0:30:00	97	9.3	9.5	9.1	0	0	0
7/08/2003	1:00:00	97	9.2	9.4	8.9	0	0	0
7/08/2003	1:30:00	97	9	9.4	8.2	0	0	0
7/08/2003	2:00:00	97	8.8	9.4	10.6	0	0	0
7/08/2003	2:30:00	97	8.4	9.3	10.1	0	0	0
7/08/2003	3:00:00	99	8	9.3	8.2	0	0	0
7/08/2003	3:30:00	100	7.7	9.2	7.6	0	0	0
7/08/2003	4:00:00	102	7.7	9.1	7.5	0	0	0
7/08/2003	4:30:00	101	7.5	9	7.9	0	0	0
7/08/2003	5:00:00	102	7.5	9	9	0	0	0
7/08/2003	5:30:00	101	7.6	8.9	10.5	0	0	0
7/08/2003	6:00:00	99	7.7	8.8	11.1	0	0	0
7/08/2003	6:30:00	98	7.7	8.8	11.1	0	0	0
7/08/2003	7:00:00	98	7.6	8.7	10.8	0	0	0
7/08/2003	7:30:00	99	7.6	8.6	10.3	0	0	0
7/08/2003	8:00:00	99	7.7	8.6	9.6	0	0	0.043
7/08/2003	8:30:00	99	8.2	8.6	8.7	0	0	0.116
7/08/2003	9:00:00	98	8.5	8.6	7.8	0	0	0.187
7/08/2003	9:30:00	93	10.8	8.6	12.2	0	0	0.518
7/08/2003	10:00:00	85	11.2	8.7	14.4	0	0	0.29
7/08/2003	10:30:00	85	11.5	8.9	15	0	0	0.402
7/08/2003	11:00:00	80	13.2	9.1	16.6	0	0	0.771
7/08/2003	11:30:00	74	13.8	9.4	18.3	0	0	0.756
7/08/2003	12:00:00	71	14.7	9.8	16.8	0	0	0.807
7/08/2003	12:30:00	66	15.4	10.2	17.6	0	0	0.873
7/08/2003	13:00:00	67	14.9	10.6	17	0	0	0.574
7/08/2003	13:30:00	65	14.7	10.9	17	0	0	0.53

Interpreting the DOWNCAST model

- If all four microclimate criteria or factors are positive ('YES"), then sporulation could have occurred and if a spray has not been applied in the last 7 days than spraying for downy mildew should be considered.
- If only one of the microclimate criteria are negative ('NO') then sporulation would not have occurred and spraying in unnecessary.

Yesterday Firstlight	Yesterday Lastlight	Today Firstlight
8:00:00 AM	6:00:00 PM	8:00:00 AM

SPORULATION FACTOR # 1

Range	<= 24 C	> 27 C
Cml hrs	10.5	0
Sporulation	- -	Yes

Factor 1 sporulation possible?

SPORULATION FACTOR # 2

Range	4 - 24 C	<4 or >24
Cml hrs	14.5	0

Factor 2 sporulation possible?

SPORULATION FACTOR # 3

Total rain (mm)	0
Sporulation possible?	Yes

SPORULATION FACTOR # 4

Factor 4 Sporulation possible?

****

DownCast Forecast

****

Has Sporulation Event Occurred ?

YES

3.4 Use of irrigation to manipulate the DOWNCAST model

Introduction

The DOWNCAST model contains four factors or microclimate criteria and if all are positive, then spore production could occur, and if the crop has not been sprayed in the last 7 days, a spray should be applied for downy mildew. However, if only one of the four factors is negative then spore production will not occur and there is no need to spray. The only factor in the DOWNCAST model, which can be manipulated, is factor 3, 'the rainfall between 11.00pm and 4.00am did not exceed 1mm'. If the rainfall exceeds 1mm during this period then factor 3 will read 'NO', producing at least one 'NO', consequently no spore production should occur and there is no need to spray.

Trials were designed to investigate whether irrigating in the early hours of the morning (12.00-4.00am) could reduced the number of sprays but still control downy mildew during the autumn peak of the disease.

Materials and methods

An Environdata weather station was established in two crops (bays) of 6-week-old spring onions of cv Paradox, at Moores Road, Clyde during March to April 2004. Refer to Chapter 5 for a description of the weather stations. At one weather station the crop was irrigated at 'anytime' of the day, while at the other it was irrigated predominantly between 12.00-4.00am 'early bird'. At each weather station 6 blocks, covering two rows of spring onions, were laid out in a randomised block design. Within each block or bed of spring onions there were two plots, representing each of two treatments, either a weekly spray program or the DOWNCAST model spray program. Plots were 5m long by 1.6m wide. Seeds were planted on 3/2/04. The weekly treatment was sprayed with 2 applications of Ridomil Gold MZ™ alternating with 2 applications of Acrobat™+mancozeb, then 2 applications of Ridomil Gold MZ™ on 17/3/04, 24/3/04, 31/3/04, 7/4/04, 14/4/04 and 21/4/04. The DOWNCAST model treatment for the 'anytime' spray program was applied on 20/3/04, 31/3/04, 7/4/04, 14/4/04, and 21/4/04. The DOWNCAST model treatment for the 'early bird' (12.00-4.00am) spray program was applied on 20/3/04, 31/3/04, 7/4/04 and 16/4/04. The crop was assessed for downy mildew on 26/4/04 and harvested on 28/4/04. The order of sprays was as previously described for the weekly spray program.

Results

There were problems with irrigation timing beyond the control of the grower and the researchers. The trial was harvested before the autumn fogs increased disease pressure. No downy mildew was detected in any of the plots. Irrigating at 'anytime' and using the DOWNCAST Model saved only one spray (Table 3.4). Irrigating between 12.00-4.00am 'early bird' and using the DOWNCAST Model saved two sprays. There were double the sporulation predictions in the 'anytime' irrigations, compared with that of the 'early bird' irrigations.

Table 3.4 Effect of irrigation timing on the number of sprays applied with the DOWNCAST model compared with weekly spraying over 49 days.

Number of sprays	Type of spray Weekly	DOWNCAST Model	Number of sprays saved	Number of sporulations predicted
Early bird irrigations (12.00-4.00am)	6	4	2	13
Anytime irrigations	6	5	1	27

Discussion

Timing of irrigation to occur during the 12.00-4.00am period saved 2 spray applications. During this period spores are produced and the irrigation or rain, is thought to destroy the spore producing structures and process (Hilderbrand and Sutton, 1982). In theory further reductions in the number of sprays may have been achieved, if problems had not occurred with the equipment. Irrigating between 12.00-4.00am will only put off a sporulation event for one day in the DOWNCAST model, so irrigating during this period would have to be on a regular basis. Consequently it could make the ground too wet, especially if there was rain during the day. Its greatest advantage may be to delay a spray for a day or two. For example if a 7 day withholding period was over, during a weekend and no staff were available to spray, then irrigating between 12.00-4.00am and running the model would produce a 'NO' sporulation event and thus no sprays would be required and spraying could be delayed to a week day.

3.5 Grower evaluation of the DOWNCAST model using the Model-T weather station

Introduction

Grower comments were sought on the DOWNCAST model and weather station to identify issues, problems and determine where improvements could be made. Mr Tony Lamattina a market gardener with 20-years experience in growing spring onions volunteered to evaluate the Model-T weather station and DOWNCAST model on a bay of spring onions.

Materials and methods

A Model-T weather station was set up, towards the north end of a bed adjacent to the irrigation line, in a bay (crop) of spring onions cv Paragon on a growers property at Clyde, Victoria from March to April 2004. The software for the weather station and the DOWNCAST model were installed on the grower's computer. The grower downloaded the station, ran the model and sprayed the crop according to the model for 55 days. The number of sprays applied by the model was compared with the number, which would have been applied if spraying on a weekly basis.

Results

The DOWNCAST model predicted 3 sprays, despite 8 sporulation events (Table 3.5). There would have been 7 sprays applied to the bay of spring onions if they were sprayed by a weekly spray program. There was no downy mildew observed in this crop. Spraying according to the predictions of the DOWNCAST model saved 4 applications of fungicides.

Table 3.5 A grower's trial of the DOWNCAST model in a spring onion crop during March to April 2004 at Clyde, Victoria

Item	Response
Duration of trial	55 days
Predicted sporulation events	8
Number of weekly sprays	7
Number of sprays applied by DOWNCAST	3
Number of sprays saved by DOWNCAST	4

Discussion
It was unfortunate that disease pressure was low and the autumn fogs, which are associated with high disease pressure, did occur during the trial. The DOWNCAST model predicted 4 fewer sprays than would have been applied by a weekly spray program.

Mr Tony Lamattina's view of the DOWNCAST model and the Model-T weather station (Table 3.5)
- ***Software*** - Easy to use.
- ***Time*** - Downloading the station and running the model each day took about 10 minutes.
- ***Field*** - Compact and easy to move.
- ***Working*** - No downy mildew about to test the DOWNCAST model. It needs to be run during a period of high disease pressure.

Issues
- Need more information on how the 4 factors of the DOWNCAST model fit together.
- Irrigating at night can make the ground too wet.
- If the weather station had not been downloaded and the model run for some time, it took a while to update.
- How long is the critical time to spray after a 'YES' prediction by the model.
- What happens if the DOWNCAST model predicts a 'YES' near harvest and no sprays have been applied for some time, e.g. over a week.

3.6 A crop consultant's comments on the DOWNCAST model and weather stations

Karl Riedel is a crop consultant with over 20 years of experience in the Cranbourne area of Victoria. During January to February 2003 he had access to the 'middle' Environdata weather station (Table 3.6).

Accessing the model/weather station:
Once you access the system a couple of times it was relatively easy to operate and it seemed simple enough. The outcomes were clear and well defined.

Issues:
- Predictions were affected by irrigation. Therefore it was easy to manipulate. Is this acceptable? During winter it may not be possible to water as required.
- I was involved over the January-February period when downy mildew is not usually a problem. So I don't know if the model works accurately in winter and spring when the disease pressure is high.
- We grow onions in a high rainfall climate so how useful is this model in this climate? May be good in a drier climate.
- If we can predict sporulation events then the application of specific systemic fungicides will control the disease more accurately. Need to know kick back times (length of time to spray after sporulation when a fungicide is still effective) for fungicides Ridomil Gold MZ™, Acrobat etc.
- This may lead to less number of sprays and more effective use of the chemicals we do have.
- May increase the life of the systemic sprays as a result?

3.7 Summary of the DOWNCAST evaluation trials

In all the trials where the DOWNCAST model was compared with weekly spraying it predicted a reduction in the number of sprays, irrespective of wether they were actual or observational trials (Table 3.6). The proportion of sprays saved with the DOWNCAST model compared with weekly sprays was on average 42% (no. sprays saved/no. weekly sprays) over all trials in Table 3.6. The incidence of downy mildew was not significantly different between the Model 1 and weekly spray program for the October-December trial of 2002, but did differ significantly between Model 1 and the weekly sprays for the April-August trial of 2003 (Table 3.6). Weekly spraying during periods of high disease pressure in autumn may be necessary. However, further improvements in the model may make it more sensitive during this period. A grower sprayed a bay of spring onions according to the DOWNCAST model and reduced the number of sprays by 4, however, this was during a very dry period of time (Table 3.5).

Table 3.6 Summary of DOWNCAST trials

Trial reference (Table)	Time	Days	Weekly → DOWNCAST sprays	No sprays saved	Observational or actual
4.8 Model 1	Oct-Dec 2002	42	6 → 4	2	A
4.8 Model 2	Oct-Dec 2002	42	6 → 2	4	A
4.9 Model 1	Apr-Aug 2003	91	13 → 8	5	A
5.1 Farm A	Nov 02-Feb 03	99	12 → 11	1	O
5.1 Farm B	Nov 02-Feb 03	99	11→ 7	4	O
5.1 Farm C	Nov 02-Feb 03	99	13 → 9	3	O
5.3 Old	Jul-Aug 2002	31	4 → 3	1	O
5.3 Young	Jul-Aug 2002	31	4 → 2	2	O
5.5 Oldest	Jan-Feb 2003	44	6 → 2	4	O
5.5 Youngest	Jan-Feb 2003	39	4 → 2	2	O
5.5 Middle	Jan-Feb 2003	37	4 → 2	2	O
5.7 North-west	Aug-Sep 2004	20	3 → 2	1	O
5.7 South-east	Aug-Sep 2004	20	3 → 2	1	O
5.7 Middle	Aug-Sep 2004	20	3 → 1	2	O
3.4 Night	Mar-Apr 2004	49	6 → 5	1	A
3.4 Early bird	Mar-Apr 2004	49	6 → 4	2	A
3.5 Grower	Mar-May 2004	55	7 → 3	4	A

A, actual trial where plants were sprayed; O, observational trial where plants were not sprayed;
→, reduced to.

3.8 Discussion

The DOWNCAST model

For this project, only the sporulation component of this model was used. Bunching onions, unlike bulb onions, have a requirement for clean and unblemished foliage (zero tolerance). The growers involved in this project indicated that the appearance of the crop was most important, and that they would prefer to maintain the highest level of protection for their crops. It was decided that spray decisions should be informed by sporulation periods identified by the model, rather than by the infection periods (as determined by the second part of this model) which may follow. As grower confidence in the use of this model increases, it may be practical to use the infection component to identify those sporulation events, which fail to subsequently lead to infection of the crop due to high (or low) temperatures, lack of leaf wetness or low levels of relative humidity.

In the bulb onion industry, MacManus (2002) was able to demonstrate that by using only the sporulation component of the model he could reduce the number of fungicide sprays for a crop by 50% (from 12 to 6 sprays), and achieved the yield and quality outcomes. It is likely that inclusion of the second component of this model may have reduced the need for sprays even further.

Friedrich *et al.* (2003) indicated that the use of true sunrise and sunset times allowed their model (ZWIPERO) to be used over a range of seasons and locations. True sunrise and sunset times were used in the model prepared for this project as earlier reported by MacManus (2002). It is considered that the form of this model used for this research project was superior to earlier versions, which were based on the use of local times. The model used in this project can be used with confidence across the different growing regions in Australia without needing to consider variation in sunrise and sunset times, which vary due to latitude, longitude and of course, seasonal variation. The use of half-hourly time periods in this model also improves the accuracy of prediction, by allowing the model to adjust in smaller steps, to changes in sunrise and sunset as seasons progress.

The improved model (ZWIPERO) by Friedrich *et al*. (2003) provides some additional prospects for fine-tuning the model. In particular the authors have developed a better understanding of the influence of rainfall on spore survival at night. The determination by these authors that rainfall exceeding 2mm from sunset + 5 h to sunrise +1h gives a more accurate way of determining the way that rain or irrigation can prevent infection in the field. This opens up irrigation as a potential management tool for reducing inoculum levels in the field.

Friedrich *et al*. (2003) measured relative humidity as vapor pressure deficit (VPD). This method of measurement appears to give a more realistic measure of the effect that humidity has on both the sporulation and infection processes. VPD is calculated as a function of both relative humidity and temperature, both of which are easily measured in the crop.

Response to industry issues with the DOWNCAST model and weather stations

Time to spray after a 'YES' prediction
A 7-day with-holding-period produced 1.4% downy mildew (Model 1) and a 10 day with-holding-period produced 1.0% downy mildew (Model 2) in a trial at Somerville during spring – summer 2002. It is likely that spraying on day 8 instead of day 7 would not make any difference as Ridomil Gold MZ™ and Acrobat™ + mancozeb have a 2 day 'kick back', i.e. curative activity (MacManus, 2002).

Time to download
Programs can be written to automatically download weather stations via their modems, every day at a set time. Such a system could make the time spent in this operation much shorter. It is also possible to have a message on the outcome sent to a mobile phone. However, sensors need to be checked to ensure they are functioning and solar panels need to be wiped clean on a regular basis.

A 'YES' prediction near harvest
During summer when downy mildew incidence is very low or not present in crops or in neighbour's crops, then it is probably best not to spray. However, during a period of high disease pressure, such as autumn fogs, then it is probably best to spray with a fungicide that has a short with-holding-period.

Irrigation timing to delay spraying
During wet periods it is probable that irrigating between 12.00-4.00am will not be an option due to making the ground too wet. During a dry period, such as summer, it is more likely that early am irrigation will be an option. It is possible that the best use of this technique will enable spraying to be delayed for a day or two.

Factors affecting spore production

As a result of the interaction with growers during the reporting meetings held for this project, the need to provide a clear understanding of how the various model components relate to spore production by the downy mildew pathogen was identified. The preparation of an A3 sized wall chart showing the linear sequence of events of sporulation and infection by *P. destructor*, and how this process is limited by environmental conditions, would assist growers in understanding both the process and the model. A draft version of this chart is included in Figure 3.2 and should help growers to better visualise how these components of the model come together.

3.9 Future directions for the DOWNCAST model

- The computer routine used in this project could be re-written to include some of the modified parameters determined recently by Friedrich *et al.* (2003). While on the surface some of these changes appear to be minor, the complex nature of these changes would necessitate significant program writing. The conversion of relative humidity values to measurements of vapour pressure deficit (VPD) should improve the accuracy of this model.

- Development of the program should also include a more user-friendly output screen, which more clearly defines the outcome for each of the model sub-components. Feedback from the grower reference group indicates that this approach would improve the usefulness of the model output to them.

- The inclusion of the second (infection) component of this model will require significant programming effort. This second component would allow the extension of this model to identify whether or not particular sporulation events will lead to an infection event. Such an enhancement to this model could lead to further improvement of this forecasting system and potentially lead to reductions in fungicide use.

- The production and dissemination of a wall chart showing how environmental factors influence sporulation and infection by *P. destructor*. Some of the microclimate factors of the DOWNCAST model can be measured with very simple equipment (eg. maximum and minimum thermometer) and this could assist decision-making.

- More grower extension, especially interstate is required. There is interest from growers in Victoria and interstate in trialing the DOWNCAST model and weather stations. It would be useful if they could borrow a weather station for up to 2 months and trial the model and the station, before they commit to investing in one. There has also been a lot of interest in weather stations from growers outside the bunch-line group. The weather stations are seen as providing extra intelligence on the crop and the model is an opportunity to reduce sprays and divert resources elsewhere in the business.

3.10 The DOWNCAST model in retrospect

The DOWNCAST disease predictive model reduced the number of sprays by 2 to 5, but there was no financial benefit to growers. One theory is that it is due to the drought. A good predictive model should work under any conditions. A predictive model should be more effective in a drought as it would forecast fewer sprays compared to a weekly spray program. The addition of the infection component of the DOWNCAST model may be necessary in a drought. During the trial at site 4 there was no downy mildew in the industry, yet conditions for sporulation were being met and sprays were applied, which in hindshight were unnecessary.

In hindsight trials to evaluate the model should have been done on different farms to avoid site effects. The differences between trial sites 1 and 2 with sites 3 and 4 were:
(a) Seed was precision sown at sites 3 and 4, whilst at sites 1 and 2 it was disc sown. The latter gives a much thicker crop of spring onions.
(b) At sites 3 and 4 there is little application of fungicides and the usually only contact fungicides, compared with systemic fungicides that were applied at sites 1 and 2.
(c) Site 4 had very poor emergence.

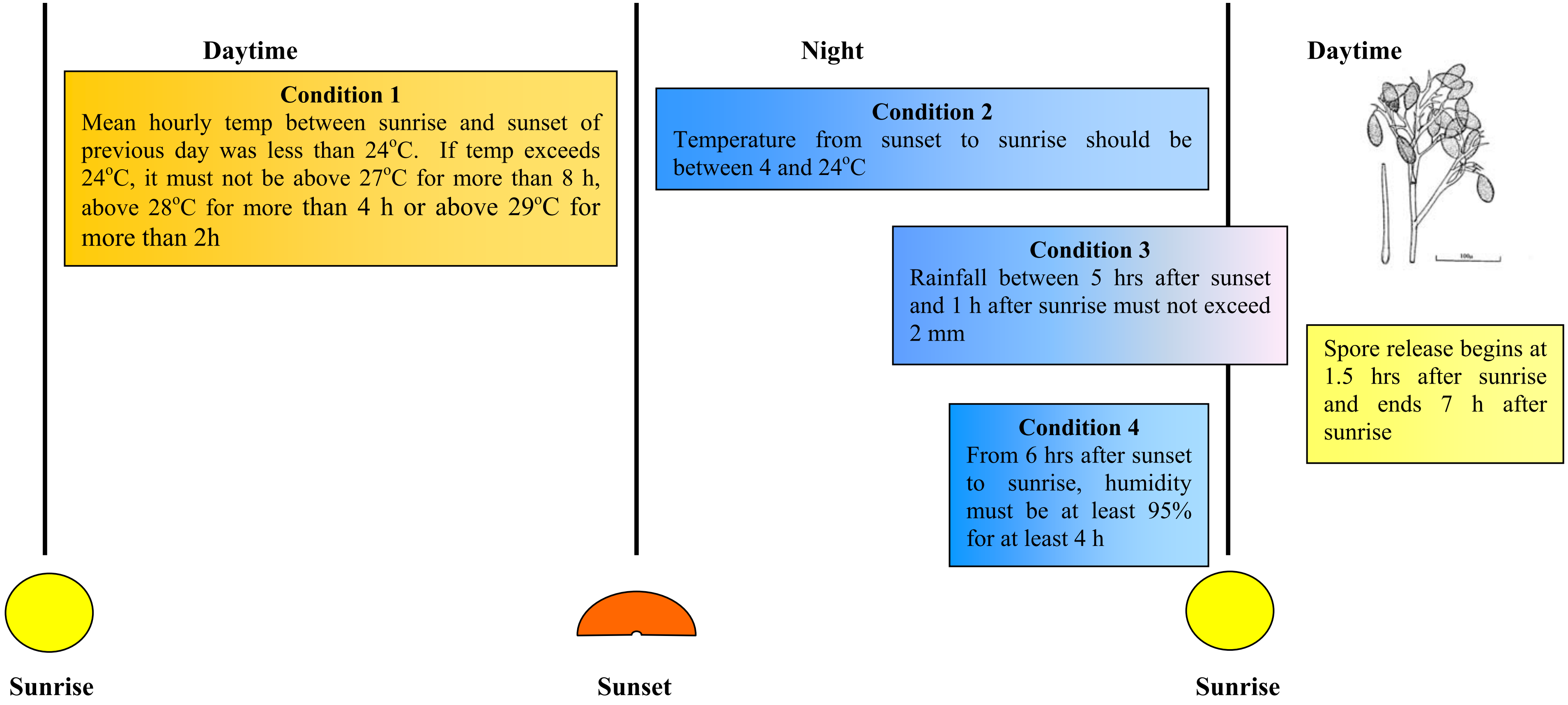
The economic analysis is only as good as the data it is provided with. It has not been possible to put a value on:
(a) The potassium (K) treatment which had no benefit in reducing downy mildew but may have had a benefit, post harvest. One grower was adamant that the spring onions were a better colour and a stronger plant after potassium was applied to the crop.
(b) Fewer pesticides in the environment, fewer pesticides on food for consumers and a reduced exposure of workers, farmers and their families to pesticides.

The analysis has highlighted a need to reduce the costs of production. There may be scope to do this by using cheaper chemicals. For example dimethomorph could be replaced with azoxystrobin as the latter is half the cost of the former. Also it would be worthwhile to evaluate phosphonic acid + mancozeb as this combination of fungicides are cheaper than the systemic fungicides and have provided good efficacy for control of downy mildew on *Brassica* seedlings (Minchinton, 1998).

Also trial F516f (boscalid and pyraclostrobin) BASF as it has a long with-holding period, so fewer applications would be required. It is registered for white blister (*Albugo candida*) control in the United Kingdom (Roy Kennedy, pers. comm.) and as *Albugo* is related to *Peronospora* (Riethmuller *et al,* 2002) chemicals which control one disease should control the other.

Benefits of the model
(a) Growers have gained a greater understanding and intelligence of the fungal lifecycle and how to impede it, such as irrigating in the early hours of the morning.
(b) It has enabled growers to manipulate the environment and reduce pressure from the disease. One grower in WA found changing irrigation times had an amazing effect on downy mildew levels to such an extent, that they would continue to grow during the winter.

Figure 3. 2: Chart illustrating the requirements for sporulation of the onion downy mildew pathogen *Peronospora destructor*
For spore production to occur, **all four conditions** outlined in the diagram below must be satisfied. Should at least one of the four conditions not be met, spore production will not occur.



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Appendix 3.1

```
'Visual basic program to determine onion downy mildew Sporulation
'Criteria.  This program is based upon the DownCast system (Jesperson
'& Sutton, 1987)which has been modified by FitzGerald & O'Brien (1994).
'
'Originally written by V.Galea (June - July, 1996)
'
'Modification in May 2002 for HAL Spring Onion Project with Liz Minchinton
'Data set collected by Environdata met station - hourly averages
'Coding adjusted to suit different data columns and hourly Vs.
'half hourly data points
'
'Modified May 27, 2002 to allow for manual input of solar radiation values from
'met station to allow for differences between estimated sunrise sunset & actual values
'
'Modified June 4, 2002 to allow program to directly determine sunrise
'and sunset times from solar radiation sensor
'
'
Sub version12()
'
'Declare variables
'
Dim Start_row: Dim Row_zero
Dim First_light_yesterday: Dim Last_light_yesterday: Dim First_light_today
Dim T: Dim Whole_hours: Dim Remainder: Dim Minutes: Dim Whole_minutes
Dim F_l_y: Dim L_l_y: Dim F_l_t
'
'
'Input box for entry of row location at start of data run - this will allow
'separation of daily data sets and to confine calculations within the
'limits and allow for location of printed output
'
Start_row = InputBox("Enter the row number for time = 00:00:00 for current day")
'
'Error trap to detect if the row number truly corresponds with a 00:00:00 time in column#2
'
Row_zero = TimeValue("00:00:00")
If Cells(Start_row, 2) <> Row_zero Then
   Do
   Start_row = InputBox("WARNING - PLEASE CHECK THAT YOU HAVE SELECTED THE
CORRECT ROW NUMBER.  Please re-enter the correct value for time = 00:00:00 for the current
day")
   Loop Until Cells(Start_row, 2) = Row_zero
Else
End If
'
' Routine to ensure that there are sufficient lines of data above start point to allow error checking
procedure to work.
'
If Start_row < 48 Then
```

```
   MsgBox "NOTE:  You need at least 24 hours of Met Data preceding this start point to allow
calculations to be made.  Move down the spreadsheet to the next day's data set"
   End
Else
End If
'
'Routine to test if correct number of data rows present in data block
'
If Cells(Start_row + 48, 2) <> Row_zero Then
   MsgBox "NOTE: There is a problem with this data set, please check as 48 data rows should be
present between time 00:00 and midnight!  There may be an extra data row present or rows missing!
This routine will now terminate!"
   End
Else
End If
'
'
If Cells(Start_row - 48, 2) <> Row_zero Then
   MsgBox "NOTE: There is a problem with this data set, please check as 48 data rows should be
present in the previous day's data set!  There may be an extra data row present or rows missing!  This
routine will now terminate!"
   End
Else
End If
''
'
'Automatic procedure to calculate first light & last light from solar radiation
'data from met station
'
'First light yesterday
'
F_l_y = 0 'reset value
J = 0
'    Start count forward at previous midnight (in half-hourly increments!)
       If Cells((Start_row - 48) + J, 9) = 0 Then  'Look for first sunlight period
          Do
             J = J + 1
          Loop Until Cells((Start_row - 48) + J, 9) > 0
       Else
       End If
   F_l_yraw = Cells((Start_row - 48) + J, 2) * 24

   F_l_y = TimeSerial(F_l_yraw, 0, 0) 'converts raw value for F_l_y into correct time format
'


'
'Last Light Yesterday
'
L_l_y = 0 'reset value
K = 0
'
   'Start count forward at previous noon (in half-hourly increments!)
     If Cells((Start_row - 24) + K, 9) > 0 Then  'Looking for first dark period
       Do
          K = K + 1
```

```
            Loop Until Cells((Start_row - 24) + K, 9) = 0
            Else
        End If
    L_l_yraw = Cells((Start_row - 24) + K - 1, 2) * 24 'Record last sunlight time
    '                                    backstep one increment from first dark period
    L_l_y = TimeSerial(L_l_yraw, 0, 0) 'converts raw value for L_l_y into correct time format

'
'
'First Light Today
'
F_l_t = 0 'reset value
L = 0
 'Start count forward from midnight(in half-hourly increments!)
     If Cells((Start_row) + L, 9) = 0 Then  'Looking for first sunlight period
        Do
            L = L + 1
            Loop Until Cells((Start_row) + L, 9) > 0
            Else
        End If
        F_l_traw = Cells((Start_row) + L, 2) * 24 'Record first sunlight period
        F_l_t = TimeSerial(F_l_traw, 0, 0) 'converts raw value for F_l_t into correct time format

'

'Write daylight length data to spreadsheet
'
Cells(Start_row, 11) = "Yesterday"
Cells(Start_row, 12) = "Yesterday"
Cells(Start_row, 13) = "Today"
Cells(Start_row + 1, 11) = "Firstlight"
Cells(Start_row + 1, 12) = "Lastlight"
Cells(Start_row + 1, 13) = "Firstlight"
Cells(Start_row + 2, 11) = F_l_y
Cells(Start_row + 2, 12) = L_l_y
Cells(Start_row + 2, 13) = F_l_t
'
'
'          ********** FACTOR 1  **********
'
'Basis:  Sporulation occurs at night (pre-dawn) when the following
'        conditions are satisfied:
'
'  1.Mean hourly temp during previous day (first light to evening
'    twilight) <= 24 deg C
'  2.If temp exceeds 24 deg C THEN must not be > 27 deg C for > 8 hours
'  3.or > 28 deg C for > 4 hours
'  4.or > 29 deg C for > 2 hours
'
'Declare variables
'
Dim A: Dim Tem: Dim T_over29: Dim T_over28: Dim T_over27
Dim T_between27_24: Dim T24and_under
'
'Define temp data range from previous day
```

```
 For A = 1 To 48   ' Previous 24 hours
   If Cells(Start_row - A, 2) >= F_l_y And Cells(Start_row - A, 2) <= L_l_y Then
'
       Tem = Cells(Start_row - A, 4)
         If Tem > 29 Then
           T_over29 = T_over29 + 1: T_over28 = T_over28 + 1: T_over27 = T_over27 + 1
         ElseIf Tem > 28 Then
           T_over28 = T_over28 + 1: T_over27 = T_over27 + 1
         ElseIf Tem > 27 Then
           T_over27 = T_over27 + 1
         ElseIf Tem <= 27 And Tem > 24 Then
           T_between27_24 = T_between27_24 + 1
         Else
           T24and_under = T24and_under + 1
         End If
         Else
   End If
   Next A
'
'Data adjusted to allow for half hourly readings
'
T_over29 = T_over29 / 2
T_over28 = T_over28 / 2
T_over27 = T_over27 / 2
T24and_under = T24and_under / 2
'
'Labels written to spreadsheet
'
Cells(Start_row + 5, 11) = "SPORULATION FACTOR # 1"
Cells(Start_row + 7, 11) = "Range"
Cells(Start_row + 7, 12) = "<= 24 C"
Cells(Start_row + 7, 13) = "> 27 C"
Cells(Start_row + 7, 14) = "> 28 C"
Cells(Start_row + 7, 15) = "> 29 C"
'
'Data sent to spreadsheet
'
Cells(Start_row + 8, 11) = "Cml hrs"
Cells(Start_row + 8, 12) = T24and_under
Cells(Start_row + 8, 13) = T_over27
Cells(Start_row + 8, 14) = T_over28
Cells(Start_row + 8, 15) = T_over29
'
'Routine to determine if temperature will prevent sporulation
'
If T_over29 > 2 Then
   Cells(Start_row + 9, 15) = "No"
   Else: Cells(Start_row + 9, 15) = "Yes"
End If
'
If T_over28 > 4 Then
   Cells(Start_row + 9, 14) = "No"
   Else: Cells(Start_row + 9, 14) = "Yes"
End If
```

```
'
If T_over27 > 8 Then
   Cells(Start_row + 9, 13) = "No"
   Else: Cells(Start_row + 9, 13) = "Yes"
End If
'
Cells(Start_row + 9, 11) = "Sporulation"
Cells(Start_row + 9, 12) = " - - "
Cells(Start_row + 11, 12) = "Factor 1 sporulation possible?"
'
If Cells(Start_row + 9, 13) = "Yes" And Cells(Start_row + 9, 14) = "Yes" And Cells(Start_row + 9,
15) = "Yes" Then
   Cells(Start_row + 11, 15) = "Yes"
   Else: Cells(Start_row + 11, 15) = "No"
End If
''
'
'
'  **********   FACTOR 2   **********
'
'Basis: Sporulation occurs at night (pre-dawn) when the following
'      conditions are satisfied
'
'Temperature during the previous night must be within the range 4 - 24 Deg C
'If this range is exceeded, sporulation will not occur
'Night range from Last light (previous day) to First light (current day)
'
'Declare variables
'
Dim Midnight1: Dim Midnight2: Dim B: Dim Tem2
Dim Night_in_range: Dim Night_out_range

'Set midnight values
'
Midnight1 = TimeValue("23:59:59")
Midnight2 = TimeValue("00:00:00")

  For B = 1 To 36 'spans previous night phase
'
'Period from Last light yesterday to midnight
'
   If Cells((Start_row + 18) - B, 2) >= L_l_y And Cells((Start_row + 18) - B, 2) < Midnight1 Then
      Tem2 = Cells((Start_row + 18) - B, 4)
         If Tem2 >= 4 And Tem2 <= 24 Then
            Night_in_range = Night_in_range + 1
         Else
            Night_out_range = Night_out_range + 1
         End If
'
'Period from midnight to First light today
'
   ElseIf Cells((Start_row + 18) - B, 2) >= Midnight2 And Cells((Start_row + 18) - B, 2) <= F_l_t
Then
      Tem2 = Cells((Start_row + 18) - B, 4)
         If Tem2 >= 4 And Tem2 <= 24 Then
```

```
            Night_in_range = Night_in_range + 1
          Else
            Night_out_range = Night_out_range + 1
          End If
    Else
    End If
  Next B
'
'
'Data adjusted to allow for half hourly readings
'
Night_in_range = Night_in_range / 2
Night_out_range = Night_out_range / 2
'
'Labels & data written to spreadsheet
'
Cells(Start_row + 14, 11) = "SPORULATION FACTOR # 2"
Cells(Start_row + 16, 11) = "Range"
Cells(Start_row + 16, 12) = "4 - 24 C"
Cells(Start_row + 16, 13) = "<4 or >24"
Cells(Start_row + 17, 11) = "Cml hrs"
Cells(Start_row + 17, 12) = Night_in_range
Cells(Start_row + 17, 13) = Night_out_range
Cells(Start_row + 19, 12) = "Factor 2 sporulation possible?"
'
If Night_out_range > 0 Then
    Cells(Start_row + 19, 15) = "No"
    Else: Cells(Start_row + 19, 15) = "Yes"
End If
'
'
'
'     **********  FACTOR 3    **********
'
'Basis: Sporulation will not occur if rainfall between 23:00:00 and 04:00:00
'       (previous night) exceeds a total of 1mm

'NOTE:  This is a modification of Jesperson & Sutton (1987) original format
'       "No rain to occur after 01:00:00" which was changed by
'       Fitz Gerald & O'Brien (1994) to account for differences in diurnal light
'       cycle between Australian winter & Canadian summer.
'
'Declare variables
'
Dim Rain_total: Dim C
'
'
Rain_total = 0
'
For C = 1 To 10
    Rain_total = Rain_total + Cells((Start_row - 2 + C), 8)
Next C

'Labels and data written to sheet
```

```
Cells(Start_row + 22, 11) = "SPORULATION FACTOR # 3"
Cells(Start_row + 24, 11) = "Total rain (mm)"
Cells(Start_row + 25, 11) = "Sporulation possible?"
Cells(Start_row + 24, 13) = Rain_total

If Rain_total <= 1 Then
    Cells(Start_row + 25, 13) = "Yes"
    Else: Cells(Start_row + 25, 13) = "No"
   End If

'       **********  FACTOR 4    **********
'
'Basis: Sporulation will occur when relative humidity is >= 95% for
'       a continuous 4 hour period between the time when at least 6 hours
'       of darkness have accumulated (previous night fall) and before sunrise
'       of current day.
'
'Declare variables
'
Dim Six_hrs: Dim Four_hrs: Dim Dark_check: Dim Dark_increment: Dim RH_switch
Dim D: Dim RH_count: Dim E: Dim RH
'
'
' This routine is complicated because this programming language has trouble
' coping with the change in time values at midnight.  For this reason
' the night has been separated into two components (dark period before
' midnight & dark period after midnight).
'
' Set midnight values
'
Midnight1 = TimeValue("23:59:59") 'changed from 23:59:59 (26/7/97)
Midnight2 = TimeValue("00:00:00")
Six_hrs = TimeValue("05:59:00")
Four_hrs = TimeValue("03:30:00")
'
'Check for at least six hours dark before midnight
'required for calculations on times after midnight.
'
'This calculation determines if there were more (or less) than 6 hrs
'of darkness before midnight.  If a value of <6 hrs is calculated, the
'program allows forward stepping (after midnight) of the routine to allow
'for the full 6 hrs of darkness to be taken into consideration.
'
'
'
  Dark_check = Midnight1 - L_l_y
    If Dark_check >= Six_hrs Then
        Dark_increment = 0
    Else: Dark_increment = Dark_check - Six_hrs
    End If
 '

'
RH_switch = "No"
```

```
  For D = 1 To 36 'spans previous night phase
'
'Period from Last light yesterday to midnight.
'This routine begins to assess the met data for %RH if there has been
'at least 6 hours of darkness before midnight.
'
    If Cells((Start_row + 18) - D, 2) >= (L_l_y + Six_hrs) And Cells((Start_row + 18) - D, 2) <
Midnight1 Then
        RH_count = 0
        For E = 1 To 8      'Tests next 4 hours for cont' RH >= 95%
        RH = Cells((Start_row + 18) - D + E - 1, 3)
            If RH >= 95 Then
                RH_count = RH_count + 1
            Else
            End If
        Next E
            If RH_count = 8 Then
                RH_switch = "Yes"
            Else
            End If

'Period from midnight to First light today.
'This routine allows the program to "forward step" if a short night (<6 hrs
'darkness before midnight) exists.  If this is the case, the program
'commences calculation of the periods of continuous high %RH after making
'allowance for the 6 hrs of darkness into the post midnight phase.  This
'will have little effect in the winter months, but may become critical
'in the longer days heading into late spring.

    ElseIf Cells((Start_row + 18) - D, 2) >= (Midnight2 - Dark_increment) And Cells((Start_row + 18)
- D, 2) <= (F_l_t - Four_hrs) Then
        RH_count = 0
        For E = 1 To 8      'Tests next 4 hours for cont' RH >= 95%
        RH = Cells((Start_row + 18) - D + E - 1, 3)
            If RH >= 95 Then
                RH_count = RH_count + 1
            Else
            End If
        Next E
            If RH_count = 8 Then
                RH_switch = "Yes"
            Else
            End If
    Else
    End If

  Next D

'Labels and data written to sheet

Cells(Start_row + 28, 11) = "SPORULATION FACTOR # 4"
Cells(Start_row + 30, 12) = "Factor 4 Sporulation possible?"
Cells(Start_row + 30, 14) = RH_switch
'
'
```

```
'
'Final determination of possibility of sporulation
'All four SPORULATION FACTORS must be satisfied
'
'Declare variables
'
Dim Red_Alert
'
If Cells(Start_row + 11, 15) = "Yes" And Cells(Start_row + 19, 15) = "Yes" And Cells(Start_row +
25, 13) = "Yes" And Cells(Start_row + 30, 14) = "Yes" Then
   Red_Alert = "YES"
   Else: Red_Alert = "NO"
   End If

'Labels and data written to sheet

Cells(Start_row + 33, 11) = "********************************"
Cells(Start_row + 34, 11) = "  DownCast Forecast"
Cells(Start_row + 35, 11) = "********************************"
Cells(Start_row + 36, 11) = "Has Sporulation Event Occurred ?"
Cells(Start_row + 38, 12) = Red_Alert
'
MsgBox "DownCast Job Completed!"
'
End Sub
```

Chapter 4 Field evaluation of the DOWNCAST model and of its application in decision support involving selected protectant and systemic fungicides, adjuvants and nutrition treatments

Summary

This chapter reports on field evaluation of fungicides, adjuvants, fertilisers and the DOWNCAST model for control of downy mildew in commercial crops of spring onions. Systemic fungicides were superior to contact fungicides for disease control. The addition of adjuvants and fertilisers had no additional benefit in disease reduction. However, in the opinion of one grower the addition of potash increased the quality of the spring onions. Use of the DOWNCAST model reduced the number of fungicide applications to crops by 2 to 5 without affecting the quality or yield of spring onions.

4.1 Introduction

Fungicides

There is little information on fungicide control for downy mildew on spring onions, but much has been published on control of the disease in bulb onions. Early fungicide control of downy mildew on bulb onions was centred on the copper-based fungicides, then moved to the dithiocarbamates, such as mancozeb. The introduction of the systemic acylalanine fungicides, especially metalaxyl, revolutionised control of downy mildew, however, over use has resulted in the emergence of metalaxyl resistant *Peronospora destructor* (Berkeley) Caspary ex Berlely, (O'Brien, 1992). The introduction in the 1990's of another systemic fungicide dimethomorph (Acrobat), with a different mode of action to the acylalanine fungicides, gave excellent control of the disease (Jensen and Lundsgaard, 1999). It became an important tool for fungicide resistance management strategies in *P. destructor* by providing another systemic fungicide to alternate with the acylalanines. The most recent introduction of systemic fungicides for control of the Peronosporales are the strobilurins, such as azoxystrobin.

The systemic and contact fungicides trialed for downy mildew on bulb onions come from the Fungicide Activity Groups A, B, D, X and Y (Avcare). These fungicides include benalaxyl, metalaxyl, fosetyl, dimethomorph, copper oxychloride, copper hydroxide, cuprous oxide, thiram, ziram, mancozeb, chlorothalonil, dichlofluanid, propamocarb, iprodione, carbendazim, captan and sulphur. (Krauthausen *et al*., 1997; Develash and Sugha, 1997; Tesoriero *et al*., 1993; O'Brien, 1992; Rod, 1986; Gladders and Pye, 1984; Smith *et al*., 1985; Stofella and Sonoda, 1982; Wilson, 1980; Teviotdale *et al*., 1980; Issa *et al*., 1979; Woolliams 1957; Newall and Rawlins, 1951 and Yarwood, 1943). A number of other fungicides have been trialed for downy mildew control, which do not fit into the Fungicide Activity Groups (Avcare) probably because they are not available in Australia and these include cymoxanil, cyprofuram, dyrene, difolatan, folpet, cuman, fentin hydroxide, ferbam and parzate (Rod, 1986; Teviotdale *et al*., 1980; Issa *et al*., 1979; Mirakhur *et al*., 1977 and Woolliams 1957).

Nutrition

Nutrient levels affect the susceptibility or tolerance of bulb onions to *P. destructor*. Palti and Rotem (1981) reported that a balance of NKP was very important in the first one-third to one-half of the crop's growth to avoid excessive growth and manage downy mildew. Excessive nitrogen has been observed to favour dense leaf growth and subsequent development of downy mildew (Palti *et al.,* 1958, 1972). Nitrogen up to 175 kg/ha of any form (urea, calcium ammonium nitrate or ammonium sulphate) and to a lesser extent phosphorous stimulated downy mildew development; whilst the severity of downy mildew decreased with increasing potassium in bulb onions (Develash and Sugha, 1997; El Ganaiey *et al*., 1998). The situation in spring onions, which have a much shorter production period, is unknown.

Adjuvants

Adjuvants are an additive which can assist or modify the action of the active ingredient (Foy, 1989). They can (i) enhance the activity of systemic fungicides (Steurbaut, 1993), (ii) reduce fungicide application rates (Laverick, 1991) and (iii) lower the number of spray applications (Rogiers, 1995). Consequently they could be important tools for disease control with the worldwide trend to reduced pesticide usage (Rogiers, 1995). MacMamus *et al*., (1997, 2002), working on bulb onions in Queensland found that application of dimethomorph + mancozeb with either of the adjuvants DC-Tron™, Codacide™, or Synertrol Oil™, post inoculation of *P. destructor* spores, enhanced the penetration and translocation of the systemic fungicide and significantly reduced the incidence of downy mildew.

The DOWNCAST Model

DOWNCAST is a mathematical model to predict when environmental conditions (temperature, relative humidity and rainfall) are conducive to *P. destructor* sporulation or infection and when conditions are not, so that fungicide sprays can be applied in the former and not in the latter. Fungicide applications are timed for their greatest efficacy and not applied when unnecessary. Consequently they have the potential to reduce calendar or weekly sprays.

Various forms of the DOWNCAST model have reduced the number of sprays applied to bulb onions crops for downy mildew control by 1 to 3 (Jesperson and Sutton, 1987) and 2 to 5 (Whiteman and Beresford, 1999) with no significant differences in symptom levels from weekly sprays. Harper (1998), working in the Lockyer Valley of Queensland, reported that use of the DOWNCAST model reduced the number of sprays applied to bulb onion crops for downy mildew control from 12 down to 9, 8 and 5, however, there was no disease in any of the crops. Later, MacManus (2002) working in the same area, reduced the number of sprays applied to these crops by 50%, from 12 to 6, whilst maintaining downy mildew control and yields.

4.2 Materials and Methods

Field trials

Efficacy trials were established in years 2001 (trial no. 1, Devon Meadows), 2002 (trial no.2, Clyde), 2002 (trial no. 3, Pearcedale, Vic.) and 2003 (trial no. 4, Cannons Creek, Vic). Trials numbered 1 and 2 compared chemical treatments and a standard spray program, whilst trials numbered 3 and 4 compared control of downy mildew on spring onions with the DOWNCAST predictive model against a standard weekly spray program for the disease. The standard spray program was based on a crop scout recommendation. The cultivar Paragon was grown in the first two trials and the cultivar Straight Leaf in the second two trials. All seed was direct sown and grown at 3 rows per bed. In trials 1 and 2 seed was sown with a disc seeder, while in trials 3 and 4 it was sown with a precision seeder, at the growers own preferred plant spacing.

In trial no 1 (spring – summer 2001), there were 7 blocks laid out in an incomplete randomised block design. Within each block, there were 6 plots representing 6 of the 7 treatments (Table 4.1). Plots were 4.5m long by 1.62m wide. Seed was planted on 28/8/01and emerged about 10/9/01. The first spray was applied to all treatments on 12/9/01 (week 2) and the last spray was applied on 15/11/01 (week 11). The crop was assessed for downy mildew on 6/11/01 (week 10) and harvested on 21/11/01 (week 12).

In trial no 2 (autumn –winter 2002), there were 22 blocks laid out in an incomplete randomised block design. Within each block, there were 3 plots representing 3 of the 10 treatments (Table 4.2). Plots were 5m long by 1.2m wide. Seed was planted on 13/3/02 and emerged on 20/3/02. The first sprays were applied to all treatments on 3/4/02 (week 2) and the last sprays applied on 19/6/02 (week 13). The crop was assessed for downy mildew on 18/6/02 and harvested on 19/6/02 (week 14).

In trial no 3 (spring – summer 2002), there were 8 blocks laid out in a randomised block design. Within each block, there were 9 plots representing each of 9 treatments (Table 4.3). Plots were 6m long by 1.5m wide on the bed. Seed was planted on 10/09/02 and emerged on 01/10/02. The first sprays were applied to all treatments (except the Models) on 29/10/02 (week 7) and continued on a weekly basis with the last spray applied on 4/12/02 (week12). The crop was assessed for downy mildew on 11/12/02 (week 13) and harvested on 16/12/02 (week 14).

In trial no 4 (autumn – winter 2003), there were 6 blocks laid out in a randomised block design. Within each block there were 7 plots representing each of 7 treatments (Table 4.4). Plots were 7m long by 1.5m wide on the bed. Seed was planted on 07/04/03, emerged on 14/04/03. The fungicide sprays were applied to all treatments (except the Models) on 13/05/03 (week 5) and continued on a weekly basis with the last spray applied on 06/08/03 (week 17). The crop was assessed for downy mildew on 22/07/03, 29/07/03, 6/08/03 and on 14/08/03 and harvested on 19/08/03 (week 18).

Table 4.1 Spray schedule for trial No 1 spring – summer 2001

Treatment	Week (date) 1 (31/8/01)	2 (12/9/01)	3 (19/9/01)	4 (26/9/01)	5 (3/10/01)	6 (9/10/01)	7 (18/10/01)	8 (24/10/01)	9 (1/11/01)	10 (8/11/01)	11 (15/10/01)
Control		water	water	water	water	water	water	water	water	water	water
STD		MZ	MZ	MZ	Kocide	RGMZ	RGMZ	RGMZ	RGMZ	MZ	Acrobat
Agri-Fos 600 spray +STD		MZ+AFS	MZ+AFS	MZ+AFS	Kocide+AFS	RGMZ+AFS	RGMZ+AFS	RGMZ+AFS	RGMZ+AFS	MZ+AFS	Acrobat+AFS
Agri-Fos 600 drench +STD	AFD	MZ+AFD	MZ+AFD	MZ+AFD	Kocide+AFD	RGMZ+AFD	RGMZ+AFD	RGMZ+AFD	RGMZ+AFD	MZ+AFD	Acrobat+AFD
Aminofit.Xtra + STD	AX	MZ	MZ+AX	MZ	Kocide	RGMZ	RGMZ+AX	RGMZ	RGMZ	MZ	Acrobat+AX
DC-Tron +STD		MZ	MZ	MZ	Kocide	RGMZ	RGMZ	RGMZ	RGMZ	MZ	Acrobat+DCT
Sulphate of potash+STD		MZ	MZ	MZ	Kocide	RGMZ	RGMZ	RGMZ	RGMZ+K	MZ	Acrobat

STD, Standard spray program; AFD, Agri-Fos 600 drench; AFS, Agro-Fos 600 spray; AX, Aminofit.Xtra; DCT, DCTron; K, Sulphate of potash; MZ, Dithane M45; RGMZ, Ridomil Gold MZ

Table 4.2 Spray schedule for trial No 2 autumn - winter 2002

Treatment Lam 2002	Week (date) 1 (27/3/02)	2 (3/4/02)	3 (10/4/02)	4 (17/4/02)	5 (24/4/02)	6 (1/5/02)	7 (8/5/02)	8 (15/5/02)	9 (22/5/02)	10 (29/5/02)	11 (5/6/02)	12 (12/6/02)	13 (19/6/02)
Control		water	water	water	water	water	water	water	water	water	water	water	water
STD		MZ	MZ	MZ	Kocide	MZ	MZ	Ac+MZ	Ac+MZ	RGMZ	RGMZ	Ac+MZ	Ac+MZ
AgriFos 600+STD		MZ	MZ	MZ	Kocide	MZ	MZ	Ac+MZ	Ac+MZ	RGMZ	RGMZ	Ac+MZ	Ac+MZ
	AF-D	AF-D	AF-D	AF-D	AF-D	AF-D	AF-D	AF-S	AF-S	AF-S	AF-S	AF-S	AF-S
Amistar+STD		MZ	MZ	MZ	Kocide	MZ	MZ	Amistar	Amistar	MZ	MZ	Amistar	Amistar
Synertrol+STD		MZ	MZ	MZ	Kocide	MZ	MZ	Ac+MZ	Ac+MZ	RGMZ	RGMZ	Ac+MZ	Ac+MZ
		Synertrol	Synertrol	Synertrol	Synertrol	Synertrol	Synertrol	Synertrol	Synertrol	Synertrol	Synertrol	Synertrol	Synertrol
Aminofit.Xtra+STD		MZ+AX	MZ	MZ+AX	Kocide	MZ	MZ	Ac+MZ+AX	Ac+MZ	RGMZ	RGMZ	Ac+MZ+AX	Ac+MZ
Bion+STD		MZ	MZ	MZ	Kocide	MZ	MZ	Ac+MZ	Ac+MZ	RGMZ	RGMZ	Ac+MZ	Ac+MZ
		Bion	Bion	Bion	Bion	Bion	Bion	Bion	Bion	Bion	Bion	Bion	Bion
Bion		Bion	Bion	Bion	Bion	Bion	Bion	Bion	Bion	Bion	Bion	Bion	Bion
Sulphate of Potash+STD		MZ	MZ	MZ	Kocide	MZ	MZ	Ac+MZ	Ac+MZ	RGMZ	RGMZ	Ac+MZ	Ac+MZ
				Potash						Potash			
Dithane M45+Kocide		MZ	MZ	MZ	MZ	MZ	MZ	MZ	MZ	MZ	MZ	MZ	MZ
		Kocide	Kocide	Kocide	Kocide	Kocide	Kocide	Kocide	Kocide	Kocide	Kocide	Kocide	Kocide

Ac, Acrobat ; AF-D, Agri-Fos 600 drench; AF-S, Agri-Fos 600 spray; AX, Aminofit.Xtra; MZ, Dithane M45; STD, Standard spray program; RGMZ, Ridomil Gold MZ

Table 4.3 Spray schedule for trial No 3 spring – summer 2002

Treatment	Week (date)						
	6 (22/10/02)	7 (29/10/02)	8 (6/11/02)	9 (14/11/02)	10 (20/11/02)	11 (27/11/02)	12 (4/12/02)
Control (water)	Water	Water	Water	Water	Water	Water	Water
Agri-Fos 600 + STD	-	Dithane-M45 Agri-Fos 600	Ridomil Gold MZ Agri-Fos 600	Ridomil Gold MZ Agri-phos 600	Acrobat+Dithane M45 Agri-phos 600	Acrobat+Dithane M45 Agri-phos 600	Ridomil Gold MZ Agri-phos 600
Aminofit.Xtra + STD	-	Dithane-M45 Aminofit.Xtra	Ridomil Gold MZ -	Ridomil Gold MZ Aminofit.Xtra	Acrobat+Dithane M45 -	Acrobat+Dithane M45 Aminofit.Xtra	Ridomil Gold MZ -
AmistarWG	-	Dithane-M45	Amistar	Amistar	Dithane-M45	Dithane-M45	Amistar
Model 1	Dithane-M45 (24/10/02)	-	Ridomil Gold MZ (8/11/02)	-	-	Ridomil Gold MZ (25/11/02)	Acrobat+Dithane M45 (2/12/02)
Model 2	-	-	-	-	Ridomil Gold MZ (20/11/02)	-	Ridomil Gold MZ (2/12/02)
Sulphate of potash + STD	-	Dithane-M45 -	Ridomil Gold MZ Sulphate of potash	Ridomil Gold MZ -	Acrobat+Dithane M45 -	Acrobat+Dithane M45 Sulphate of potash	Ridomil Gold MZ -
Synertrol + STD	-	Dithane-M45 Synertrol	Ridomil Gold MZ Synertrol	Ridomil Gold MZ Synertrol	Acrobat+Dithane M45 Synertrol	Acrobat+Dithane M45 Synertrol	Ridomil Gold MZ Synertrol
STD	-	Dithane-M45	Ridomil Gold MZ	Ridomil Gold MZ	Acrobat+Dithane M45	Acrobat+Dithane M45	Ridomil Gold MZ

STD, Standard spray program.

Table 4.4 Spray schedule for trial No 4 autumn – winter 2003

Treatment	Week (date)																
	0 (7/4/03)	2 (14/4/03)	3 (21/4/03)	4 (28/4/03)	5 (13/5/03)	6 (20/5/03)	7 (28/5/03)	8 3/6/03)	9 10/6/03)	10 (18/6/03)	11 (25/6/03)	12 (1/7/03)	13 (8/7/03)	14 (16/7/03)	15 (21/7/03)	16 (29/7/03)	17 (6/8/03)
Control	-	-	-	-	-	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water
Aminofit.Xtra+STD	-	-	-	A	RGMZ	RGMZ+A	Ac+MZ	Ac+MZ+A	RGMZ	RGMZ+A	Ac+MZ	Ac+MZ+A	RGMZ	RGMZ+A	Ac+MZ	Ac+MZ+A	RGMZ
AmistarWG+STD	-	-	-	-	Am	Am	RGMZ	RGMZ	Ac+MZ	Ac+MZ	RGMZ	RGMZ	Ac+MZ	Ac+MZ	RGMZ	Am	Am
Model 1	-	-	-	-	RGMZ	RGMZ	-	-	Ac+MZ	Ac+MZ	RGMZ	-	-	RGMZ	RGMZ	Ac+MZ	-
						(19/5/03)			(8/6/03)	(16/6/03)	(28/6/03)			(13/7/03)		(3/8/03)	
Model 3	-	RGMZ (22/4/03)	RGMZ (29/4/03)	Ac+MZ (9/5/03)	Ac+MZ (19/5/03)	RGMZ (19/5/03)	-	-	RGMZ (8/6/03)	Ac+MZ (16/6/03)	-	-	-	-	-	-	-
STD	-	-	-	-	RGMZ	RGMZ	Ac+MZ	Ac+MZ	RGMZ	RGMZ	Ac+MZ	Ac+MZ	RGMZ	RGMZ	Ac+MZ	Ac+MZ	RGMZ
Potash+STD	K (g)	-	-	K(g)	RGMZ	RGMZ	Ac+MZ+K(g)	Ac+MZ	RGMZ	RGMZ+K(l)	Ac+MZ	Ac+MZ	RGMZ+K(l)	RGMZ	Ac+MZ	Ac+MZ+K(l)	RGMZ

A, Aminofit.Xtra; Ac, Acrobat; Am, AmistarWG; RGMZ, Ridomil Gold MZ; MZ, Dithane M45

Application of chemicals

All chemicals and liquid fertilisers were applied with a hollow cone nozzle SPX8 at 30psi by a Silvan Selectra 12v knapsack (Silvan pumps and Sprayers (Aus) Pty. Ltd.). Fungicides were applied at a volume of 100L/ha. Granular fertilisers were scattered over plots and raked in (Table 4.5). A plastic barrier, 1m high reinforced with plastic coated aluminium stakes at 1m intervals and 7m long, was used to prevent drift of chemicals.

Table 4.5 Chemicals and rates of application for the spring onion trials

Trade name	Active	Company	Rate	Trial
Control (water)	-	-	-	1, 2, 3, 4
Acrobat (Acrobat+Dithane M-45)	Dimethomorph	BASF	2 kg/ha	1, 2, 3, 4
	Mancozeb	Rhom & Hass	1.5 kg/ha	
Agri-Fos 600	Phosphonic acid	Agrichem	4 L/ha spray	1, 2, 3
			6 L/ha drench	1
Agripotash	41.5% Potassium	Phosyn	10 L/ha	4
Aminofit.Xtra	Amino acids	Industrial Products Marketing	5 ml/L	1, 2, 3, 4
Amistar WG	Azoxystrobin	CropCare, Syngenta	60 g/100L	2, 3, 4
Bion	Acibenzolar-S-Methyl	Serve-Ag	50 g/ha	2
DC-Tron	Petroleum Oil	Caltex	2%	1
Dithane M45/DF	Mancozeb	Rhom & Hass	3 kg/ha	1, 2, 3, 4
Kocide	Cupric hydroxide	Griffin	2.2 kg/ha	1, 2
Ridomil Gold MZ	Mancozeb+ Metalaxyl-M	Novatis	2.5 kg/500L	1, 2, 3, 4
Sulphate of potash	N:P:K 0:0:41	Incitec Fertilisers	375 kg/ha	1, 2, 3, 4
Synertrol	Emulsifiable vegetable oil	Organic Crop Products Pty Ltd	20-30 ml/100L	1, 2, 3, 4

Weather stations

Both the 2002 and 2003 trials were serviced by an Environdata Mark 4 weather station (Environdata Australia Pty Ltd). There were 4 sensors attached to the weather station. An electronic relative humidity (RH) sensor (RH12) and the temperature sensor (TA10) were housed in a Stevenson screen placed between rows of spring onions. The tipping bucket rain gauge (RG12, 0.2mm) was placed in the irrigation line between bays of spring onions. The solar radiation sensor (SR10) was located on the weather station housing 2m above the crop. Data was continually measured every 1 minute period and the average given every 30 minutes. This data was downloaded daily via a modem.

Assessments

In each trial assessments were made for the incidence (%) of downy mildew measured as the number of plants with downy mildew symptoms on foliage. In trial one the whole plot, consisting of 3 rows of spring onions was assessed for downy mildew. In trial 2 a randomly selected 40cm length of bed, consisting of 3 rows of spring onions was assessed for the incidence of downy mildew. In trial 3 a similar 1m length of bed was selected and in trial 4 all spring onions in the plots were assessed for downy mildew. Time to bunch spring onions was measured in trial 2 only. Yield was measured by dividing plots into 2 halves and harvesting a 1m length of bed (consisting of 3 rows of spring onions) in each half, a half m from the end of each plot. The number of bunches of spring onions were counted, weighed and an average weight and number were calculated for each plot. Data was analysed using ANOVA within Genstat 7.1, Lawes Agricultural Trust (Rothamsted Experimental Station). The number of weekly sprays applied to crops in trials 3 and 4 were compared with the number sprayed according to the predictions of the DownCast model (Tables 4.4 and 4.5).

4.3 Results

Trial No. 1 spring – summer 2001

The incidence of downy mildew was extremely low in the spring to summer chemical control trial of 2001, however, the control plots (no chemicals) had significantly more downy mildew than all the other treatments (Table 4.6). The additions of potash (0.032b), phosphorous acid (AgriFos 600®) spray (0.014b), phosphorous acid drench (0.012b), Aminofit.Xtra™ (0.012b) and DC-Tron™ (0.012b) to the standard treatment (0.050b) had no benefits in significantly reducing the incidence of downy mildew on the spring onions. Similar results were obtained with the average number of bunches harvested with the treatments. All chemical treatments significantly increased the yield of spring onions, however, no treatment was significantly better than the standard treatment. The labourer bunching the spring onions reported that the control plots were generally slower to bunch as they needed more cleaning up of damaged tissue and the spring onions in the DC-Tron™ plots were rubbery and soft.

Table 4.6 Effect of treatments on downy mildew incidence and yield of spring onions trial No.1

Treatment	Average Incidence of downy mildew (%)	Average No. bunches/m^2
Control	0.192 a	13.74 a
STD	0.050 b	15.66 b
Sulphate of potash + STD	0.032 b	16.06 b
AgriFos 600 spray + STD	0.014 b	15.76 b
AgriFos 600 drench + STD	0.012 b	15.66 b
Aminofit.Xtra + STD	0.012 b	15.45 b
DC-Tron + STD	0.012 b	15.45 b
l.s.d.	0.092	1.08

STD (standard) = Dithane M-45, Dithane M-45, Dithane M-45, Kocide, Ridomil Gold MZ, Ridomil Gold MZ, Ridomil Gold MZ, Ridomil Gold MZ, Dithane M-45, Acrobat+Dithane M45. Numbers followed by a different letter are significantly different.

Trial No. 2 autumn – winter 2002

There were naturally high levels of downy mildew during this trial as the control plots (no chemicals) had a 73% incidence of the disease (Table 4.7). They had a significantly higher incidence of downy mildew than all other treatments except phosphorous acid, mancozeb (Dithane M-45®) + cupric hydroxide (Kocide®). The best controls of downy mildew were the standard, standard + sulphate of potash and the Aminofit.Xtra™ + standard, which reduced the disease by 84 – 88%.

The quickest treatment to bunch was the sulphate of potash + standard. One grower reported that spring onions treated with fertiliser applications produced stronger onions, especially the sulphate of potash treatment in terms of colour and strength of the plants (Craig Arnott, Arnotts Vegetable Farms, pers. comm.).

Control plots produced fewer bunches of spring onions (5.2a bunches/m^2), whilst the standard plots yielded the most bunches of spring onions (13.29/m^2). There was no significant difference in yield of spring onion bunches between the standard, standard + sulphate of potash, standard + Aminofit.Xtra™, standard + Synertrol™, standard + phosphorous acid or mancozeb + cupric hydroxide treatments, yet the number of bunches varied by 16%.

Table 4.7 Effect of treatment on downy mildew incidence and spring onion production trial No. 2

Treatment	Average disease incidence (%)	Log disease incidence	Average No. bunches/m^2	Average time for two people to bunch a deck[a]
Control (water)	71.36	4.268 a	5.2 a	5.00
Dithane M-45 + Kocide	45.56	3.819 a	11.27 bc	1.72
Amistar + Dithane M45	23.36	3.151 b	12.13 bc	1.09
Bion	22.57	3.117 b	7.90 ab	2.55
Bion + STD	18.86	2.937 bc	9.80 b	-[b]
AgriFos 600 +STD	18.64	2.925 bc	12.99 c	1.44
Synertrol + STD	15.89	2.766 bc	12.80 bc	1.05
STD (standard)	11.72	2.462 cd	13.29 c	1.05
Sulphate of potash + STD	11.65	2.455 cd	12.35 bc	0.95
Aminofit.Xtra + STD	8.25	2.111 d	11.11 bc	1.03
lsd (approximate)		0.56	3.0	

[a], a deck is 10 bunches of spring onions; [b], time to bunch was not recorded.
STD (standard) = Dithane M-45, Dithane M-45, Dithane M45, Kocide, Dithane M45, Dithane M45, Acrobat + Dithane M45, Acrobat + Dithane M-45, Ridomil Gold MZ, Ridomil Gold MZ, Acrobat + Dithane M45, Acrobat + Dithane M45. Numbers followed by a different letter are significantly different.

Trial No. 3 spring – summer 2002 first evaluation of chemicals and the DownCast model against a weekly spray program

There was low disease pressure in the spring and summer 2002 trial as only 3.8% of plants in the control (no chemical) plots of the trial showed symptom of downy mildew (Table 4. 8). The standard weekly spray program of 6 sprays reduced the disease by 84% when compared to the control plots. There was no benefit in the addition of fertilisers (Aminofit.Xtra™ or sulphate of potash), the wetting agent Synertrol™ or an additional fungicide (AgriFos 600®) to the standard treatment to reduce the incidence of downy mildew, as their incidences did not differ significantly from that of the standard. Alternating azoxystrobin (Amistar®) with mancozeb gave as good a control of downy mildew as the standard treatment of alternating metalaxyl + mancozeb (Ridomil Gold MZ®) with dimethomorph (Acrobat®) + mancozeb.

The Model 1 treatment, which had 4 sprays, controlled downy mildew as well as the 6 sprays applied by the standard weekly spray program. There was no significant difference between the levels of downy mildew on the Model 1 and Model 2 treatments, although the former applied 4 sprays on a 7 day withholding period and 2 were applied by the latter on a 10 day with-holding period. There was, however, a significantly lower level of disease control for Model 2 compared to the standard treatment.

The treatments did not differ in the number of bunches harvested per m^2, except the sulphate of potash + standard had significantly more bunches than the control plots. The gain in disease control with the fungicides and fertilisers was only reflected in increased bunch number for the standard + sulphate of potash treatment.

Table 4.8 Effect of chemicals and the DownCast model on downy mildew incidence and yield of spring onions trial No. 3, spring – summer 2003

Treatment	Disease Incidence		Mean No.
	Mean disease incidence (%)	Angular transformation	of bunch m^2
Control (water)	3.8	11.2 a	12.9 a
Model 2	1.8	7.8 b	13.9 ab
Synertrol + STD	1.4	6.7 bc	13.8 ab
Model 1	1.3	6.6 bc	13.9 ab
Aminofit.Xtra + STD	0.8	5.1 c	13.7 ab
AgriFos 600 + STD	0.7	4.8 c	14.2 ab
AmistarWG + Dithan M45	0.6	4.6 c	14.5 ab
STD	0.6	4.5 c	13.1 ab
Sulphate of potash + STD	0.6	4.5 c	14.6 b
l.s.d. (5%)		2.61	1.63

STD (standard) = Dithane M45, Ridomil Gold MZ, Ridomil Gold MZ, Acrobat + Dithane M45, Acrobat + Dithane M45, Ridomil Gold MZ. Numbers followed by a different letter are significantly different.

Trial No. 4 autumn – winter 2003 second evaluation of chemicals and the DownCast model against a weekly spray program

In the autumn and winter trial of 2003 emergence of spring onions was poor, the crop grew slowly and downy mildew developed late in the trial, first appearing in control plots at week 15 (Figure 4.1). By harvest at week 18 disease pressure was high with 39% of plants showing symptoms of downy mildew in the control plots (Table 4.9).

Fig 4.1 Development of downy mildew (incidence) on spring onions plants in control (unsprayed) plots, trial No. 4, autumn – winter 2003

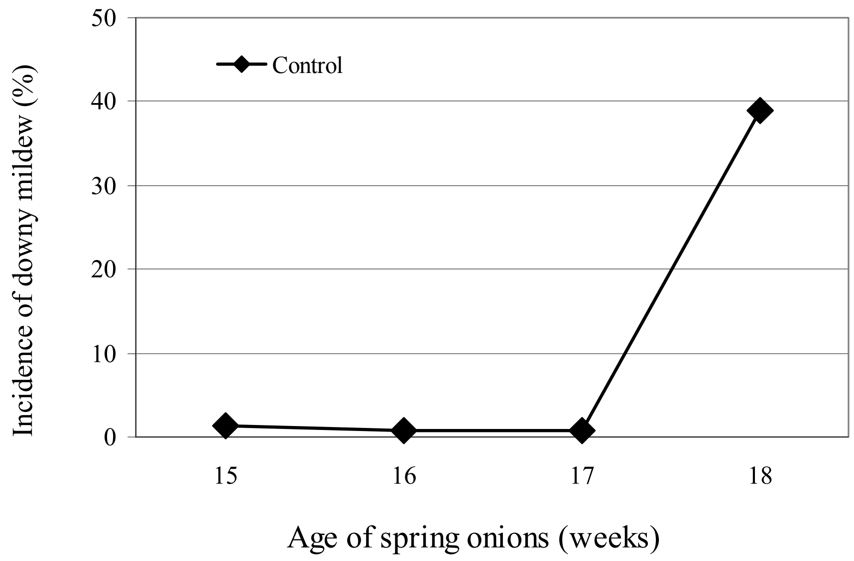

Table 4.9 Effect of treatment on downy mildew incidence and yield of spring onions trial No. 4 autumn – winter 2003

Treatment	Disease Incidence		Mean No.	Average	Time to make a bunch	
	Mean disease incidence (%)	Log disease incidence	of bunch m^2	bunch weight (g)	Mean time (sec)	Log mean time
Control (water)	39.0	3.66 a	6.6 ab	259.9 a	23.81	3.2 a
Model 3	23.8	3.17 a	7.7 ab	251.9 a	20.34	3.0 ab
Model 1	1.5	0.42 b	5.7 b	204.5 b	14.74	2.7 b
Amistar + STD	0.4	-0.95 c	8.6 a	240.5 ab	18.13	2.9 ab
STD	0.3	-1.08 c	5.9 b	228.5 ab	17.76	2.9 ab
Sulphate of potash + STD	0.3	-1.32 c	8.2 a	235.5 ab	15.34	2.7 b
Amino + STD	0.2	-1.83 c	6.9 ab	235.6 ab	14.5	2.7 b
l.s.d. (5%)		0.967	2.212 (5%)	36.25 (5%)		0.3
l.s.d. (10%)		-	1.832 (10%)	30.01 (10%)		-

STD (standard) = Ridomil Gold MZ, Ridomil Gold MZ, Acrobat + Dithane M45, Acrobat + Dithane M45, Ridomil Gold MZ, Ridomil Gold MZ, Acrobat + Dithane M45, Acrobat + Dithane M45, Ridomil Gold MZ, Ridomil Gold MZ, Acrobat + Dithane M45, Acrobat + Dithane M45, Ridomil Gold MZ. Numbers followed by a different letter are significantly different.

The standard treatment of 13 fungicide sprays applied weekly from week 5, significantly reduced downy mildew, by 99% compared with the control treatment. The Model 1 treatment that consisted of 8 sprays applied on a 7 day withholding period reduced the disease by 96% compared with the control. Plants in this treatment, however, had significantly more downy mildew compared with the standard treatment. Amistar integrated into the standard treatment gave as good a control of the disease as the standard treatment. The Model 3 treatment of sprays applied from week 2 on a 7 day withholding period produced too many applications of fungicides during the life of the crop and so the treatment was terminated at week 10. The addition of fertilisers (Aminofit™ or sulphate of potash) to the standard treatment had no additional benefit in improving downy mildew control above that of the standard.

The treatments differed in the number of bunches harvested. The potash + standard and the azoxystrobin + standard treatments had significantly more bunches than the standard and Model 1 treatments. This suggests that the addition of Potash increased the number of bunches, although it had no significant effect on lowering downy mildew levels. Interestingly the weight of bunches was highest in the Control and Model 1 treatments which had the highest level of downy mildew. The Control with the highest levels of downy mildew took a significantly longer time to bunch then the azoxystrobin + standard treatment with the least amount of downy mildew.

4.4 Discussion

The standard fungicide spray program, which largely consisted of alternating 2 sprays of metalaxyl + mancozeb with 2 of dimethomorph + mancozeb, gave the best control of the disease reducing it by 74-99% compared with unsprayed plots. It is generally typical of current industry practices. Amistar® has potential for downy mildew control on spring onions, but is not currently registered. The addition of sulphate of potash to the standard spray program did not produce any significant improvements in downy mildew control above that of the standard, although it improved quality. The DOWNCAST Model reduced the number of sprays by 2 to 5, with only significantly more downy mildew in the latter compared with the standard spray program. Reducing levels of the disease did not consistently correspond with increased yields.

Fungicides

Control (untreated plots) had the highest incidence of disease suggesting that fungicides used in the trial had efficacy against *P. destructor*. There was no indication that the systemic fungicides were not controlling the disease. Consequently there is no suggestion that *P. destructor* at any of the trial sites was exhibiting resistance to the systemic fungicides, although resistance has been reported in Queensland (O'Brien, 1992). Growers reported that benalaxyl (Galben M®) an acylamine fungicide similar to metalaxyl was no longer effective against downy mildew.

The disease appears to require a systemic fungicide to control it, as the contact fungicides (mancozeb and copper) were ineffective. Efficacy with mancozeb has been reported in Australia and overseas (O'Brien, 1992; Smith *et al*., 1985), while mixtures of dithiocarbamates and copper hydroxide have been successful overseas (Abd Elrazik and Lorbeer, 1980). Copper hydroxide had no efficacy on bulb onions in Australia (O'Brien, 1992) and may not be worth using in a spray program for spring onions. Chlorothalonil (Bravo) is not registered for downy mildew on spring onions and O'Brien (1992) reported no efficacy with it on bulb onions. However, an improved formulation, Bravo Weather Stick, had excellent efficacy against downy mildew on bulb onions (Hausbeck and Cortright, 1996) and would be worth trialing on spring onions.

The current industry standard, metalaxyl + mancozeb alternating with dimethomorph + mancozeb was the most effective treatment for downy mildew control in spring onions. The addition of other chemicals to it did not significantly improve its efficacy. Metalaxyl + mancozeb has a curative activity or post-infection period of 48h, a protectant activity or pre-infection period of 7 days and antisporulant activity (MacManus, 2002).

Dimethomorph causes cell lysis and inhibits spore formation. When mixed with mancozeb or an adjuvant its efficacy was greatly increased and the latter mixture had a kickback time of 2 days (MacManus, 2002; O'Brien, 1992). Fortunately both systemic fungicides are registered for downy mildew on onions and both are in different activity groups. Alternating 2 consecutive sprays of one with 2 of the other will conform to maintenance of resistance management strategies for fungicides (Gunn, 1991).

Azoxystrobin alternated with mancozeb had efficacy when disease pressure was low. Azoxystrobin is a systemic fungicide which inhibits mitochondrial respiration, has antisporulant activity with a curative activity or post-infection period of 3 to 7 days (Anon, 1996). It has efficacy against downy mildew on hebe and cucumber (O'Neill and Bobbin, 2000; Robak, 2001). It could be very useful as another systemic fungicide to incorporate into a spray program for *P. destructor,* being from a different chemical grouping to metalaxyl (Group D) and dimethomorph (Group X).

The addition of phosphorus acid (AgriFos 600®) as either a spray or a drench to the standard spray program did not improve the control of downy mildew, did not reduce harvest time or significantly increase yield. Phosphonate based fungicides applied as drenches have efficacy against Oomycete fungi (Schwinn and Staub, 1995). Foliage application of phosphonic acid were very effective in controlling *Plasmopara viticola* on grapevines, *Bremia lactucae* on lettuce and *P. parasitica* on cauliflower seedlings (Wicks *et al*., 1991; Wicks *et al*., 1993; Minchinton *et a*l., 1997). Yet O'Brien (1992) found that foliage applications were not effective in controlling *P. destructor* on bulb onions. Although efficacy could be increased with the addition of mancozeb in bulb onions (Rod, 1986) and mancozeb or dichlofluanid for brassicas (Minchinton *et al*, 1997). Its lack of control was associated with poor inhibition of sporangial germination Develash and Sugha (1997a) or possibly poor penetration through the waxy cuticle of onion foliage (MacManus, 2002). As phosphorous acid is a relatively cheap fungicide it would be useful to tests its efficacy with an adjuvant, one of the dithiocarbamates or dichlofluanid.

Commencement of spraying for the standard weekly spray program started at week 2 for trials 1 and 2, but at week 5 and week 6 for trials 3 and 4, respectively. The industry practice is to commence spraying when spring onions are about 8 – 10 cm tall (week 5-7). During the spring - summer period of 2001 and 2002 when disease pressure was low, spraying probably commenced too early in trial 3 and especially in trial 1. Even when disease pressure was high in trial no 3, the start of spraying was to early, as in adjacent crops managed by the grower, spraying commenced about week 6 and no downy mildew was observed in them. During trial no 4, spraying started at week 5, which was obviously too early as no downy mildew was observed till week 15 in unsprayed or control plots. The late appearance of the disease may be associated with drought conditions during the last few years in Melbourne and little or no downy mildew in crops. During periods of low disease pressure (spring – summer), it may be worth considering delaying the commencement of weekly sprays or the commencement of sprays using the DOWNCAST model.

Nutrition

The addition of sulphate of potash (K) and Aminofit.Xtra™ to the standard spray program did not produce any significant improvements in downy mildew control above that of the standard spray program. Any benefits of reducing the impact of the disease may (i) have been masked by the fungicides (Develash and Sugha, 1997b did not apply fungicides); (ii) potassium levels may already be high so any additional K was of no benefit; or (iii) be more obvious in the longer grown bulb onion crops of Develash and Sugha (1997b). The sulphate of potash treatment appears to be producing other benefits as spring onions receiving the sulphate of potash treatment were the quickest to bunch and a grower reported that the colour and strength of the spring onions was superior. With spring onions it is possible the benefits of extra K may lie in improved quality, which may be difficult to measure in the field but may be measurable post harvest as better shelf life.

Adjuvants

Spring onions treated with DC-Tron™ were rubbery and soft. Unfortunately the incidence of downy mildew in the trial was too low to determine if the DC-Tron™ had any efficacy in enhancing the standard fungicide treatment. The Synertrol™ oil + standard produced higher but not significantly higher levels of downy mildew compared with the standard. MacManus (1997, 2002) obtained enhanced downy mildew control on bulb onions when using these adjuvants with Acrobat, however, the same effect does not appear to be duplicated when it was used in a spray program with metalaxyl + mancozeb and dimethomorph + mancozeb. The effect may be unique to Acrobat or alternatively as these adjuvants smooth out the leaf surfaces waxes, they may be making the plants more susceptible to downy mildew.

Removal of leaf surface waxes by wiping enhanced the germination of *P. destructor* sporangia and their germtube growth (Develash and Sugha, 1996; Berry, 1959). Smith *et al*., (1985) observed less downy mildew on greenhouse grown onions than on than those grown outside and found that removal of waxes on the former increased their susceptibility to downy mildew. They suggested that weathering of waxes off leaf surfaces may make them more susceptible to downy mildew. An adjuvant with a different type of action, such as sodium dodecyl sulphate which lysis spore cell walls of *Albugo candida* and reduces levels of white blister on English spinach and broccoli (Irish *et al*., 2002; Minchinton *et al*., 2004), may have efficacy against downy mildew on spring onions. *Albugo* and *Peronospora* belong to the order Peronosporales and are closely related (Riethmuller *et al*., 2002), consequently chemicals which are active on one genera should be active on the other.

Yields

Control plots generally had the worst yields, confirming that if downy mildew is left unchecked it will reduce yields. Controlling the disease produced higher yields, compared to the controls, in trials 1, 2 and 3, but not in trial 4. Yields in trial 4 were generally low across all treatments, possibly because of poor emergence of spring onions. The standard fungicide treatment generally gave the best control of the disease with generally the highest yields or yields which were not significantly different from the highest.

The best control of the disease did, however, not consistently correspond with the highest yield, e.g. in trial 2 Aminofit.Xtra™ + standard had a disease incidence 8.25% and yield of 11.11bc bunches/m^2, yet mancozeb + cupric hydroxide was 45.56% and 11.27bc, respectively. Factors which may have contributed to this inconsistency could be; (i) large variability in spring onion production on the site, (ii) the presence of white rot (*Sclerotium cepivorum* Berk.) on the site or (iii) the method of harvest. When spring onions are harvested, infected leaves are often picked off, so the number of onions making up the bunch and thus the number of bunches may not change.

Downcast Model

The spring to summer trials had a low incidence of downy mildew whereas the autumn to winter trials had a higher incidence of the disease. During periods of low disease pressure (trial no 3 spring – summer) the DownCast Model 1 reduced the number of sprays by 2, from 6 to 4, with no significant difference in the incidence of downy mildew compared with the standard fungicide treatment. During periods of high disease pressure (trial no 4 autumn-winter) Model 1 reduced the number of sprays by 5, from 13 to 8, when compared with the standard spray program. But levels of downy mildew were significantly higher, 1.5% b for Model 1 compared to 0.3% c for the standard spray program. However, the problems associated with trial no. 4, poor emergence, late appearance of the disease in the crop, a late harvest and low yields may have influenced the results. It appears that the model may be more useful in periods of low disease pressure than in periods of high disease pressure.

Sprays were generally applied on the day predicted, or if weather was unsuitable, on the next day. The 24 hr delay in applications should not have been a problem as the systemic fungicides used reportedly have a 48h post-infection period of activity (MacManus, 2002). Model 1 was based on a 7 day with-holding period and the Model 2 on a 10 day with-holding period. The levels of downy mildew in the former (1.3% bc) but not in the latter (1.8% b), did not differ significantly from the standard weekly spray program (0.6% c). Consequently the 10 day withholding period is less suitable for downy mildew control in spring onions than a 7 day with-holding period.

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Chapter 5 Preliminary evaluation of positioning weather stations for the DOWNCAST model

Summary

The positioning of weather stations to run the DOWNCAST model was evaluated. The best position to place a weather station was in an older crop of spring onions as they produced more spray predictions than younger, less dense crops of spring onions. There was a 5-10% variation in DOWNCAST predictions across a bay of spring onions. Sharing weather stations between crops grown on different properties was not advisable as management practices varied, especially times of irrigation, and consequently model predictions varied.

5.1 Introduction

Little mention is made of the best position to place a weather station for collecting meteorological data to run a disease predictive model. The feasibility of sharing weather station data amongst growers and amongst crops of different maturity has the potential to reduce the cost of the operation for growers.

Where crops are irrigated by rainfall, sharing weather station data between crops is possible. In Canada, weather stations running the TomCast predictive model for diseases on processing tomatoes were located within regions and the data shared between growers to successfully reduce the number of fungicide sprays and still control the diseases (Pitblado, 1992). Similarly, for the Brassica Spot model for diseases on brassicas in England (Roy Kennedy, pers. comm.).

Both on-site and off-site weather stations have been used to collect data for predictive models on sprinkler irrigated crops. Sullivan *et al* (2003), working on a weather based advisory spray program for white blister on spinach in the US, were able to collect meteorological data from a weather station 0.5 km from the field and successfully reduce the number of fungicide applications to control the disease. De Visser (1998) used a nearby automatic weather station 1 km distant from the bulb onion crop to run DOWNCAST in the Netherlands. However, in later work, De Visser (2001) positioned temperature and relative humidity sensors within the crop. Both Fitz Gerald and O'Brien (1994) in Australia and Jesperson and Sutton (1987) in Canada had weather stations located in bulb onion crops where they were running the DOWNCAST model. DOWNCAST was successfully run for bulb onion growers in four districts of Queensland, using a weather station located within each of four districts, and differences in predictions were observed between each of the four regions (Harper *et al*., 1999).

The positioning of weather stations was investigated to determine if their weather data could be shared between growers within a region, between crops of different or similar ages and within a crop to reduce the cost of purchasing and operating the weather stations.

5.2 Materials and Methods

Weather stations

Either Environdata Mark 4 weather stations (Environdata Australia Pty Ltd) or Model T MetStations (Western Electronic Design) were used to collect meteorological data. There were 4 sensors attached to each type of weather station. The Environdata stations had the electronic relative humidity sensor and the temperature sensor housed in a Stevenson screen placed on the ground between rows of spring onions on a bed. The tipping bucket rain gauge was placed in the irrigation line between bays of spring onions. The solar radiation sensor was located on the weather station housing 2m above the crop along with the solar panel. The Model T stations were a much smaller unit and placed in the crop while the solar panel was placed in the irrigation line. The electronic RH sensor and temperature sensors were housed in a radiation screen under the logger and the tipping bucket rain gauge and solar radiation sensors were attached to the sides of the logger. The base of the equipment was 10cm off the ground. Data was measured every minute and the average calculated every 30 minutes. This data was down-loaded during working days via a modem.

Analysis of data

Weather data from crops of spring onions was run through the DOWNCAST model and the hypothetical number of fungicide sprays forecast with the model was compared with a hypothetical weekly spray program. No fungicides were applied for either spray program. For the DOWNCAST model a 7 day withholding period was assumed prior to the hypothetical spray applications. The degree of similarity between crops was calculated as a percentage of the number of days showing the same predictions between the compared crops. The same prediction was defined as: (i) when the model recorded a sporulation event using the weather data from both crops (‘YES’) or (ii) when it did not record a sporulation event using the weather data from both crops (‘NO’).

Evaluation of sharing a weather station and the DOWNCAST model between farms

An Environdata Mark 4 weather station was set up on each of 3 farms, which were within 6 km of each other in the Pearcedale area (Victoria), during summer of 2002-2003. All 3 farms had different irrigation schedules and were growing different cultivars. Farm A grew cv Javelin, Farm B grew cv Paragon and Farm C grew cv Straight Leaf.

Evaluation of sharing a weather station and the DOWNCAST model between spring onion crops of different ages

An Environdata Mark 4 weather station was placed in a 7 week-old crop of spring onions and another was placed in a 10 week-old crop of spring onions on a farm at Clyde, Victoria, during January and February 2003. Both crops were cv Paragon and both were irrigated at the same time. Data was collected and analysed as previously described.

Evaluation of the DOWNCAST model in crops of similar ages

Mark 4 Environdata weather stations were placed in spring onion crops of cv Paragon at 4, 5 and 6 weeks before harvest at Clyde, Victoria, during January – February 2004. All crops were irrigated at the same time. The date of spray application was obtained from the grower and used for the comparison with the model predictions. Data was analysed as previously described.

Evaluation of the DOWNCAST model within a crop (bay) of spring onions

Three Model-T weather stations were placed in a bay of spring onions of cv Paragon which were 8 weeks old, at Clyde, Victoria, during August – September 2004. Meteorological data was collected for 20 days and analysed as previously described.

5.3 Results

Evaluation of sharing a weather station and the DOWNCAST model between farms

All 3 farms had a different number of sprays forecasted by the DOWNCAST model over a 3-month period (Table 5.1). The DOWNCAST model predicted one to 4 sprays less than a weekly spray program during summer (November 2002 - February 2003). Although all 3 farms had different times of irrigation, the time of irrigation does not affect downy mildew levels on spring onions during summer (see Chapter 2) The degree of similarity between two farms was low and between three farms was even lower (Table 5.2)

Table 5.1 A comparison of the DOWNCAST model predictions with a weekly spray program on 3 farms within 6 km of each other at Pearcesdale, Victoria, during November 2002 - February 2003

Farm	No. of sporulation predictions	Estimated N^{o}. of weekly sprays	N^{o}. of DOWNCAST model sprays forecasted	N^{o}. of sprays less than weekly
A	33	12	11	1
B	9	11	7	4
C	25	13	10	3

Table 5.2 A Comparison of the DOWNCAST model with weekly sprays in spring onion crops of similar ages on three farms at Pearcedale over a 99 days period during November 2003 - February 2003

Farm	Degree of similarity (%) (percentage of number of days showing the same predictions between the compared crops)
AB	67.7
AC	69.7
BC	78.9
ABC	58.6

Evaluation of sharing a weather station and the DOWNCAST model between spring onion crops of different ages

Over a one month period there would have been 1 or 2 more sprays applied to the spring onions with the weekly spray program compared to the DOWNCAST model spray program (Table 5.3). The older bay of spring onions (10 weeks) had one more prediction of sporulation and one more spray forecasted compared with the younger bay of spring onions (7 weeks). There was a moderate degree of similarity between spring onion crops 3 weeks apart in age (Table 5.3).

Table 5.3 A comparison of the DOWNCAST model with weekly sprays in two spring onions crops of different ages, on a farm at Clyde during July to August 2002

Item (trial duration = 31 days)	Estimated number of sprays Old onions (10 weeks)	Young onions (7 weeks)
Number of sporulation events	9	8
Weekly sprays	4	4
DOWNCAST model sprays	3	2
Number of sprays saved with the model	1	2
Degree of similarity between crops	84%	

Evaluation of the DOWNCAST model on crops of similar ages

The oldest crop of spring onions was harvested first and the middle and youngest crops were harvested within a day of each other (Table 5.4). The oldest crop of spring onions had the most sporulation predictions (7) followed by the middle (4) and then the youngest (3). In each crop the model only predicted 2 sprays, however, some of these came at different times. The number of grower sprays varied between crops from 4 to 6. Consequently, when comparing the difference in grower sprays with those predicted by the DOWNCAST model, there is a range of 2 to 4 sprays less with the model. There was a high degree of similarity (92%) between crops of similar ages but a slightly lower similarity between crops of different ages (82%) (Table 5.5).

Table 5.4 A Comparison of the DOWNCAST model in three adjacent spring onion crops using Environdata weather stations placed in each crop at Clyde during January – February 2004

Details of trial crop	Oldest	Middle	Youngest
Weeks to harvest from the start of monitoring	4	5	6
Days monitored with the DOWNCAST model	37	44	39
Predicted sporulation periods	7	4	3
No. of grower sprays	4	6	4
No. of model predicted sprays	2	2	2
No. of sprays saved by using DOWNCAST	2	4	2

Table 5.5 A comparison of the degree of similarities in the predictions of the DOWNCAST model in three adjacent crops of spring onions, 4, 5, and 6 weeks off harvest at Clyde during January – February 2004

Type of crop	Degree of similarity (%) (percentage of number of days showing the same predictions between the compared crops)
Oldest[A] and Middle[B]	92
Middle and Youngest[C]	92
Oldest and Youngest	82
Oldest, Middle and Youngest	82

[A], 4 weeks to harvest; [B], 5 weeks to harvest; [C], 6 weeks to harvest

Evaluation of the DOWNCAST model within a crop (bay) of spring onions

The weather stations located towards the edge and ends of the bays had a higher number of sporulation predictions compared with the weather station in the middle of the bay of spring onions (Table 5.6). Running the DOWNCAST model during this 20-day period of time suggested a reduction of 1-2 sprays. The degree of similarity within the crop ranged from 90-95% indicating that 90-95% of the time predictions did not vary across the bay of spring onions (Table 5.7). There appears to be a high degree of similarity within this bay.

Table 5.6 A comparison of the DOWNCAST model predictions within a crop (bay) of spring onions using a Model T weather station at Clyde over a 20 day period during August-September 2004

Item	Position of weather station in crop North-east Row 1	 Middle Row 4	 South-west Row 7
No. of sporulation predictions	8	6	7
No. weekly sprays	3	3	3
No. of sprays predicted by DOWNCAST	2	1	2
No. sprays saved with DOWNCAST	1	2	1

Table 5.7 A comparison of degree of similarities in the predictions of the DOWNCAST model within a crop (bay) of spring onions using a Model T weather station at Clyde over a 20 day period during August - September 2004

Position of weather station in crop	Degree of similarity (percentage of number of days showing the same predictions between the compared crops)
North-west and middle	90
North-west and south-east	95
Middle and south-east	95
North-west, middle and south-east	90

5.4 Discussion

The best position to place a weather station is in an older crop of spring onions as they produce the highest number of sporulation predictions. This may, however, lead to an over estimate of sporulation events in younger crops. The closer crops are in age the more similar are their predictions and the more feasible to share weather station data for the DOWNCAST model. Sharing weather station data between farms is not advised as the variation between sites for the DOWNCAST model predictions was too great, probably due to individual management of crops by the growers and variation in weather patterns.

There was a high degree of similarity in the DOWNCAST model predictions within a bay of spring onions, but still a 5-10% variation across a bay. The highest number of sporulation predictions in this trial was achieved at the ends of the bays near the irrigation lines. The volume of water delivered by sprinklers may vary from site to site. The best placement within a bay will be the one with the greatest likelihood of sporulation predictions, such as where there are over-lapping sprinklers, wet spots where water accumulates in the furrow, or on the lowest site in a sloping bay.

The DOWNCAST model in our trials predicted 1-4 fewer sprays than a weekly spray program. The proportion of sprays saved was on average 39% (No. sprays saved/No. weekly sprays) compared with weekly sprays. The next step with the DOWNCAST model is to evaluate it against an actual weekly spray program and to give growers access to the model and weather stations to determine the practical use of the system, especially during periods of high and low disease pressure. During periods of low disease pressure it may over-estimate the number of sprays as the sporulation component of the model assumes downy mildew is present in the crops. This is not necessarily the case during hot dry summers when no downy mildew was observed in the industry (see Chapter 1).

Size of weather stations is an issue and the larger stations initially used for this component of the project were cumbersome, difficult to move and the solar panel and cross-beam tended to get in the way of farm machinery. They were also more expensive than the smaller weather stations used in the last trial. The smaller one, however, is probably more suited to vegetable crops which are rotated as it was easily moved. The larger one is probably more suited to a fixed position e.g. vineyards or orchards.

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Chapter 6 Drip irrigation as a means of controlling downy mildew on spring onions

Summary
Drip irrigation was evaluated as a management strategy for downy mildew, by reducing relative humidity, in order to make plants less susceptible to the disease. Drip irrigation had no effect on downy mildew levels and plants grew better under overhead irrigation.

6.1 Introduction

Downy mildew, caused by the fungus *Peronospora destructor* (Berk.) Casp. is the major foliage disease on spring onions in Victoria. Sporangiospores of *P. destructor* germinate only in the presence of free water (Viranyi, 1981). Free water can be in the form of mist, fog, drizzle rain or irrigation for the development and spread of downy mildew (Bedson, 1992). This is significant since spring onion production in Victoria is irrigated by overhead sprinklers. Any practice, which reduces the number of hours that leaves are covered by a film of water, will be useful in inhibiting downy mildew development (Palti and Rotem, 1981). Rainy weather during the night, however, can be unfavourable for disease development as it inhibits sporangial development and sporangiospore production (Hilderbrand and Sutton 1982).

Water on leaf surfaces has effects other than providing a climate for germination of sporangiospores. Rain on onion leaves was shown to weather leaves thus reducing leaf-surface waxes (Verity *et al*., 1981). Smith *et al*., (1985) observed that a reduction in leaf-surface waxes made onions more susceptible to downy mildew. The reduction in leaf-surface wax is unlikely to affect *P. destructor*'s penetration into host tissue as it enters via the stomata, not via the cuticle (Mukerji, 1975). However, when green house grown onions, which have lots of wax on their leaves, had the wax removed manually, their susceptibly to *P. destructor* was enhanced (Smith *et al*., 1985). It appears that the removal of leaf-surfaces waxes by wiping enhanced germination of sporangiospores and germ-tube growth, compared with unwiped surfaces (Develash and Sugha, 1996).

Many crops such as processing tomatoes are now grown on drip irrigation (Horn, 2003). Trickle irrigation trials have been conducted on potatoes (Nigel Crump, pers. comm.) and leeks (Craig Murdoch, pers. comm.) in Victoria and on bulb onions (Gilbert and Henderson, 2002), and brassicas (Victor Galea pers. comm.) in Queensland. In processing tomatoes and potatoes, the drip irrigation was sub-surface. In a bulb onion trial it was on the surface and strong winds tended to move it around in the rows (MacManus, pers com). The author has also observed a crop of parsley grown successfully on surface drip irrigation in Queensland.

This trial was established to look at the effect of irrigation method on disease development, as part of an integrated management strategy for downy mildew on spring onions. Two systems were compared; (1) standard overhead irrigation and (2) drip-line irrigation and fertigation.

6.2 Materials and Methods

Trial design

The irrigation trial was run on a property at Ballarto Road Clyde, during the autumn of 2002. The spring onion cultivar Paragon (South Pacific Seeds Pty Ltd, Lot No. 1906228AA) was direct seeded on 13 March 2002 and emerged on 20 March 2002. Seeds were sown at the standard planting space at 3 rows per bed (1.68m wide) on raised beds in 6 bays of spring onions, 3 either side of a track. The trial was a randomised block design with each bay of spring onions representing a block, which were approximately 38m long x 15m wide. Spring onion seedlings were germinated and grown to about 6-8 cm and on 6/05/2002 (week7) drip and overhead irrigation commenced. Three of the blocks were overhead irrigated and the other three were irrigated and fertigated by drip tape, Netafim Typhoon 0.3m emitter spacing, laid in 2 rows, between the 3 rows of spring onions on each bed, at 15 cm (6 inches) below the surface.

The trial was sprayed weekly by the grower with a standard industry chemical spray program and an area of 5m x 1.5m in each plot was used for the trial spray treatment. In each plot another area of 5m x 1.5m was treated as the control, was not sprayed by the grower and received only water for the duration of the trial.

Irrigation

Overhead-irrigated plots were watered for approximately 1 hour, an average of 3 times per week. Drip irrigated plots were watered twice and fertigated once per week for 1.5 hours each time. The fertiliser regime consisted of Diamond Blue (N-P-K ratio of 19-2.5-17) for weeks 7-11, potassium nitrate for week 12 and calcium nitrate for weeks 13-15. Tensiometers were placed at four different depths: 15, 30, 45 and 60 cm. Groups of 2 or 3 tensiometers (different depths) were placed randomly throughout the trial plots. Readings were taken during the morning, 3 times per week, prior to irrigating, using a Soilspec Tensiometer System and Moisture LPOTV2 Software.

4.2.3 Nutrient analysis

During weeks 9 and 13, about a kg of plant material was taken from overhead-irrigated plots and from drip-irrigated plots for SAP analysis. Serve-Ag Pty Ltd, Devonport, Tasmania carried out the SAP analysis.

Assessment

The trial was assessed for downy mildew incidence at weeks 9, 11 and 14 by scoring the number of plants with and without downy mildew in a randomly selected 30cm length of row, across 3 rows of spring onions on a bed, for each plot. The trial was harvested at week 14 (20 June 2002), by grower employed pickers. In each plot a 1m length of bed was randomly selected and spring onions were bunched across the 3 rows on the bed. The average number of bunches of spring onions per meter and the average bunch length was determined for each treatment.

6.3 Results

Downy mildew and yield

Downy mildew first appeared in the trial crop at week 9 and gradually increased in the unsprayed (control) plots till harvest (Table 6.1). The natural background incidence of downy mildew at the site was 15 – 20%. There was also downy mildew in the trial sprayed plots. Insufficient water was applied on the initial drip irrigation treatment and the whole site was also heavily infested with white rot caused by *Sclerotium cepivorum.*

In the unsprayed plots there was no significant difference in the incidence of downy mildew between the drip and overhead irrigated spring onions at weeks 9, 11 or 14. Similarly for the sprayed plots there was no significant difference in the incidence of downy mildew between the drip and overhead-irrigated treatments. Sprayed plots had significantly less downy mildew than the unsprayed plots, irrespective of the type of irrigation.

The average number of bunches and the average bunch length per meter was noticeably higher on the overhead-irrigated treatments than on the drip-irrigated treatments for both the sprayed and unsprayed plots. Yet, there were no significant differences between drip and overhead irrigation in either the unsprayed or sprayed treatments for the average number of bunches/m^2 or the average bunch length of spring onions.

Table 6.1 Incidence (%) of downy mildew and yield of spring onions on over-head irrigated and drip irrigated bays of spring onions during autumn and winter 2002 at Clyde, Victoria.

Treatment		Incidence of downy mildew (%)[A] Week 9	Week 11	Week 14	Average No. bunches/m Week 14	Average bunch length (cm) Week 14
Unsprayed	Drip	0	2.8	19.1	9.0	47.7
(control)	Over-head	0	1.4	14.6	11[B]	54.0[B]
Sprayed	Drip	0	0.0	0.0	10.6	53.2
	Overhead	0.5	1.8	0.5	14.3	56.2

[A], The only significant difference was in the incidence of downy mildew between sprayed and unsprayed treatments at week 14. [B], only one value due to white rot on the trial site.

Irrigation and nutrition

The depths of the tensiometer did not allow measurement of soil moisture above 15 cm and in the initial stages of the trial seedlings were water stressed. There was very little difference in the nutrient levels with the drip and overhead irrigations at either week 9 or week 13 (Table 6.2). Nitrate was slightly higher in the overhead irrigation compared with the drip irrigation at week 9.

Table 6.2 Concentration of nutrients under both drip and overhead irrigation at weeks 9 and 13

Nutrient	Overhead	Drip	Overhead	Drip
	Weed 9		Week 13	
Boron	3.44	3.65	1.44	1.62
Calcium	213.00	203.00	107.00	105
Copper	0.26	0.23	0.32	0.26
Iron	1.03	1.55	1.24	1.44
Magnesium	325.00	288.00	242.00	203
Manganese	0.80	1.12	0.84	0.88
Nitrate	990.00	514.00	917.00	797
Phosphorus	273.00	342.00	235	216
Potassium	2580.00	2470.00	2400	2340
Sulphur	270.00	201.00	189	249
Zinc	2.81	2.37	3.93	4.13

6.4 Discussion

Drip irrigation on spring onions appeared to have no impact on downy mildew levels. Spring onions grew visibly better under the overhead irrigation in terms of size, quality and quantity, although there were no significant differences between type of irrigation. The visible observed differences could not be attributed to variation in nutrient levels, which did not differ between the drip and overhead irrigated crops. The trial results were confounded by:

(i) Large variation in soil type across the site,
(ii) Water stress in the crop at the beginning of the trial,
(iii) Severe white rot symptoms and
(iv) Small number of replicated plots, which may not have been enough to detect significant differences between treatments under such conditions.

This trial became an exercise in how not to drip irrigate spring onions. The main problem was the type and depth of tensiometers. Spring onions are very shallow rooted with mature plants having a root depth of about 10cm. The tape could not be placed any higher due to management issues. Consequently, even the shallowest tensiometer (15cm) would not accurately measure soil moisture in the root zone. This situation initially lead to under watering in the drip bays at the commencement of drip irrigation. The initial stress may have resulted in reduced growth and possibly the development of white rot which appeared more prevalent in the drip bays as compared with the overhead irrigated bays.

In hindsight, either the tensiometers used in our trial should have been placed at shallower depths or alternatively Aquaflex™ tensiometers, which measure soil moisture at shallower depths, should have been used. Also with hindsight, the trial should have included both sub-surface and surface drip irrigation. Surface drip irrigation of bulb onions reduced water consumption by half in a Queensland crop (Gilbert and Henderson 2002). MacManus (pers. comm.) noted, however, that strong winds tended to move the tape around in the rows.

There was no evidence from our trial that the weathering of leaf surface waxes by overhead irrigation makes plants more susceptible to downy mildew. However, weathering of leaf-surface waxes by overhead irrigation may be making leeks more susceptible to pests and diseases. Craig Murdoch (pers. comm.) reported that leeks with sub surface drip irrigation had a distinct bluish green bloom and the grower was spraying less for pests and diseases.

An alternative to using drip irrigation to control downy mildew would be to irrigate between the hours of 12 midnight and 4.00am. During this period *P. destructor* sporulates. Its sporulation can be inhibited by a film of moisture, in the form of rain or dew, on the sporulating leaves (Hilderbrand 1983; Hilderbrand and Sutton, 1982). The DOWNCAST disease predictive model for downy mildew on onions incorporates this characteristic of the disease into the model (Jesperson and Sutton, 1987; Fitz Gerald and O'Brien, 1994). The amount of irrigation or rain required to inhibit sporulation varies with different versions of the model. More than 1mm of rainfall was predicted by the model of Fitz Gerald and O'Brien (1994), whilst the model of Friedrich *et al* (2003) predicted greater than 2mm of rainfall.

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Chapter 7 Susceptibility of spring onion cultivars to downy mildew

Summary

Cultivars of spring onions were evaluated for resistance to downy mildew in two trials. Although there was variation in the levels of resistance to the disease, no cultivar was significantly more or less resistant than the industry standard cultivar, Paragon.

7.1 Introduction

Little information is currently available on the susceptibility of spring onion, *Allium cepa* L.*,* cultivars to downy mildew caused by the fungus, *Peronospora destructor* (Berkeley) Caspary. Bulb onions (*A. cepa* L.) are known to vary markedly in their susceptibility to downy mildew and none are totally resistant (Palti, 1989). Resistance appears to be associated with high levels of phenolic compounds (Runkova and Talieva 1970, 1973). While at least one or two dominant genes for resistance have recently been located in *A. roylei* Stearn (Kofoet *et al.,* 1990, Vries *et al*., 1992).

The spring onion cultivars, Paragon, Javelin and Straight Leaf are the main cultivars grown by the Victorian industry. Little is know of their resistance to downy mildew or the resistance of other cultivars, which are less commonly grown. The susceptibility of spring onion cultivars to downy mildew was examined in two cultivar trials during 2002 and 2003.

7.2 Materials and Methods

Both cultivar trials were planted at the standard rate per ha, irrigated by over-head sprinklers and managed and sprayed by the growers.

Cultivar trial No. 1, 2002

The first cultivar trial was directed seeded, at 3 rows per bed on 7 raised beds at Ballarto Road, Clyde, Victoria on 13 March 2002 and emerged on 20 March 2002. The trial was an incomplete block design with 5 replicated plots of each of the 13 spring onion cultivars (Table 7.1). There were also 3 non-replicated plots of 3 new lines for observational purposes only. Each plot was 4.6 m long and 1.2 m wide. There were 10 plots along a bed.

Table 7.1 Spring onion cultivars and suppliers for cultivar trial No1, Clyde, autumn-winter 2002

Cultivar	Company	Stock
Bunching onion ON 0578	S & G (Novartis Seeds Pty Ltd)	ON 0578
Bunching onion ON 0619	S & G (Novartis Seeds Pty Ltd)	ON 0619
Bunching onion ON 0620	S & G (Novartis Seeds Pty Ltd)	ON 0620
Electra	S & G (Novartis Seeds Pty Ltd)	ON 0507
Icicles	Fairbanks Selected Seed Co. Pty Ltd	Lot 7300052
Javelin	Fairbanks Selected Seed Co. Pty Ltd	Lot 4402003
Kin Chu	S & G (Novartis Seeds Pty Ltd)	ON 0132
Paradox	S & G (Novartis Seeds Pty Ltd)	ON 0354
Paragon	South Pacific Seeds	ON 0346
Polaris	Fairbanks Selected Seed Co. Pty Ltd	Lot 4002009
Straight Leaf (H)	Henderson Seed Group Pty Ltd	pkt No 22125
Straight Leaf (S&G)	S & G (Novartis Seeds Pty Ltd)	ON 0094
Straight Leaf Bunching (Y)	Yates Vegetable Seeds Pty Ltd	2282N1PRH
White Ace	Yates Vegetable Seeds Pty Ltd	trial sample
Winter King	Henderson Seed Group Pty Ltd	pkt No 22071
Zelda	Yates Vegetable Seeds Pty Ltd	2306D8OKO

Cultivar trial No. 2, 2003

The second cultivar trial was situated on a site at Old Dandenong Road Heatherton. Seed was direct sown on 15 January 2003 and emerged on 23 January 2003. There were 3 rows of spring onions per bed sown on 12 raised beds, which covered two bays (6 rows per bay). The trial was a resolvable row-column design with 9 cultivars, 6 cultivars were replicated 6 times and 2 were replicated 3 times due to shortages of seed. In each block there were 8 plots of 2 adjacent beds with 4 plots along each bed. The 8 plots represented each of 9 treatments (cultivars). Each plot was 7m long and 1.6m wide. The trial was irrigated by over-head sprinklers and managed by the grower (Table 7.2).

Table 7.2 Spring onion cultivars and suppliers for cultivar trial No 2, Heatherton, summer-autumn 2003

Cultivars	Company	Stock
Javelin	Fairbanks Selected Seed Co. Pty Ltd	Lot 4402003
Kin Chu	S & G (Novartis Seeds Pty Ltd)	ON 0132
Legend	Wing Tac	-
ON 0623	S & G (Syngenta Pty Ltd)	Sample
ON 0619	S & G (Syngenta Seeds Pty Ltd)	Sample
Paladin	South Pacific Seeds	Lot 6245/1
Paragon	South Pacific Seeds	ON 0346
Straight Leaf (H)	Henderson Seed Group Pty Ltd	pkt No 22125
Winter King	Henderson Seed Group Pty Ltd	pkt No 22071

Assessment of cultivar trials

The first and second cultivar trials were assessed for incidence of downy mildew (%) on the 14 June 2002 at week 13 and on 16 April 2003 at week 11, respectively. The number of plants with and without downy mildew was scored in a randomly selected 30cm length of row, across 3 rows of spring onions on a bed, for each plot.

The first trial was harvested on 20 June 2002 (week 12) and the second on 23 April 2003 (week 12) by pickers employed by the growers. In each trial a 1m length of bed was randomly selected and spring onions were bunched across the 3 rows on the bed. In the first trial bunches of spring onions were scored for the average number of bunches per m. In the second trial bunches were assessed for the average number of bunches per metre, the average bunch length, the total bunch weight and the average bunch weight.

Cultivars were given a general assessment for maturity of plants, flagging and tip burn by observing each plot as a whole and then calculating an average of each of the 5 plots. Maturity of plants were assessed as early, mid or late maturing at the time of assessment. Flagging was defined as the amount of bending-over of the tips, on a scale of 0 to 3 where 0 = no bending and 3 = majority of plants showing symptoms. Tip burn was assessed on a scale of 0 to 2, where 0 = no tip burn and 2 = majority of plants with tip burn. In the second cultivar trial, cultivars were not scored for agronomic characteristics, only general observations were made.

Growers comments of the cultivars were also sort at the field days held for each trial on 2nd July 2002 and 16 April 2003, respectively.

7.3 Results

Incidence of downy mildew

The incidence of natural infections of downy mildew was low in the first cultivar trial and ranged from 4% to 22% (Table 7.3). The cultivars Zelda and Straight Leaf (S&G) were significantly less susceptible to the disease whilst the cultivar Polaris was significantly more susceptible to the disease. The industry standard cultivar Paragon had a disease incidence midway in the range. In the second trial no downy mildew was observed either within the assessed area of the plots or outside the assessed area of the plots (Table 7.4).

Yield

In the first trial, which matured in June 2002, there were no significant differences in yield measured as average number of bunches per metre, although Straight Leaf Bunching (Y) yielded 18.3 bunches per metre and Straight Leaf (S&G) only yielded 11.4 (Table 7.3). The second trial matured in April 2003 and cultivar ON516 had significantly fewer bunches per metre compared with all the other cultivars. There were no differences in the average bunch length or the average bunch weight of spring onions (Table 7.4).

Characteristics

Attempts were made to measure agronomic characteristics in the first cultivar trial (2002). Most of the cultivars appeared to be early maturing, whilst Kin Chu and White Ace were scored as early to mid-season, Zelda was mid-season to late and Straight Leaf (S&G) and Straight Leaf Bunching were more variable with maturity spread between early and late season. Icicles had the highest levels of flagging and Kin Chu the lowest. Kin Chu had the highest levels of tip burn and Javelin and Straight Leaf (H) the least (Table 7.3). In the second cultivar trial (Table 7.4) Paladin exhibited flagging whilst little flagging occurred in Winter King and Javelin. Tip yellowing was apparent in Paladin and Kin Chu.

Table 7.3 Incidence of downy mildew and yield of spring onions at 13 weeks in the first spring onion cultivar trial at Clyde, June 2002

Cultivar	Incidence of downy mildew (%)	Average number of bunches/m	Maturity[B]	Average Flagging[C]	Tip burn[D]
Polaris	21.5 a[A]	15.6 abcd	E	2.1 (0-3)[E]	1.0
Straight Leaf Bunching (Y)	15.4 ab	18.3 abcd	E-L	1.3 (0-3)	1.3
Straight Leaf (H)	13.3 bcde	15.2 bcd	E	2.0 (0-2)	0.9
Icicles	10.8 bcde	14.0 bcde	E	2.8 (0-4)	1.2
Paragon	9.2 bcdef	15.4 abcd	E	1.2 (0-2)	1.4
Paradox	8.7 bcdef	16.6 abcd	E	1.8 (0-2)	1.5
Electra	7.8 cdefg	16.3 abcd	E	2.2 (0-2)	1.6
Javelin	6.5 cdefg	16.4 abcd	E	1.9 (0-3)	0.9
Winter King	5.1 defg	16.1 abcd	E	2.0 (0-2)	1.1
Kin Chu	5.0 defg	15.3 abcd	E-M	0.8 (0-3)	1.8
White Ace	4.2 defg	17.4 abcd	E-M	2.0 (0-3)	1.2
Straight Leaf (S&G)	4.1 fg	11.4 de	E-L	1.9 (0-3)	1.1
Zelda	3.5 fg	13.7 bcde	M-L	1.6 (0-3)	1.4

[A] Numbers followed by different letters are significantly different at P= 5%.
[B] Maturity was measured on a scale where E = early; M = mid season; L = Late.
[C] Flagging was measured on a scale of 0-3, where 0 = straight and 3 = very bent over.
[D] Tip burn was measured on a scale of 0-2, where 0 = none, 1 = some and 2 = lots.
[E] Range of flagging scores.

Table 7.4 Incidence of downy mildew[A] and yield of spring onions at 12 weeks in the second spring onion cultivar trial at Heatherton, April 2003

Cultivar	Average number of bunches	Average bunch length (cm)	Total bunch weight (kg)	Average bunch weight (g)
Javelin	21.4a	69.4	5.9	281.5
Paragon	20.7a	73.4	5.9	302.6
Legend	19.9a	73.2	6.5	325.9
Winter King	19.8a	69.0	5.7	284.9
Straight Leaf (H)	19.1a	68.4	5.6	299.6
Kin Chu	18.1a	70.4	5.4	300.1
Paladin	18.0a	68.4	5.5	294.1
ON 619	13.1 b	66.3	4.4	303.9
lsd (5%)	4.91	6.91 (ns)	1.94 (ns)	45.96 (ns)

ns, not significant
[A], No downy mildew was observed in this trial.

Growers comments

Growers visiting the site and workers bunching the onions rated Paragon, Kin Chu, Paradox and Winter King as the best spring onions in terms of feel, appearance and ease to bunch in the first cultivar trial. In the second trial growers who visited the site rated Legend and Paragon as the best in overall appearance and feel. Most of the remaining cultivars were described as soft. ON619 had a distinct blue-green hue, was too stumpy, tubular and soft, while Winter King was very soft at that time of the year.

7.4 Discussion

Spring onion cultivars showed variation in resistance to naturally occurring infections of downy mildew in the autumn-winter cultivar trial of 2002. No cultivar was completely resistant as also noted by Palti (1989). However, these cultivars may preform differently on other sites and at other times of the year. The industry standard cultivar, Paragon, was moderately resistant to downy mildew and yielded well. No downy mildew developed in the summer–autumn trial of 2003, which may be due to the dry summer conditions.

The characteristics of the cultivar Legend, which is grown by NSW growers in the Sydney Basin, impressed the local industry. The general perception was that no other cultivar out-performed Paragon. Knowledge on cultivar resistance is no doubt held by seed companies and is of a confidential nature. Although information on resistance to downy mildew in spring onion cultivars would be useful in a breeding program, quality is also important, as it is a crop with high aesthetic standards.

7.5 References

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Chapter 8 Economic analyses of various treatments for reducing the incidence of downy mildew in spring onions and the net benefits of using the DOWNCAST predictive model

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Summary

An economic analysis of the DOWNCAST disease predictive model to time fungicide applications for downy mildew on spring onions, revealed there was no economic benefit in reducing fungicide applications by 2 to 5 per crop. The cost of the weather station and the estimate of its depreciation may be a contributing factor. The analysis, however, could not put an economic benefit on reducing exposure of workers, grower's family, the environment and the consumer to fungicides.

8.1 Introduction

This chapter reports an economic analysis of a trial (trial no. 2) carried out on the property of a co-operative grower at Clyde during winter and spring of 2002. The trial compared the efficacy of treatments comprised of various fungicides with that of the standard weekly program used to reduce the impact of downy mildew in spring onions. It then contains analyses of the net benefits of using the DOWNCAST predictive model for deriving an optimum control program compared with using a variety of fungicide treatments including the spring onion industry's standard weekly spray program for controlling the disease. Net benefits include higher profits and very importantly the environmental benefits derived from a reduction in the amount of fungicide used in reducing the impact of downy mildew in the production of spring onions.

8.2 An economic analysis of various treatments to reduce the incidence of downy mildew in spring onions

Treatments and percentage incidence of downy mildew on spring onions

Table 8.1 shows the spray program used in the field trial whilst the percentage incidence of downy mildew infections on leaf material at harvest time for the various treatments is displayed in Table 8.2. The Bion and Bion + Standard treatments do not appear in the results because Bion is a fungicide that is no longer available.

Table 8.1 Spray program for the control and various treatments.

Treatment Lam 2002	Week (date) 1 (27/3/02)	2 (3/4/02)	3 (10/4/02)	4 (17/4/02)	5 (24/4/02)	6 (1/5/02)	7 (8/5/02)	8 (15/5/02)	9 (22/5/02)	10 (29/5/02)	11 (5/6/02)	12 (12/6/02)	13 (19/6/02)
Control		water	water	water	water	water	water	water	water	water	water	water	water
STD		MZ	MZ	MZ	Kocide	MZ	MZ	Ac+MZ	Ac+MZ	RGMZ	RGMZ	Ac+MZ	Ac+MZ
AgriFos 600+STD	AF-D	MZ AF-D	MZ AF-D	MZ AF-D	Kocide AF-D	MZ AF-D	MZ AF-D	Ac+MZ AF-S	Ac+MZ AF-S	RGMZ AF-S	RGMZ AF-S	Ac+MZ AF-S	Ac+MZ AF-S
Amistar+STD		MZ	MZ	MZ	Kocide	MZ	MZ	Amistar	Amistar	MZ	MZ	Amistar	Amistar
Synertrol+STD		MZ Synertrol	MZ Synertrol	MZ Synertrol	Kocide Synertrol	MZ Synertrol	MZ Synertrol	Ac+MZ Synertrol	Ac+MZ Synertrol	RGMZ Synertrol	RGMZ Synertrol	Ac+MZ Synertrol	Ac+MZ Synertrol
Aminofit.Xtra+STD		MZ+AX	MZ	MZ+AX	Kocide	MZ	MZ	Ac+MZ+AX	Ac+MZ	RGMZ	RGMZ	Ac+MZ+AX	Ac+MZ
Bion+STD		MZ Bion	MZ Bion	MZ Bion	Kocide Bion	MZ Bion	MZ Bion	Ac+MZ Bion	Ac+MZ Bion	RGMZ Bion	RGMZ Bion	Ac+MZ Bion	Ac+MZ Bion
Bion		Bion	Bion	Bion	Bion	Bion	Bion	Bion	Bion	Bion	Bion	Bion	Bion
Sulphate of Potash+STD		MZ	MZ	MZ Potash	Kocide	MZ	MZ	Ac+MZ	Ac+MZ	RGMZ Potash	RGMZ	Ac+MZ	Ac+MZ
Dithane M45+Kocide		MZ Kocide	MZ Kocide	MZ Kocide	MZ Kocide	MZ Kocide	MZ Kocide	MZ Kocide	MZ Kocide	MZ Kocide	MZ Kocide	MZ Kocide	MZ Kocide

Ac, Acrobat ; AF-D, Agri-Fos 600 drench; AF-S, Agri-Fos 600 spray; AX, Aminofit.Xtra; MZ, Dithane M45; STD, Standard spray program; RGMZ, Ridomil Gold MZ

Table 8.2 Chemical treatments used to reduce the incidence of downy mildew and the percentage incidence of the disease for various treatments

Treatment	Incidence of downy mildew (%)
Control	71
Dithane + Kocide	46
Amistar	23
Agriphos + Standard	19
Synertrol + Standard	16
Standard	12
Potassium sulphate + Standard	12
Aminofit + Standard	8

Yield and gross income for the control and the various treatments

Table 8.3 shows changes in the yield of spring onions and their levels of gross income for the control and treatments based on a price of $5 per deck of spring onions.

Table 8.3 Yields of spring onions and gross income to reduce downy mildew for the control and treatments

Treatment[a]	Yield of bunches per trial plot	No. bunches[b] per m^2	No decks per m^2	No decks per ha.	Gross Income per ha. @ $5 per deck ($)
Control	37.91	5.2	0.52	5,200	26,000
Dithane + Kocide	89.5	12.28	1.23	12,277	61,386
Amistar	89.5	12.28	1.23	12,277	61,386
Synertrol + Std.	89.5	12.28	1.23	12,277	61,386
Agriphos + Std.	89.5	12.28	1.23	12,277	61,386
Standard (Std.)	89.5	12.28	1.23	12,277	61,386
Sulphate of potash+Std.	89.5	12.28	1.23	12,277	61,386
Aminofit + Std.	89.5	12.28	1.23	12,277	61,386

a Bion and Bion + Standard have been removed from the results because Bion is no longer commercially available.
b Number of bunches per m^2 based on a statistical analysis of numbers counted for the array of treatments.

Labour cost for bunching

In Table 8.4, the amount of labour required to carry out bunching and its cost for the control and treatments is displayed.

Cost for implementing the various treatments

Table 8.4 Labour required and cost for bunching spring onions for the control and treatments

Treatment	Time for 2 labour units to bunch a deck (mins/deck)	No. decks per ha.	Total time for bunching decks (Hrs/ha)	Labour cost for bunching at $15 per hr ($/ha)
Control	5.00	5,200	867	13,000
Dithane + Kocide	1.72	12,277	704	10,558
Amistar	1.44	12,277	589	8,840
Synertrol + Std.	1.10	12,277	450	6,752
Agriphos + Std.	1.10	12,277	450	6,752
Standard (Std.)	1.10	12,277	450	6,752
Sulphate of potash + Std.	1.10	12,277	450	6,752
Aminofit + Std.	1.10	12,277	450	6,752

Table 8.5 reveals the cost per hectare for implementing the various chemical treatments to reduce the incidence of downy mildew. Appendices 8.1 and 8.2 show the derivation of the costs per hectare for those treatments.

Table 8.5 Cost of treatments to reduce the incidence of downy mildew in spring onions.

Treatment	Cost per ha. ($)
Control	0
Dithane + Kocide	627
Amistar + Dithane	856
Synertrol + Std.	2,685
Agriphos + Std.	2,893
Standard (Std.)	2,675
Sulphate of potash + Std.	3,320
Aminofit + Std.	3,005

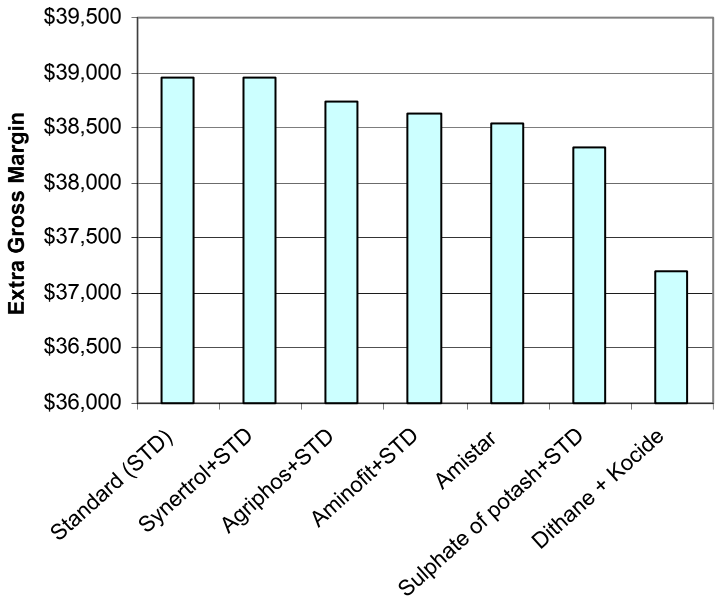
Table 8.6 Change in gross margin per hectare for the various treatments relative to the gross margin for the control.

Treatment	Change in gross income per hectare ($/ha)	Change in labour for bunching ($/ha)	Change in cost of treatment ($/ha)	Change in gross margin per hectare ($/ha)	Rank
Dithane + Kocide	35,386	-2,442	627	37,200	7
Amistar + Dithane	35,386	-4,160	1,016	38,530	5
Synertrol+Std.	35,386	-6,248	2,685	38,948	2
Agriphos+Std.	35,386	-6,248	2,893	38,740	3
Standard (Std.)	35,386	-6,248	2,675	38,958	1
Sulphate of potash+Std.	35,386	-6,248	3,320	38,313	6
Aminofit+Std.	35,386	-6,248	3,005	38,628	4

Change in gross margin per hectare

Table 8.6 shows the change in gross margin per hectare for the various treatments relative to the cost of the control based on variations in the various parameters shown above. The relative changes in gross margins are also displayed in Figure 8.1.

Figure 8.1 Increases in gross margin per hectare for the treatments relative to that of the control.



Discussion and conclusion

Using the Standard treatment that included 5 weekly applications of Dithane®, one of Kocide®, 2 weekly applications of Acrobat® and Dithane®, followed by 2 weekly applications of Ridomil Gold MZ® and a final 2 weekly applications of Acrobat® and Dithane®, the incidence of downy mildew was reduced to a low level of 12 per cent of affected plant material. Or put another way, the level of unaffected plant material as a result of using the Standard treatment was 88 per cent of the total mass of spring onions produced. Additionally, there was a high Pearson's Coefficient of Correlation (r) of 0.86 between gross margins for the control and treatments and the percentage of plants that did not show signs of being effected by downy mildew.

Dithane + Kocide was by far the least expensive fungicide treatment, but that advantage was offset by it having the highest cost for bunching. It was also interesting to note that whilst growers expressed the subjective view that adding potassium sulphate to the Standard treatment increased the quality of the spring onions, the resulting gross margin was prejudiced by the relatively high cost of including it in the treatment.

From the above economic analysis, the recommendation to growers would be that to achieve optimum levels of gross margins per hectare from growing spring onions they should continue to use the Standard spray program thereby minimising damage caused by downy mildew. However, the advantage was only slightly better than that achieved by adding Synertrol Oil™ as an adjuvant.

8.3 Net benefits of using the DOWNCAST predictive model for determining an optimum program for controlling downy mildew in spring onions

Introduction

Two trials were conducted to compare the control of downy mildew using the DOWNCAST predictive model as opposed to relying on the spring onion industry's standard weekly spray program. One was conducted at Pearcedale between October and December 2002 (trial 3) and the other at Cannon's Creek between April and August 2003 (trial 4).

Treatments and percentage incidence of downy mildew on spring onions for the two trials to assess the effectiveness of the DOWNCAST predictive model

Tables 8.7 and 8.8 show the spray programs used in the two field trials to assess the effectiveness of the DOWNCAST predictive model whilst Tables 8.9 and 8.10 display the incidence of downy mildew present on plant material at harvest.

Table 8.7 Spray program and time of application for chemicals used in the various treatments for the effectiveness of the *DownCast* predictive model, October to December 2002.

Treatment	Week (date)						
	6 (22/10/02)	7 (29/10/02)	8 (6/11/02)	9 (14/11/02)	10 (20/11/02)	11 (27/11/02)	12 (4/12/02)
Control (water)	Water	Water	Water	Water	Water	Water	Water
Agri-Fos 600 + STD	-	Dithane-M45 Agri-Fos 600	Ridomil Gold MZ Agri-Fos 600	Ridomil Gold MZ Agri-phos 600	Acrobat+Dithane M45 Agri-phos 600	Acrobat+Dithane M45 Agri-phos 600	Ridomil Gold MZ Agri-phos 600
Aminofit.Xtra + STD	-	Dithane-M45 Aminofit.Xtra	Ridomil Gold MZ -	Ridomil Gold MZ Aminofit.Xtra	Acrobat+Dithane M45 -	Acrobat+Dithane M45 Aminofit.Xtra	Ridomil Gold MZ -
AmistarWG	-	Dithane-M45	Amistar	Amistar	Dithane-M45	Dithane-M45	Amistar
Model 1	Dithane-M45 (24/10/02)	-	Ridomil Gold MZ (8/11/02)	-	-	Ridomil Gold MZ (25/11/02)	Acrobat+Dithane M45 (2/12/02)
Model 2	-	-	-	-	Ridomil Gold MZ (20/11/02)	-	Ridomil Gold MZ (2/12/02)
Sulphate of potash + STD	-	Dithane-M45 -	Ridomil Gold MZ Sulphate of potash	Ridomil Gold MZ -	Acrobat+Dithane M45 -	Acrobat+Dithane M45 Sulphate of potash	Ridomil Gold MZ -
Synertrol + STD	-	Dithane-M45 Synertrol	Ridomil Gold MZ Synertrol	Ridomil Gold MZ Synertrol	Acrobat+Dithane M45 Synertrol	Acrobat+Dithane M45 Synertrol	Ridomil Gold MZ Synertrol
STD	-	Dithane-M45	Ridomil Gold MZ	Ridomil Gold MZ	Acrobat+Dithane M45	Acrobat+Dithane M45	Ridomil Gold MZ

STD, Standard spray program.

Table 8.8 Spray program and time of application for chemicals used in the various treatments for the effectiveness of the DOWNCAST predictive model, April to August 2003.

Treatment	Week (date)																
	0 (7/4/03)	2 (14/4/03)	3 (21/4/03)	4 (28/4/03)	5 (13/5/03)	6 (20/5/03)	7 (28/5/03)	8 3/6/03)	9 10/6/03)	10 (18/6/03)	11 (25/6/03)	12 (1/7/03)	13 (8/7/03)	14 (16/7/03)	15 (21/7/03)	16 (29/7/03)	17 (6/8/03)
Control	-	-	-	-	-	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water
Aminofit.Xtra+STD	-	-	-	A	RGMZ	RGMZ+A	Ac+MZ	Ac+MZ+A	RGMZ	RGMZ+A	Ac+MZ	Ac+MZ+A	RGMZ	RGMZ+A	Ac+MZ	Ac+MZ+A	RGMZ
AmistarWG+STD	-	-	-	-	Am	Am	RGMZ	RGMZ	Ac+MZ	Ac+MZ	RGMZ	RGMZ	Ac+MZ	Ac+MZ	RGMZ	Am	Am
Model 1	-	-	-	-	RGMZ	RGMZ (19/5/03)	-	-	Ac+MZ (8/6/03)	Ac+MZ (16/6/03)	RGMZ (28/6/03)	-	-	RGMZ (13/7/03)	RGMZ	Ac+MZ (3/8/03)	-
Model 3	-	RGMZ (22/4/03)	RGMZ (29/4/03)	Ac+MZ (9/5/03)	Ac+MZ (19/5/03)	RGMZ (19/5/03)	-	-	RGMZ (8/6/03)	Ac+MZ (16/6/03)	-	-	-	-	-	-	-
STD	-	-	-	-	RGMZ	RGMZ	Ac+MZ	Ac+MZ	RGMZ	RGMZ	Ac+MZ	Ac+MZ	RGMZ	RGMZ	Ac+MZ	Ac+MZ	RGMZ
Potash+STD	K (g)	-	-	K(g)	RGMZ	RGMZ	Ac+MZ+K(g)	Ac+MZ	RGMZ	RGMZ+K(l)	Ac+MZ	Ac+MZ	RGMZ+K(l)	RGMZ	Ac+MZ	Ac+MZ+K(l)	RGMZ

A, Aminofit.Xtra; Ac, Acrobat; Am, AmistarWG; RGMZ, Ridomil Gold MZ; MZ, Dithane M45

Table 8.9 Chemical treatments used to reduce the effectiveness of the DOWNCAST preventive model, October to December 2002, (Trial 3) and the percentage incidence of downy mildew present at harvest for the various treatments.

Treatment	Incidence of downy mildew (%)
Control	3.8
Model 2	1.8
Synertrol + Standard	1.4
Model 1	1.3
Aminofit + Standard	0.8
Agriphos + Standard	0.7
Amistar + Dithane	0.6
Standard	0.6
Potassium sulphate + Standard	0.6

Yield and gross income for the control and the various treatments to assess the effectiveness of the DOWNCAST predictive model

Table.8.10 Chemical treatments used to reduce for the effectiveness of the DOWNCAST preventative model, April to August 2003, (trial 4) and the percentage incidence of downy mildew present at harvest for the various treatments.

Treatment	Incidence of downy mildew (%)
Control	39
Model 1	1.5
Amistar + Standard	0.4
Standard	0.3
Potassium sulphate + Standard	0.3
Aminofit + Standard	0.2

Table 8.11 and Table 8.12 show changes in the yields of spring onions and their levels of gross income for the control and treatments based on a price of $5 per deck for spring onions for trial 3 in 2002 and trial 4 in 2003 respectively. Figures for yields are based on a statistical analysis of yields recorded for the control and treatments.

Table 8.11 Yields of spring onions and gross income per hectare for the control and treatments in trial 3 of October to December 2002 to assess the effectiveness of the DOWNCAST predictive model.

Treatment	Yield of bunches per trial plot	Number of bunches per m2	Number of decks per m2	Number of decks per ha.	Gross Income per ha. @ $5 per deck ($/ha)
Control	124	13.7	1.37	13,739	68,694
Model 2	124	13.8	1.38	13,830	69,150
Synertrol + Std.	124	13.8	1.38	13,830	69,150
Model 1	124	13.8	1.38	13,830	69,150
Aminofit + Std.	124	13.8	1.38	13,830	69,150
Agrifos + Standard	124	13.8	1.38	13,830	69,150
Amistar + Dithane	124	13.8	1.38	13,830	69,150
Standard (Std.)	124	13.8	1.38	13,830	69,150
Sulphate of potash + Std.	126	14.0	1.40	13,950	69,750

Table 8.12 Yields of spring onions and gross income per hectare for the control and treatments in trial 4 of April to August 2003 to assess the effectiveness of the DOWNCAST predictive model.

Treatment	Yield of bunches per trial plot	Number of bunches per m^2	Number of decks per m^2	No decks per ha.	Gross Income per ha. @ $5 per deck ($)
Control	73.4	7.0	0.70	6,988	34,942
Model 1	66.2	6.3	0.63	6,300	31,500
Amistar + Std.	79.8	7.6	0.76	7,600	38,000
Standard (Std.)	66.2	6.3	0.63	6,300	31,500
Sulphate of Potash + Std.	79.8	7.6	0.76	7,600	38,000
Aminofit + Std.	73.5	7.0	0.70	6,988	34,942

Labour cost for bunching

Tables 8.13 and 8.14 show the cost of labour required for bunching spring onions for trials 3 and 4. Labour costs were also based on a statistical analysis of time spent in bunching for the control and treatments.

Table 8.13 Labour cost for bunching spring onions for the control and treatments for trial 3, October to December 2002.

Treatment	Time for 2 labour units to bunch a deck (minutes/deck)	Number of decks per ha.	Total time for bunching decks (Hrs/ha)	Labour cost for bunching at $15 per hr ($/ha)
Control (water)	1.00	13,739	458	6,869
Model 2	1.00	13,830	461	6,915
Synertrol + Std.	1.00	13,830	461	6,915
Model 1	1.00	13,830	461	6,915
Aminofit+Std.	1.00	13,830	461	6,915
Agri-phos+Std.	1.00	13,830	461	6,915
Amistar + Dithane	1.00	13,830	461	6,915
Standard (STD)	1.00	13,830	461	6,915
Sulphate of potash + Std.	1.00	13,950	465	6,975

Table 8.14 Labour cost for bunching spring onions for the control and treatments for trial 4, April to August 2003.

Treatment	Time for 1 labour unit to bunch a deck (minutes/deck)	Number of decks per ha.	Total time for bunching decks (Hrs/ha)	Labour cost for bunching at $15 per hr ($/ha)
Control	3.0	6,988	349	5,288
Model 1	3.0	6,300	314	4,713
Amistar + Std.	3.0	7,600	379	5,686
Standard (Std.)	3.0	6,300	314	4,713
Potash sulphate + Std.	3.0	7,600	379	5,686
Aminofit + Std.	2.7	6,988	312	4,686

Cost of implementing the various treatments

Tables 8.15 and 8.16 show the cost of the various treatments used in trial 3 and 4. Information about the cost of individual fungicides and the costs of the various treatments is contained in Appendices 8.1, 8.3 and 8.4.

Table 8.15 Cost of treatments for trial 3 for assessing the effectiveness of the DOWNCAST predictive model.

Treatment	Cost per ha. ($)
Control (water)	0
Model 2	210
Synertrol + Std.	1,502
Model 1	813
Aminofit + Std.	1,744
Agri-phos + Std.	1,628
Amistar + Dithane	566
Standard (Std.)	1,497
Sulphate of potash + Std.	2,142

Table 8.16 Cost of treatments for trial 4 for assessing the effectiveness of the DOWNCAST predictive model.

Treatment	Cost per ha ($)
Control	0
Model 1	2,261
Amistar + Std.	3,111
Standard (Std.)	4,207
Potash sulphate + Std.	5,336
Aminofit + Std.	4,784

Change in gross margin per hectare for the treatments in trial 3 and trial 4 to assess the effectiveness of the DOWNCAST predictive model in controlling downy mildew on spring onions

Tables 8.17 and 8.18 show the changes in gross margins for the various treatments compared with that of the control as an indicator of the net benefits of using the DOWNCAST predictive model for reducing the impact of downy mildew in the production of spring onions. Figures 8.2 and 8.3 display the change in gross margins per hectare relative to those of the control for trials 3 and 4 respectively**.**

Table 8.17 Change in gross margins for the various treatments used in trial 3 including the DOWNCAST predictive model compared to that of the control.

Treatment	Change in gross income/ha ($/ha)	Change in labour for bunching ($/ha)	Change in cost for treatment ($/ha)	Change in application cost/ha[ab] ($/ha)	Change in gross margin/ha ($/ha)	Rank
Model 2	456	46	210	312	-112	1
Synertrol + Std.	456	46	1,502	937	-2,028	5
Model 1	456	46	813	625	-1,027	2
Aminofit + Std.	456	46	1,744	937	-2,271	8
Agriphos + Std.	456	46	1,628	937	-2,154	6
Amistar + Dithane	456	46	566	937	-1,093	3
Standard (Std.)	456	46	1,497	937	-2,023	4
Potash sulphate + Std.	1,056	106	2,142	1,037	-2,228	7

[a]Cost for 1 spray per ha. = $156 for machinery plus labour costs.
[b]Cost for spreading granular K_2SO_4 per ha. = $50 for machinery plus labour

Table 8.18 Change in gross margins for the various treatments used in trial 4 including the DOWNCAST predictive model compared to that of the control

Treatment	Change in gross income/ha. ($/ha)	Change in labour for bunching ($/ha)	Change in cost of treatment ($/ha)	Change in application. cost/ha[ab] ($/ha).	Change in gross margin/ha. ($/ha)	Rank
Model 1	-3,442	-515	2,261	1,250	-6,437	4
Amistar + Std..	3,058	458	3,111	2,031	-2,541	1
Standard (Std.)	-3,442	-515	4,207	2,031	-9,164	5
Potash sulphate + Std	3,058	458	5,336	2,181	-4,916	2
Aminofit + Std	0	-542	4,784	2,187	6,429	3

[a]Cost for 1 spray per ha. = $156 for machinery plus labour costs.
[b]Cost for spreading granular K2SO4 per ha. = $50 for machinery plus labour costs.

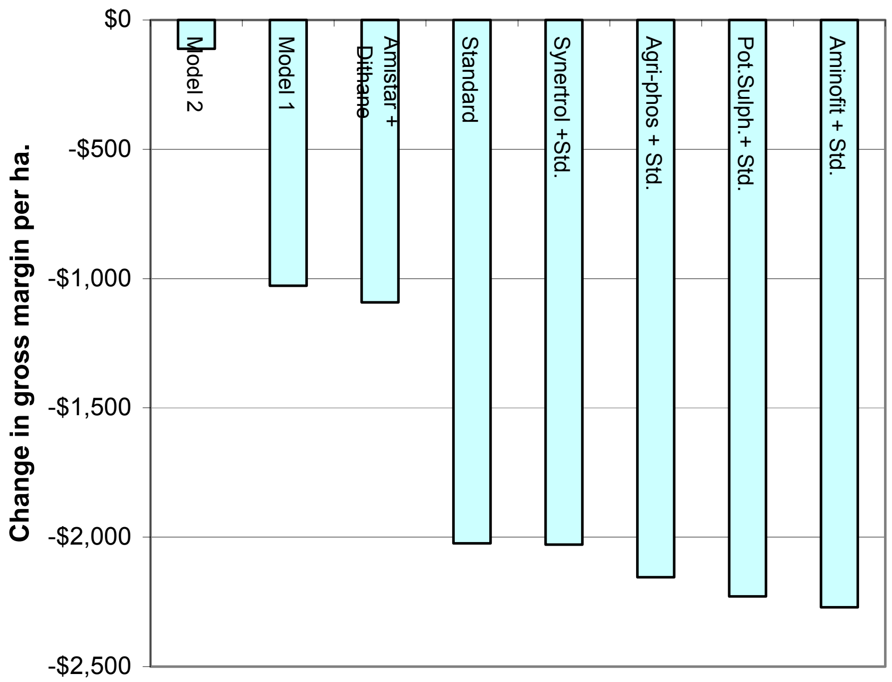


Figure 8.2 Change in gross margins per hectare relative to the control for trial 3.

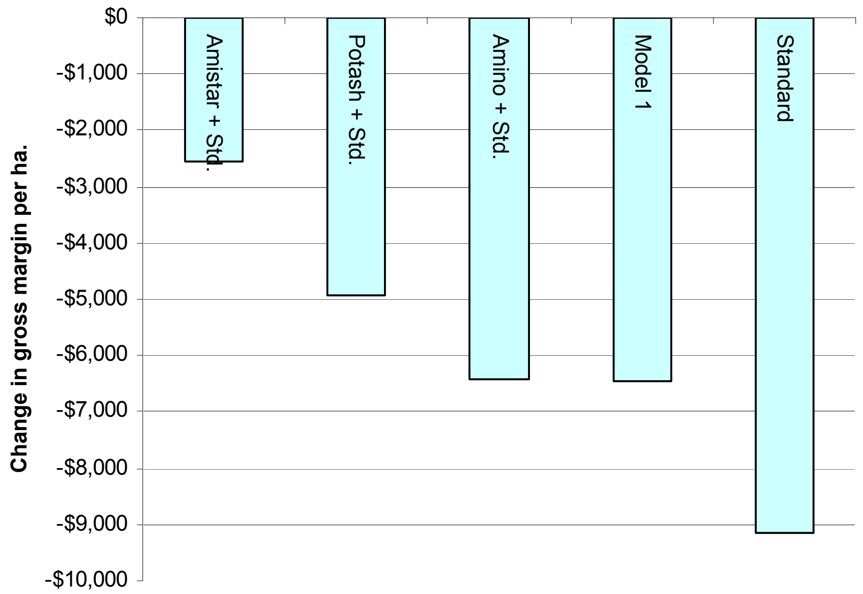


Figure 8.3 Change in gross margins per hectare relative to the control for trial 4.

Discussion and conclusion

The extra capital cost of installing a weather station plus monitors to use the DOWNCAST predictive model for 5 hectares of spring onions has been estimated at $2,500. The depreciation per annum over a 5 year period to depreciate the weather station and monitors to a value of zero over a period of 5 years would be $500 per annum. On a per hectare basis, the depreciation would be $100 per annum. The average capital value invested in the weather station and monitors would be $500 for the 5 hectares or $100 per hectare. To provide a return of 20 per cent per annum after tax to the extra investment in the weather station plus monitors, the extra gross margin per hectare for the model treatments above that of the control would have had to be an extra $120 per hectare per annum; $100 to cover depreciation plus an additional $20 to earn an extra return of 20 per cent on the increase in capital invested.

For both trials 3 and 4 this did not occur. In trial 3, Models 2 and 1 returned the best gross margins for the various treatments relative to that of the control but they were respectively -$112 and -$1,027. In trial 4, the best treatment was Amistar + Standard but it made a negative return compared to the control of -$2,541 and Model 1 had a gross margin of -$6,457 relative to the control.

The reason for negative returns for all the treatments compared to the control was that environmental conditions during the trials were not conducive to the development of downy mildew infections.

In trial 3, infection rates were very low. The Control had an infection rate of 3.8 per cent, and the incidence of infection on Models 2 and 1 were only 1.8 per cent and 1.3 per cent respectively. In trial 4, the infection rates were higher for the control at 39 per cent but the next highest infection rate was for Model 1 which had an infection rate of only 1.5 per cent. For Amistar + Standard, the next highest infection rate, the incidence was 0.4 per cent and the worst treatment, Aminofit + Standard, had an extremely low infection rate of 0.2 per cent.

The other important issue was that the yields and gross incomes for trial 4 to prove the benefits of using the DOWNCAST predictive model were much lower than for trial 3 which was comparable to the comparative treatments trial (trial 2) at Clyde from March to June in 2002. Trial 4 had an average yield for the treatments of 6,958 decks per hectare and an average gross income of $34,788 whereas the comparative results for trial 4 were an average of 13,845 decks per hectare for an average gross income of $34,788.

So, not only were the trials to prove the benefits of using the DOWNCAST predictive model unsuccessful from an economic point of view, it was also unfortunate that they were unable to show the environmental benefits of being able to reduce the number of sprays and amount of fungicides used to minimise the impact of downy mildew in the production of spring onions.

Appendix 8.1 Cost of fungicides and fertilizer used in trials 2, 3 and 4

Trade name of chemical	Active constituent	Rate for application per Ha.	Cost of chemical per unit ($)	Cost of chemical spray per Ha.($)
Dithane	Mancozeb	3.5 kg	7.00/kg	24.50
Kocide	Cupric hydroxide	2.2 kg	12.63/kg	27.79
Acrobat	Dimethomorph & Mancozeb	2.0 kg	277.13/kg	554.26
Ridomil Gold MZ	Mancozeb & Metalaxyl-M	2.5 kg	41.94/kg	104.85
Agri-Fos	Phosphoric acid Agriphos 600	4 L spray 6 L drench	3.64/L	14.56 21.84
Aminofit	Amino acids	5 L	16.50/L	82.50
Synertrol	Emulsifiable vegetable oil	150 ml	5.74/L	0.86
Sulphate of potash	NPK (0:0:41.0)	375 kg	0.86/kg	322.50
Amistar	Azoxystrobin	450 g	364.77/kg	204.27

Appendix 8.2 Cost of treatments used in trial 2

Treatment	Chemicals	Number of applications	Cost per application / Ha. ($)	Total cost of chemicals per Ha. ($)	Treatment cost per Ha. ($)
Standard	Dithane	9	24.50	220.50	
	Kocide	1	27.79	27.79	
	Acrobat	4	554.26	2,217.04	
	Ridomil G	2	104.85	209.70	2,675
Phos Acid	Dithane	9	24.50	220.50	
(Agrifos)	Kocide	1	27.79	27.79	
+STD	Acrobat	4	554.26	2,217.04	
	Ridomil G	2	104.85	209.70	
	Agriphos drench	6	14.56	87.36	
	Agriphos spray	6	21.84	131.04	2,893
Aminofit	Dithane	9	24.50	220.50	
+STD	Kocide	1	27.79	27.79	
	Acrobat	4	554.26	2,217.04	
	Ridomil G	2	104.85	209.70	
	Aminofit	4	82.50	330.00	3,005
Synertrol	Dithane	9	24.50	220.50	
+STD	Kocide	1	27.79	27.79	
	Acrobat	4	554.26	2,217.04	
	Ridomil G	2	104.85	209.70	
	Synertrol	12	0.86	10.33	2,685
Sulph Pot	Dithane	9	24.50	220.50	
+STD	Kocide	1	27.79	27.79	
	Acrobat	4	554.26	217.04	
	Ridomil G	2	104.85	209.70	
	Potassium Sulphate	2	322.50	645.00	3,320
Dithane +	Dithane	12	24.50	294.00	
Kocide	Kocide	12	27.79	333.43	627
Amistar	Dithane	7	24.50	171.50	
	Kocide	1	27.79	27.79	
	Amistar	4	204.27	817.08	1,016

Appendix 8.3 Cost of treatments used in trial 3

Treatment	Chemicals	Number of applications	Cost per application / Ha.($)	Total cost of chemicals per Ha. ($)	Treatment cost per Ha ($)
Standard (Std.)	Dithane	3	24.50	73.50	
	Acrobat	2	554.26	1,108.52	
	Ridomil G	3	104.85	314.55	1,497
Model 1	Dithane	2	24.50	49.00	
	Acrobat	1	554.26	554.26	
	Ridomil MZ	2	104.85	209.70	813
Model 2	Ridomil MZ	2	104.85		210
Agrifos+Std.	Dithane	3	24.50	73.50	
	Acrobat	2	554.26	1,108.52	
	Ridomil G	3	104.85	314.55	
	Agriphos spray	6	21.84	131.04	1,628
Aminofit+Std.	Dithane	3	24.50	73.50	
	Acrobat	2	554.26	1,108.52	
	Ridomil G	3	104.85	314.55	
	Aminofit	3	82.50	247.50	1,744
Synertrol+Std.	Dithane	3	24.50	73.50	
	Acrobat	2	554.26	1,108.52	
	Ridomil G	3	104.85	314.55	
	Synertrol	6	0.86	5.17	1,502
Potassium Sulphate+Std	Dithane	3	24.50	73.50	
	Acrobat	2	554.26	1,108.52	
	Ridomil G	3	104.85	314.55	
	Potassium Sulphate	2	322.50	645.00	2,142
Amistar + Dithane	Dithane	3	24.50	73.50	
	Amistar	3	164.15	492.44	566

Appendix 8.4 Cost of treatments used in trial 4

Treatment	Chemicals	Number of . applications	Cost per application Ha. ($)	Total cost of chemicals per Ha. ($)	Treatment cost per Ha. ($)
Standard (Std.)	Dithane	6	24.50	147.00	
	Acrobat	6	554.26	3,325.56	
	Ridomil MZ	7	104.85	733.95	4,207
Model 1	Dithane	3	24.50	73.50	
	Acrobat	3	554.26	1,662.78	
	Ridomil MZ	5	104.85	524.25	2,261
Aminofit+Std.	Dithane	6	24.50	147.00	
	Acrobat	6	554.26	3,325.56	
	Ridomil G	7	104.85	733.95	
	Aminofit	7	82.50	577.50	4,784
Potassium Sulphate +Std.	Dithane	6	24.50	147.00	
	Acrobat	6	554.26	3,325.56	
	Ridomil G	7	104.85	733.95	
	Potassium Sulphate (gr.)	3	322.50	967.50	
	Potassium Sulphate (liq.)	3	54.00	162.00	5,336
Amistar +Std.	Dithane	4	24.50	98.00	
	Acrobat	4	554.26	2,217.04	
	Ridomil G	5	27.79	138.93	
	Amistar	4	164.15	656.59	3,111

Chapter 9 Evaluation of protectant and systemic fungicides for control of white blister on radish

Summary

Protectant and systemic fungicides, fertiliser and seed treatments were tested in three trials for their efficacy in controlling white blister on red radish. All fungicides and the seed treatment were effective in controlling the disease. The application of additional potassium and phosphorous fertilisers had no additional benefit in disease reduction and were phytotoxic.

9.1 Introduction

Radish production

Victorian bunch-line growers reported that white blister, caused by *Albugo candida* (Pers. Ex. Lev.) Kuntze, has been a problem in their radish crops for about 30 years. Growers located near the coast have ceased growing the crop due to the white blister disease pressure. White blister largely causes cosmetic damage to red radish by producing lesions on the foliage. Red radishes are sold with their foliage attached in Australia and leaves with white blister symptoms are removed during bunching. A high incidence of white blister on foliage increases labour costs due to increasing the time to harvest the crop. At the commencement of this project no fungicides were registered for white blister on radish in Australia.

White blister control on radish

There is very little published work on the chemical control of white blister on radish. Glaeser (1973) found that consecutive foliage application of contact fungicides controlled localised foliage symptoms on radish. Sharma and Sohi (1982) reported that four foliage sprays of captafol, chlorothalonil, mancozeb, metalaxyl+mancozeb or fosetyl-al at intervals of 8-10 days gave the best control of the disease and were superior to those fungicides used as seed treatments. While more recently, Laun (1998) found that an activator of plant defence systems, benzothiadiazole, gave good control of systemic and foliage symptoms on radish.

White blister chemical control of various crops

Chemicals trialed for *A. candida* control of turnip, rocket, Brussels sprouts, mustards and spinach included a number of surfactants and systemic and contact fungicides. The systemic and contact fungicides trialed have come from Fungicide Activity Groups A, C, D, E, K, X and Y (Avcare). These fungicides include metalaxyl, metalaxyl+mancozeb, fosetyl, oxadixyl, cymoxanil, dimethomorph, benalaxyl, copper oxychloride, thiram, ziram, mancozeb, propineb, iprodione, triadimefon, captan, triadimefon, propineb, sulphur, zineb+copper, captafol, calixin, benomyl, carbendazim, thiophanate-methyl, azoxystrobin, fluazinam, chlorothalonil, dichlofluanid (Arvinder Kaur and Kolte, 2001; Dubey 1996; Dueck and Stone, 1979; Glaeser, 1973; Godika *et al*., 2001; Godika and Pathak 2002; Gupta *et al*., 1977; Kapoor and Sugha, 1995; Khangura and Sokhi, 2000; Khunti *et al*., 2001; Kumar, 1996; Macias and Robak, 1999; Meier, 1996; Pandya *et al*., 2000; Stone *et al*., 1987a). All except benomyl (Gupta *et al*., 1977) have been reported to have a degree of efficacy against *A. candida* on the previously mentioned hosts.

Consecutive foliage application of contact fungicides controlled localised foliage symptoms on turnip rape but not systemic infections (Dueck and Stone, 1979). The most effective controls were metalaxyl-based fungicides, azoxystrobin or thiophanate-methyl, often used in combination with contact fungicides (Khunti *et al*., 2001; Godika and Pathak, 2002; Godika *et al*., 2001; Kumar, 1996; Macias and Robak, 1999; Dubey, 1996). The activator of plant defence systems, benzothiadiazole, gave good control of systemic and foliage symptoms on mustards (Arvinder Kaur and Kolte, 2001). Unfortunately, its availability is limited and its registration is uncertain. The surfactants Naiad and sodium dodecyl sulphate were as effective as fungicides in controlling white blister on spinach (Irish *et al*., 2002). The economics of these spray programs, which were developed for mustards, have been well documented (Godika and Pathak, 2002; Kumar, 1996; Dubey, 1996; Bharagava *et al*., 1996), however, the treatment which gives the best control of the disease is not always the most cost effective (Pandya *et al*., 2002). Even though good control of white blister can be achieved with some chemicals, there are financial and environmental problems associated with their use (Meier, 1996).

Although seed dressings with fungicides have efficacy for white blister control, they do not provide sufficient reduction in disease levels for industry requirements and need to be followed up with foliage fungicide applications to maximise disease control. Stone *et al*. (1987a) demonstrated that metalaxyl (Apron) had potential as a seed treatment as it could be found in seedling leaves. However, when metalaxyl 50WP or metalaxyl SD-35 (Apron) was used as seed dressings they gave only up to 12% or 40% control of white blister on foliage of turnip rape. But additional sprays of either Ridomil MZ, chlorothalonil or mancozeb, reduced white blister incidence by a further 60% to 100% in field trials (Stone *et al*., 1987b; Bharagava *et al*., 1997). Mancozeb behaved similarly to metalaxyl SD-35 (Apron) when trialed as a seed treatment (Bharagava *et al*., 1997). Seed dressings of metalaxyl (Apron Combi FS) were not effective for controlling white blister on spring oilseed rape in Scotland (Coll *et al*., 1998) and soil drenching of seedlings with metalaxyl 50WP was phytotoxic to seedlings of mustard (Stone *et al*., 1987b).

Effects of nutrition on white blister

Nutrition has been shown to affect the tolerance of plants to white blister. Savulescu (1960), reported that 70-100 kg/ha of potassium (K) and phosphorus (P) reduced the disease in cauliflower. A reduction in white blister on Indian mustard was observed with the application of 40 kg/ha potassium and phosphorus (Godika *et al*., 2001). Saharan and Verma (1992) found addition of phosphorus and potassium or organic manure decreased white blister levels on canola, but excessive nitrogen increased it. This chapter reports on evaluation of contact and systemic fungicides, and fertiliser for control of white blister on radish.

9.2 Materials and Methods

Three trials were conducted to evaluate fungicides for white blister control on radish. In the Victorian industry radish is direct seeded at 6 rows per bed and harvested at about 6 weeks of age depending on season. Irrigation is by fixed overhead sprinklers.

Chemicals and application

A total of 14 chemicals and fertilisers were evaluated over the 3 trials (Table 9.1). In each trial there was a water control. Seedlings were sprayed with fungicides weekly, whilst fertiliser applications varied with the type of fertiliser. Chemicals (fungicides and liquid fertiliser) were applied with 3 hollow cone nozzles SPX brown No 12, mounted on a boom, at the rate of 30psi by a Silvan Selectra 12v knapsack (Silvan pumps and Sprayers (Aus.) Pty. Ltd.). Fungicides were applied at a volume of 1000L/ha. Liquid fertilisers were mixed with fungicides, whilst solid fertilisers were applied by hand and incorporated into soil using rakes. A barrier of black plastic 1 m high by 7 m long and reinforced with aluminium stakes was constructed and placed along the beds to prevent drift of chemicals during spraying.

Table 9.1 Chemicals and rates of application for the radish trials

Trade name	Active	Company	Label Rate
Acrobat	dimethomorph	BASF	2 kg/ha
Apron XL	Metalxyl-M	Syngenta	1.75ml/kg seed
Agripotash	K_2CO_3 (41%)	Phosyn	10L/ha
Amistar	azoxystrobin	Crop Care (Syngenta)	37.5g/100L[1],60g/100L[2], 40g/100L[3]
Aminofit Xtra	amino acids	Industrial Products Marketing	2.5ml/L[3],5 ml/L[1&2]
Barrack	chlorothanonil	Crop Care	1.8 L/ha[1], 2.3L/ha[3]
Dithane M45	mancozeb	Rhom & Haas	2 kg/ha
	mancozeb+acrobat	Rhom & Haas	1.5 kg/ha
Dithan DF	mancozeb	Rhom & Haas	3.5kg/ha
Dithan DF	mancozeb+acrobat	Rhom & Haas	1.5kg/ha
Euparen	dichlofuranid	Bayer	2 kg/ha
Nitrophoska	NPK	BASF	1.5 L/ha
Ridomil Gold MZ	mancozeb & metalaxyl-M	Novartis	2.5 kg/100L
Seniphos	P (13.5%) $CaPO_4$ (4%)	Phosyn	10L/ha
Sulphate of Potash	N:P:K (0:0:41)	Incitec Fertilizers	70-100 kg/ha[1&3], 375 kg/ha[2]
Trifos	N:P:K (0:20.7:0)	Incitec Fertilizers	70-100 kg/ha[1&3], 375 kg/ha[2]

[1], Trial no 1 spring 2002; [2], Trial no 2 autumn 2003; [3], Trial no 3 summer 2003

Trial 1

The first trial was conducted on a property at Moores Road, Five Ways, Victoria, during spring 2002 on cv. Red Planet, where 7 blocks were laid out in a randomised block design. Within each block, or bed of radish, there were 8 plots, representing each of 8 treatments. Plots were 3.5 m long by 1.6 m wide. There was no chicken manure applied to the Nitrophoska treatment. Seeds were planted on 17/10/2002 and emerged on 21/10/2002. The first sprays were applied to the trial on 28/10/2002 (Table 9.2). The crop was assessed on 22/11/2002 and harvested on 25/11/2002.

Table 9.2 Spray schedule for trial No 1 spring 2002

	Week of application (date)			
Treatment	2 (28/10/2002)	3 (6/11/2002)	4 (14/11/2002)	5 (20/11/2002)
Control (water)	Water	Water	Water	Water
Barrack/Aminofit (2)	Barrack/Aminofit	Barrack	Barrack/Aminofit	Barrack
Barrack/Amistar	Amistar	Amistar	Barrack	Barrack
Barrack+chicken manure	Barrack	Barrack	Barrack	Barrack
Barrack+Nitrophoska	Barrack+Nitrophoska	Barrack+Nitrophoska	Barrack+Nitrophoska	Barrrack+Nitrophoska
Barrack/Acrobat+DithaneM45	Acrobat+Dithane	Acrobat+Dithane	Barrack	Barrack
Barrack/P & K	Barrack/P& K	Barrack/P&K	Barrack	Barrack
Barrack/Ridomil Gold MZ	Ridomil Gold MZ	Ridomil Gold MZ	Barrack	Barrack

Trial 2

The second trial was conducted on a property at Craigs Road, Devon Meadows, Victoria, during autumn 2003. There were 8 blocks (beds) laid out in a randomised block design. Within each block, there were 7 plots, representing each of 7 treatments. Plots were 6 m long by 1.5m wide. Seeds of cv Red Planet were planted on 29/3/03. The first sprays were applied to the trial on 4/4/2003 (Table 9.3). The crops was assessed on 1/5/2003 and harvested on 6/5/2003. Liquid fertiliser was applied as previously described.

Table 9.3 Spray schedule for trial No 2 autumn 2003

Treatment	Sowing	Week of application (date) 1 (04/04/03)	2 (11/04/03)	3 (17/04/03)	4 (24/04/03)	5 (29/04/03)
Control (water)		Water	Water	Water	Water	Water
Amistar /Ridomil Gold MZ/Acrobat/P+K	P+K	Amistar	Amistar & P+K	Ridomil GMZ	Ridomil GMZ & P+K	Acrobat
Amistar/Ridomil Gold MZ/Acrobat/Aminofit		Amistar & Aminofit	Amistar	Ridomil GMZ & Aminofit	Ridomil GMZ	Acrobat & Aminofit
Amistar/Ridomil Gold MZ/Acrobat		Amistar	Amistar	Ridomil GMZ	Ridomil GMZ	Acrobat
Acrobat/Ridomil Gold MZ/Amistar		Acrobat	Acrobat	Ridomil GMZ	Ridomil GMZ	Amistar
Dithane DF		Dithane	Dithane	Dithane	Dithane	Dithane
Euparen		Euparen	Euparen	Euparen	Euparen	Euparen

Trial 3

The third trial was conducted on a property at Craigs Road, Devon Meadows, Victoria, during summer 2003. There were 6 blocks laid out in a randomised block design, which ran across 8 beds of radish. Within each block there were 8 plots, representing each of 8 treatments. Plots were 6 m long by 1.5 m wide. Seeds of cv. Fire Ball were planted on 24/11/2003 and emerged on 1/12/2003. The first spray was applied on 1/12/2003 (Table 9.4). The trial was assessed on 18/12/2003 and 22/12/2003 and harvested on 22/12/2003. The Apron seed treatment was applied courtesy of Syngenta and the liquid fertiliser was applied as previously described. Radish samples were collected from each treatment plot for the P and K treatment and sent to Serv-Ag Analytical Services (P.O. Box 690, Devonport, Tasmania), to determine the concentration of P and K.

Table 9.4 Spray schedule for trial No 3 summer 2003

Treatment	Planting/seed (24/11/2003)	Week of application (date) 1 (1/12/2003)	2 (8/12/2003)	3 (15/12/2004)
Control (water)	Not Apron	water	water	water
Not Apron/Aminofit/Barrack	Not Apron	Aminofit & Barrack	Barrack	Aminofit & Barrack
Apron/Amistar	Apron (seed treatment)	water	Amistar	water
Not Apron/Amistar	Not Apron	water	Amistar	water
Not Apron/P+K/Barrack	Not Apron & P+K solid spread	Barrack	P+K liquid spray & Barrack	Barrack
Apron/Barrack	Apron (seed treatment)	Barrack	Barrack	Barrack
Not Apron/Barrack	Not Apron	Barrack	Barrack	Barrack
Apron/Nil	Apron (seed treatment)	water	water	water

Assessment

For the purposes of assessment, in all 3 trials a 1/2m length of row at the end of each plot was treated as a guard section and radish plants in this section were not assessed for white blister. The remainder of each plot was divided into half and in each half a randomly selected 40cm length of bed, running across all 6 rows of radishes were examined for the presence of white blister. White blister was assessed as the average percentage of plants with white blister symptoms on foliage per plot. In trials 1 and 2, radishes were harvested across the whole bed in a 1m length, avoiding the guard sections and average number of bunches was calculated. The average bunch weight was calculated in trial 1 and the total bunch weight was calculated in trial 2. Radishes were not harvested in trial 3. Data was analysed using ANOVA within Genstat 7.1, Lawes Agricultural Trust (Rothamsted Experimental Station).

9.3 Results

Trial 1

The incidence of white blister on radish was very low in this trial (Table 9.5), which was also severely affected by diamond-backed moths. Any treatment containing systemic fungicides controlled the disease by up to 72-85%. The contact fungicide had no efficacy and the fertilisers provided no additional benefit for disease control. The nitrophoska treatment significantly reduced the average weight of radish bunches compared with all other treatments, whilst none of the treatments affected the average number of bunches harvested per m^2.

Table 9.5 Efficacy of chemicals to control white blister on radish during spring 2002, trial No 1

Treatment	Incidence of white blister		Average bunch number/m^2		Average bunch weight (kg)
	Angular transformed	Percentage	Square root	Back transformed (actual no./m^2)	
Barrack/P&K	11.34a	3.9	1.90	3.6	1.31a
Control (water)	8.82a	2.4	1.92	3.7	1.28a
Barrack / Aminofit(2)	8.72a	2.3	1.91	3.7	1.25a
Barrack+Nitrophoska	8.15a	2.0	1.83	3.3	0.98 b
Barrack	7.82a	1.9	1.99	3.9	1.32a
Barrack / Ridomil Gold MZ	2.45 b	0.2	2.00	4.0	1.32a
Barrack / Acrobat+Dithane	2.45 b	0.2	1.84	3.4	1.18a
Barrack / Amistar	1.29 b	0.1	1.87	3.5	1.28a
l.s.d. (5%)	4.85		0.17ns		0.17

ns, not significant

Trial 2

All chemicals trialed significantly reduced the incidence of white blister compared with the control (Table 9.6). The most effective spray program was the systemic combination, where Acrobat was applied last. It controlled the disease by 98%, compared with the control. The addition of fertiliser to this combination did not give a significant increase in white blister control. Both fertiliser treatments (Aminofit, P and K) were phytotoxic. Phytotoxicity with the Aminofit treatment was expressed as white bleaching of foliage, while with the P and K treatment it was leaf burn and stunting of foliage and plants. There was no difference in the average number of bunches harvested between the treatments, however, the P and K treatment had a significantly lower total bunch weight compared with the control and contact fungicide treatments. Cotyledons were heavily infected with white blister.

Table 9.6 Efficacy of chemicals to control white blister on radish during autumn 2003, trial No 2

Treatment	Incidence of white blister Log	Percentage	Average bunch number /m^2	Total bunch weight (kg)
Control (water)	4.27 a	18.2a	14.0 abc	5.6 bc
Acrobat/Ridomil Gold MZ/Amistar	3.32 b	11.0b	12.3 c	4.8 c
Euparen	1.73 c	3.0c	14.6 ab	6.0 ab
Dithane	1.41 c	2.0c	16.3 a	6.7 a
Amistar/Ridomil Gold MZ/Acrobat	0.08 d	0.0d	13.0 bc	5.2 bc
Aminofit/Amistar/Ridomil Gold MZ/Acrobat	0.00 d	0.0d	12.0 c	4.7 c
P+K /Amistar/Ridomil Gold MZ/Acrobat	0.00 d	0.0d	9.4 c	3.4 c
l.s.d.(5%)	0.52		2.26	1.03

Numbers followed by different letter are significantly different.

Trial 3

White blister symptoms first appeared at week 3 and one week later all of plants had symptoms, although severity was low (Fig. 9.1). Symptoms on cotyledons were rare. All chemicals trialed significantly reduced the incidence of white blister compared with the controls, which were sprayed with water only (Table 9.7). The most effective treatment was one spray of Amistar at week 2, which controlled the disease by nearly 100%, but unfortunately the rates of application were higher than recommended, due to an error in calculations. There were no additional benefits for white blister control in combining the Apron seed treatment with one spray of Amistar at week 2. The Apron seed treatment alone reduced the disease by 80%. Three weekly sprays of Barrack controlled the disease by 92%. The addition of a seed treatment or fertilisers to the Barrack treatment produced no extra reduction in white blister control. No phytotoxicity was observed with either of the fertiliser treatments. There was no difference in the levels of phosphorous and potassium between the radishes grown in the control plots and those grown in plots treated with phosphorous and potassium.

Fig 9.1 Incidence of white blister (%) on control radish plants

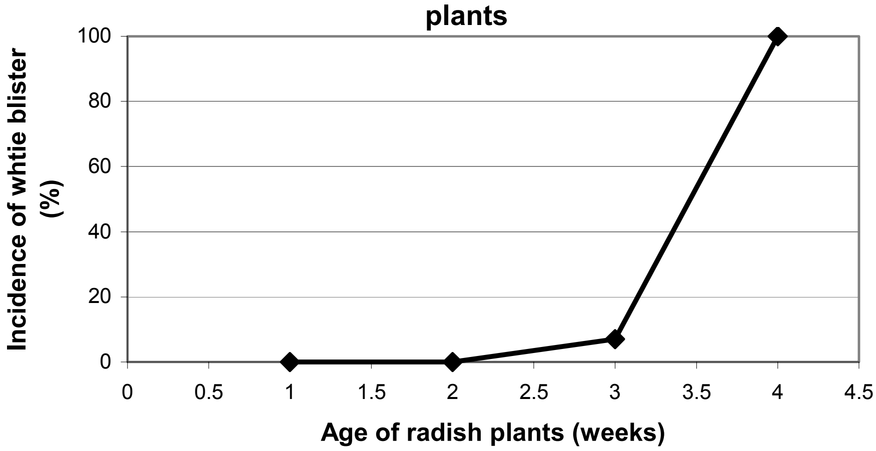


Table 9.7 Efficacy of chemicals for control of white blister on radish during summer 2003, trial No 3

Treatment	Incidence of white blister		Mean concentration (ppm)	
	Log	Percentage	Phosphorous (P)	Potassium (K)
Control	a	100a	116.0	3201.5
Apron	4.61 b	21.3b	-	-
Barrack	2.86 c	8.2c	-	-
Apron Barrack	2.56 c	6.6c	-	-
Barrack P+K	2.30 c	5.3c	112.7	3153.0
Barrack / Aminfit	2.16 c	4.7c	-	-
Amistar	0.41 d	0.17d	-	-
Apron / Amistar	0 d	0d	-	-
l.s.d (5%)	1.013			

Numbers followed by different letters differ from each other significantly.

9.4 Discussion

Treatments containing systemic fungicides had greater efficacy than the contact fungicides in controlling field symptoms of white blister on radish. This work confirms research conducted overseas (Dueck and Stone, 1979). However, the price of the systemic fungicides does not always make them the most cost effective (Pandya *et al*., 2000; Godika and Pathak, 2002). Interestingly Acrobat had greater efficacy than Amistar when applied late in the spray program, suggesting that Amistar should be more effective used earlier in spray programs. The last trial found some evidence to support this as one spray of Amistar at week 2 gave nearly 100% control of the disease.

Persistent and large-scale use of the systemic fungicide metalaxyl has lead to the development of resistant strains of phytophthoras (Ferrin and Rhode, 1992) and downy mildews (O'Brien, 1992; Klein, 1994). *A. candida* can develop resistance to fungicides after five consecutive sprays of a systemic fungicide (Rimmer, pers. comm). Systemic fungicides should be used with caution for white blister control on radish and rotated to reduce development of fungicide resistance in *A. candida*.

The application of the new formulation of Apron seed treatment was very quick and easy. When it was applied alone, it controlled the disease by 80% and prevented symptoms of white blister developing on cotyledons. Cotyledons are known to be more susceptible to white blister than seedling leaves (Pound and Williams, 1963; Hill *et al*., 1988), so keeping them free of symptoms may prevent the spread of the airborne sporangiospores in the crop. However, only 80% efficacy at harvest is not sufficient disease control for a crop with high aesthetic standards, and a follow up spray would be necessary, as has been the case with Indian mustard (Bartaria *et al*., 1998; Bhatia and Gangopadhyay, 1996). In our trials the Apron seed treatment was not as effective in controlling white blister as foliage sprays of contact and systemic fungicides. Sharma and Sohi (1982) also found seed treatments were less effective than foliar sprays for white blister control on radish leaves. Seed treatments may have benefits under conditions of high disease pressure, such as in commercial nursery situations, as seed can be contaminated with oospores.

The addition of P and K to the systemic fungicide treatments showed no white blister symptoms in plots during assessment, but the treatment was phytotoxic in the second trial. The use of lower rates in the third trial reduced phytotoxicity, but did not significantly reduce levels of white blister. The phytoxicity with the Aminofit treatment appeared as a white bleaching of foliage, whereas with the P and K treatment plants were smaller and the foliage did not cover the bed. This contradicts work reported from overseas where P and K were found to reduce the susceptibility of cauliflowers and Indian mustards to white blister (Savulescu, 1960; Godika *et al.,* 2001). It is possible that P and K had no affect on white blister reduction, as levels of these elements were already high in the intensively cropped market garden areas.

Data generated by this work has been passed onto AgAware and ServAg to aid in minor chemical use registration. Currently, Amistar and copper oxychloride have minor use permits for white blister on radish (Peter Dal Santo pers. comm.).

In our trials, controlling the disease under circumstances of low disease pressure and with either contact or systemic fungicides produced no significant increases in yield (number of bunches/m^2) above the control (water only). Radish is sold with the foliage attached and infected leaves are removed whilst bunching. Controlling the disease on foliage will reduce the time to bunch, increase the quality and consequently the marketability of the crop. It would be very beneficial to do a cost benefit analysis of white blister control on radish.

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Chapter 10 Testing for seed transmission of *Albugo candida* in radish seed

Summary

Three cultivars of radish seed (30,000 seeds) were tested for seed transmission of *Albugo candida* (white blister) and none were found to be carrying the fungal oospores.

10.1 Introduction

White blister, caused by *Albugo candida* (Pers. Ex. Lev.) Kuntze, was first reported in Victoria on *Raphanus sativus* L. (radish) in 1903. According to growers the disease started to be a problem in their crops about 30 years ago. *A. candida* is known to be seed-borne (Richardson, 1990). In Canada over 60% of radish seed lots contained oospores with 1.8 oospores/gm radish seed, which is considered to be a problem for seed producers (Petrie, 1986).

Seed-borne oospores have the potential to play a critical role in initiation of field infections of other *Brassica* species, for example turnip rape (*B. rapa* formally *B. campestris*). Petrie (1975, 1978), working on turnip rape (*B. rapa*) identified high levels of seed and seed lot contamination in Canada. On average there were 28 oospores/gm seed and 80% of commercial seed lots were contaminated with oospores. Verma and Petrie (1980) demonstrated that inoculation of turnip rape seed with oospores resulted in a significant increase in local and systemic symptoms of white blister on plants in field plots. The threshold, however, leading to infection of radish in the field is unknown (Petrie 1986).

This chapter describes the examination of the seed of three radish cultivars for *A. candida* oospores, to determine whether infested seed could be a source of primary inoculum for radishes grown in market gardens in Victoria, Australia.

10.2 Materials and methods

Seed washing and filtration technique

Seed of the commercial radish cultivars ‘Red Planet’ (Henderson Seed, Lot No. 15231), ‘Geisha Girl’ (Fairbanks, Lot No. 2400267) and ‘Radio’ (Fairbanks, Lot No. 2801035) were screened for the presence of oospores of *A. candida*. A total of 30,000 seeds were divided into six 5g sub-samples (540-570 seed per 5g). Each 5g sub-sample was agitated in 30ml of deionised water containing a drop of the wetting agent Tween 20 (Merck, Germany). A filtering system was devised in which the seed was collected in gauze material as the wash water was sucked through a 1.0 μm filter disc. On removal, the discs were air-dried, cut in half and mounted onto microscope slides. Mineral oil (Sigma Diagnostics heavy white oil) was used to clear the discs prior to microscopic examination. The number of oospores per slide was counted.

Glasshouse grow-on trial
Seed (1 g = 80-100 seed) of the cultivars Radio (Fairbanks, Lot No. 2801035), Geisha Girl (Fairbanks, Lot No. 2400267) and Red Planet (Henderson Seed, Lot No. 15231) was also assessed for oospore contamination in a randomised glasshouse trial. The experiment consisted of 10 replicates of 2 treatments: control and nitrogen enriched. The treatments were subjected to natural light conditions with a day/night temperature regime of 20-25°C and 15-20°C, respectively. Seed was planted in 20cm diameter pots with a standard potting mix and fertilised with Osmocote™. The nitrogen-enriched treatment also received a weekly application of a high N liquid fertiliser (Thrive™). Plants were inspected daily for the development of white blister up to the age of 6 weeks.

10.3 Results

No *A. candida* oospores were detected in 30,000 seeds of radish cultivars Radio, Red Planet or Geisha Girl (daikon) in the seed washes. All seed batches had been coated with the fungicide Thiram™ and a green dye, which made observations difficult. The work took three weeks to complete. In the glasshouse grow-on trial there was no development of white blister on any radish plants from either treatment up to six weeks after planting.

10.4 Discussion

Failure to detect oospores of *A. candida* in the three batches of radish seeds using the seed wash is unlikely to be a failure of the technique employed. The filtration technique was found to be reliable for the rapid quantitative screening of large numbers of *Brassica* seed samples for the presence of oospores (Petrie, 1975 and 1978). Therefore the failure to detect spores was most likely due to their absence rather than a flawed screening technique. The disadvantages of the technique were, it was time consuming and not practical for screening large numbers of seed lots.

The grow-on trial screened only 2,000 seeds of each cultivar and took 6 weeks to conduct. The addition of extra nitrogen may have enhanced development of white blister on seedlings in the grow-on trial if it was present. Excessive nitrogen or animal manures are known to make plants more susceptible to *A. candida* (Saharan and Verma, 1992).

Petrie (1986) detected low levels of oospores on radish seed in a large number of batches of radish seed available in Canada, which was sourced from Washington, USA. Nearly 30 years later, no oospores were detected in radish seed sourced from the same region, for Australian growers. It appears that the currently sourced seed may be cleaner than seed available nearly 30 years ago. This work does not rule out the possibility that contaminated seed may have entered the Australian vegetable production areas some time in the past. Seed does not appear to be a consistent source of infection although it may have been associated with initial introductions of *A. candida* on radish seeds into Australia in the past.

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Chapter 11 Relationships with industry

Craig Murdoch – Vegetable Extension Officer

Summary

This chapter reports on the benefits of a project advisory group for steering research projects. This group increased communication and cooperation between growers, researchers and allied support businesses and resulted in an accelerated impact of research and development within the Bunchline Vegetable Industry.

11.1 Background

Industry advisory groups and project steering committees have proved to be an excellent means of accelerating the impact of research and development (R&D) projects. These groups provide an opportunity for researchers to describe their approach and current progress to both vegetable growers and allied support businesses such as crop advisers, nurserymen, seed suppliers and chemical manufacturers. The group member's diverse experience and their special industry networks have encouraged each person to contribute more towards achieving a successful project outcome for growers. The group members have come to appreciate each other's contribution to a better understanding of the many issues concerning bunching vegetable production. Some of the unique benefits of the project advisory group approach have been:

1. Putting a human face to the issues confronting bunching vegetable growers and a shared celebration of progress towards improving long-standing problems.
2. A better understanding of the impact of downy mildew on spring onion crops that could only come through in-depth discussions with group members throughout the course of the project.
3. The opportunity to demonstrate how a combination of research and grower experience can combine to provide a richer understanding of industry issues and their solution.
4. Researchers have the opportunity to deliver preliminary reports to a supportive industry audience and to better prepare for presentations to local and interstate grower groups.
5. Advisory group members, in the course of their daily business, are strong advocates of the value of the R&D levy and have given personal examples to critics & sceptics of this system.
6. Researchers have been invited to several grower properties to inspect other disease problems including leeks, parsley, parsnips broccoli and celery, which may lead to future R&D work.
7. Participating growers have developed better relationships with researchers and those working in the nursery, chemical and seed industries. This has given growers another forum to discuss recurring problems and issues.

The advisory group approach works very well and is now our preferred approach to group involvement with the Vegetable industry. The advisory group model has been successfully applied to other vegetable R&D projects including, Onion White Rot VG01096, *Brassica*-white blister VG02118 and through the Lettuce aphid advisory group under Lettuce Best Practice VG01038.

VegCheque
extension for the vegetable industries

Department Of
Natural Resources and Environment

Downy Mildew on Spring Onions?

You are invited to an informal farm walk as part of:

'Disease management strategies for bunching vegetable growers'

**A research project supported by
your vegetable industry levy, Horticulture Australia and DNRE.**

- **Visit the trial site and see how the chemical and fertiliser treatments for downy mildew have performed.**
- **Discuss your views with the project officers and other growers.**

When : 3-5pm Tuesday 10th December 2002

Where: Darren Pivarto farm
Tyabb/Tooradin Rd
Tyabb, Melways map 149 E6 (**Sth of the equestrian centre**)

Victoria The Place To Be

Horticulture Australia

Veg Cheque
extension for the vegetable industries

You are invited learn about and discuss the latest findings on:

Controlling Diseases of Spring Onions & Leeks

**Research projects supported by
your vegetable industry levy and Horticulture Australia.**

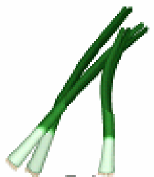
Speakers:

Peter DalSanto, Crop Protection Approvals
Chemical registration program for bunching vegetables
– lessons from Virginia SA

Elizabeth Oxspring, SARDI Adelaide
Update on Leek diseases in Southern Australia

Oscar Villalta, IHD-Knoxfield
Controlling White Rot on Spring Onions

Elizabeth Minchinton & Narelle Kita, IHD-Knoxfield
Controlling downy mildew on Spring Onions



When : 3:45 - 6 pm Friday 28th February 2003

Where: Chisholm Institute Theatre
Cranbourne TAFE
Corner Cameron St and Berwick-Cranbourne Rd
Cranbourne East, Melways Map134, A6

Light food & drink provided

Contact: Craig Murdoch on (03) 9210-9354

Horticulture Australia

Victoria The Place To Be

VegCheque
extension for the vegetable industries

Department Of Primary Industries

Comparing Spring Onions varieties ?

You are invited to an informal farm walk as part of:

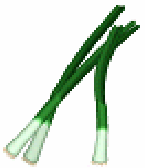
'Disease management strategies for bunching vegetable growers'

**A research project supported by
your vegetable industry levy, Horticulture Australia and DPI.**

- **Visit the trial site and see how the different cultivars have performed.**
- **Discuss your views with the project officers and other growers.**

When : 3:30 - 5pm Wednesday 16th April 2003

Where: Butler Market Gardens
198 Old Dandenong Rd
Heatherton, Melways map 78 J11



Contact: **Craig Murdoch on 9210-9354**

Victoria The Place To Be

Horticulture Australia

Veg Cheque
extension for the vegetable industries

You are invited learn about and discuss the latest findings on:

Controlling Diseases of Spring Onions

**Research projects supported by
your vegetable industry levy and Horticulture Australia.**

Speakers:

Glenn Geitz, DPI-Queensland
Nozzle selection, adjuvants, and spray equipment for onions

Oscar Villalta, DPI-Knoxfield
Controlling White Rot on Spring Onions – Latest developments

Elizabeth Minchinton & Narelle Kita, DPI-Knoxfield
Controlling downy mildew on Spring Onions

When : 3:45 - 6 pm Friday 19th September 2003

Where: Chisholm Institute Theatre
Cranbourne TAFE
Corner Cameron St and Berwick-Cranbourne Rd
Cranbourne East, Melways Map134, A6

Light food & drink provided

Contact: **Craig Murdoch on (03) 9210-9354**

Horticulture Australia

AUSVEG

Queensland Government Department of Primary Industries

Victoria The Place To Be

DEPARTMENT OF PRIMARY INDUSTRIES - VICTORIA

An invitation to learn more about:

Bunching Vegetables

FINAL report on HAL research project VG01045

Research supported by your Vegetable Industry Levy, Horticulture Australia and DPI-Victoria,

Speakers:

Liz Minchington **DPI-Knoxfield**
On controlling diseases of spring onions & radish

Victor Galea **University of Queensland - Gatton**
Downy Mildew predictive model for spring onions

Tony Lamattina **A. & D. Lamattina & Sons**
Weather station model … a growers view

Karl Riedel **E.E. Muir & Sons**
Weather station model … a crop advisors view

Lindsay Trapnell **Farmanomics Research and Consulting**
Economics of treating spring onions for Downy Mildew

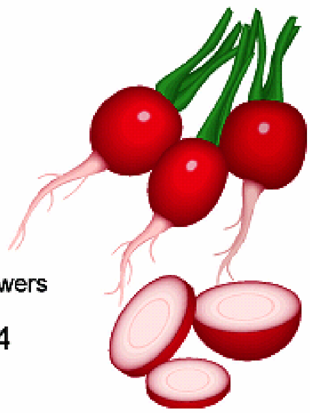
Brendan Dipple **Queensland**
Costs of production … a growers view

Peter DalSanto **AgAware Consulting**
Chemicals registrations for bunching vegetables

Rodney Dunn **Queensland**
Radish harvester video

Mike Walker **Tasmania**
Issues facing the Tasmanian spring onion growers

Danny De Ieso **South Australia**
Issues facing the South Australian spring onion growers



When : 4 – 6:00 pm Thursday 8th July 2004
Where: Amstel Golf Club – Cranbourne
1000 Frankston Cranbourne Road
Melways Map 133, D5

Contact: Craig Murdoch - 0409 957 144

Victoria The Place To Be

VegCheque
extension for the vegetable industries

Horticulture Australia

11.2 Some growers reactions to the project and workshops

TS

Overall excellent event. Some of the leek work inconclusive as yet, met with Liz Oxspring the day before so had already heard about her work. Also already knew about Peter Dal Santo's work but good to hear it first hand. Interested in followup to Oscars work with SUMICLEX and Fowl Manure synergy. Excited about Victor's work with weather stations and disease forecasting especially Septoria leaf spot. "We will probably invest in this approach". Thought the venue was excellent and should be used more. Would have liked even more time to talk with growers and researchers. Could have started earlier say 1pm. TS is definitely interested in any future workshops and would recommend them to other growers.

PC

Really good…good venue…good presentations. A lot of grower interest in weather modelling for disease prediction. Peter Dal Santo's work now familiar to many more growers. Oscar's observations on SUMICLEX and fowl manure need more work as some growers use lots of fowl manure, yet have lots of white rot too. Liz and Narelle's work was also useful.

JK

Very worthwhile day. Venue was a lot better than some of the noisy sheds we've used before. Found much of the information was still "work in progress" rather than hard recommendations. Thought researchers pretty much on the right track and found it interesting to hear their thoughts part way rather than at the end of the work. Found the use of OCTAVE on stem rot of leeks particularly useful as JK had not heard of this approach before. Scientists were still pretty guarded about recommending things though. JK thought the social time in small groups was OK over pizza and that a group discussion could bring out more experiences, we should try it next time !

RL

Excellent venue when there's no field work to look at. Could see and hear well. Break half way was important. Already knew about Peter Dal Santo's work but good to hear it again! The leek diseases were similar or related to those in spring onions, which was interesting. Seemed some overlap with Leeks, Oscar and Liz's work, perhaps the researchers could spend some time together (over dinner) to consolidate their work / findings and avoid unnecessary repetition? A lot of the work was premature and needs to be confirmed in following seasons. RL thought that Oscars work was very important to his business and all spring onion growers / researchers.

DK

Venue was quite good. Liz Oxspring's work was well presented but nothing new that could help him now. Workshop notes excellent, has shown to field workers so they know what problems to look for on leeks. The role of watering times on downy mildew on spring onions was very interesting and DK would like to go to more of these workshops. DK currently has a problem with *Fusarium* in his speedlings and would like to know more about possible entry points for this disease and ways to reduce damage. The only improvement DK could think of was to talk more on ways to control each disease and how diseases survive in the field and gain entry to plants.

ST
Good venue. Happy to stay overtime when learning something. Impressed by turnout, big slice of industry present. Knew about Peter Dal Santo's work from newsletter, but process is far too slow for growers. Met with Liz Oxspring Friday morning and had already heard her story. Impressed with Oscar's work, heading in the right direction. Interested to hear different approaches to controlling diseases and will consider adapting some of these approaches to his business. Regarding the weather station, it may be possible to save a few sprays but the consequences of failure can be $5-10,000. Each grower will have to consider if the gamble is worth it. "You make your own luck".

DC
Great venue, could see and hear everything clearly. Some of the talks were directed at too basic a level and were a bit boring but occasionally something important came up which drew attention. Had heard about Peter Dal Santo's work and was interested to hear him speak. Very interested in Liz Oxspring's work on leeks, have already made a couple of changes to disease control program and is thinking of trying these ideas on a few other problems. Very interested in Oscars work on SUMICLEX and fowl manure. Have successfully changed their mildew management practices with what was learnt from the last workshop. Group discussion may be worth a try but many growers treasure their secrets.

GF
Good venue, very interested in all talks, felt learn't a lot. Liked Peter Dal Santo's work and found the leek story interesting although they haven't enough land to grow leeks. Liz and Narelle's talks were too short, trying to save time. The weather station predictions sound good, worth $1000 or so to give it a try. Would have liked to stay and talk at the end. Improvements?…maybe get the scientists to trim their talks back, some could be told in half the time.

DS
Great afternoon. Much of their business involves export to SE Asia where residue limits are critical. Happy to listen to all the information even though they knew some of it and some info was related to crops he doesn't grow. Have listed the chemicals he uses on each vegetable line and will pass this list on to Patrick Ulloa. Would like to hear more about non-chemical alternatives to control crop diseases as they only use chemicals as a last resort.

J&B E (Western Australia)
A simple change to night irrigation has greatly improved spring onion quality by reducing downy mildew.
"Night irrigation is a winner"

11.3 Changes in knowledge, abilities, skills and aspirations

As you can see from the reactions of growers, the benefits of this research project are as diverse as the industry itself. On a technical level, bunching growers Australia-wide finally have a working understanding of downy mildew and white blister and its control. The growers and their advisers are capable and confident to use a variety of control measures in combination to control these perennial problems whose solution which has eluded them until now. Some growers have benefited from simple changes such as watering the crop only at night. Still other growers have adopted the improved fungicide control strategies developed by the project. Some growers are now using the disease prediction model to help them optimise their disease control strategies and have placed weather stations in their crops. The industry has voiced its appreciation of this HAL funded project in developing and applying research findings to provided a range of approaches to controlling diseases in bunching vegetable crops and for providing a channel for other HAL funded projects to discuss their findings with industry.

11.4 Industry advisory group

Not all growers are in a position to volunteer for R&D project advisory groups. Growing and marketing vegetables demands a great deal of time and effort. While most are able to attend half-yearly project update events, for the most part only the same few growers are able to serve on project advisory committees.

The approach Department of Primary Industries Victoria have adopted has been to invite private sector crop agronomists and similar "information retailers" to join with researchers and able growers, to plan and discuss bunching vegetable issues first-hand. As mentioned earlier, the resulting advisory group model has proved a huge success.

The advisory group members who have contributed to the success of Bunching Vegetable Project VG01045 are:

Craig Arnott – Market Gardener - Arnotts Vegetable Farms- Clyde

Peter Cochrane - Market Gardener - P.J. & J. Cochrane P/L – Devon Meadows

Geoff Foster - Market Gardener - E.W. & S.K. Foster – Lang Lang

Tony Lamattina - Market Gardener - A. & D. Lamattina & Sons – Clyde

Rocky Lamattina - Market Gardener – A. & D. Lamattina & Sons – Clyde

Karl Riedel – Vegetable Crop Agronomist - E.E. Muir & Sons **–** Cranbourne

Chapter 12 Publications

Anon, (2002). VegCheque. Access to Asian Vegetables, Issue 47, 1.

Dal Santo, P., Oxspring, E., Villalta, O., Kita, N., Minchinton, E. and Galea, V. (2003). Controlling diseases of spring onions and leeks. Workshop Notes, Cranbourne TAFE., 28 February 2003. DPI Knoxfield: 25p.

Kita, N. (2001). Downy mildew in spring onions. Vegetable Matters 3: 1.

Kita, N., Minchinton, E, Galea, V., Nguyen, N., Murdoch, C. and Pierce, P. (2003). Integration of a disease predictive model and management practices improves control of downy mildew on spring onions. Abstract and poster. Collaboration, passion and opportunities, DPI Horticulture Conference 2003. DPI Tatura 26 – 27 August 2003.

Kita, N., Minchinton, E., Nguyen, N. and Murdoch, C. (2002). Disease surveys identify management practices, which reduce downy mildew incidence in spring onions crops. 2002 Horticultural Conference: Working with plants: How do you fit into the future. Institute for Horticultural Development, Knoxfield 21st and 22nd August 2002. Abstract: 34.

Kita, N., Minchinton, E, Murdoch, C. and Kreidl, S. (2003). Guide to common disease and disorders of bunching vegetables in Australia. Primary Industries Research Victoria, Knoxfield, 58pp.

Kita, N., Minchinton, E. (2003). Latest findings from downy mildew and white blister research. Article for IDO's VegeLink submitted March 2003, 2pp.

Kita, N., Minchinton, E., Nguyen, N., Murdoch, C. and Pierce, P. (2002). An integration of watering times and fungicides will control white blister on radish. Abstract and poster. Collaboration, passion and opportunities, DPI Horticulture Conference 2003. DPI Tatura 26 – 27 August 2003.

Kita, N., Minchinton, E., Murdoch, C. and Nguyen, N. K. (2003). White blister/rust on vegetables. Poster. Werribee Vegetable Expo, Glenormiston College Werribee, Vic.

Kita, N., Minchinton, E., Nguyen, N. and Salib, S. (2002). A combination of fungicides and fertilisers improved control of downy mildew on spring onions. 2002 Horticultural Conference: Working with plants: How do you fit into the future. Institute for Horticultural Development, Knoxfield 21st and 22nd August 2002. Abstract: 36.

Kita, N., Minchinton, E., Nguyen, N. K., Murdoch, C. and Galea, V. (2003). Update: Disease Management Strategies for Bunching Vegetable Growers. Handout for State IDO, Vegetables, 2pp.

Kita, N.J., Minchinton, E. (2003). Latest findings from downy mildew research on spring onions. Article for IDO’s VegeLinks, submitted December 2003.

Kita, N.J., Minchinton, E.J., Nguyen, N. and Murdoch, C. (2003). Disease surveys identified management practices which reduced downy mildew incidence in spring onion crops. Abstract. 8th International Congress of Plant Pathology. Sunday 2 to Friday 7 February 2003, Christchurch, New Zealand, 2: 263.

Minchinton, E. (2001). Tackling diseases in bunching vegetables. *VegeLink Vic* **10:** 4.

Minchinton, E. (2001). Tackling diseases in bunching vegetables. *VegeLink WA* **9:** 4.

Minchinton, E. (2002). Reducing mildew in spring onions. Market Place News, March p17.

Minchinton, E. (2003). Bunching Vegetables. VegeLINK Victoria. Issue 15, Winter, 6.

Minchinton, E. and Anderson, A. (2001). Tackling diseases in bunching vegetables. *Vegelink NSW* **2**:1.

Minchinton, E. and Kita, N. (2002). Control of downy mildew in spring onions. *VegeLink NSW*, **3**: 6.

Minchinton, E. and Kita, N. (2002). Research on downy mildew in bunching vegetables continues. VegeLink VIC, 12:4.

Minchinton, E. and Kita, N. (2003). Controlling downy mildew on shallots. VEGELink NSW, p2.

Minchinton, E. and Kita, N. (2003). Downy mildew and white blister research update. VEGELink NSW, Issue 6, Winter, p5.

Minchinton, E., Faggian, R., Kita, N. and Murdoch, C. (2003). Management of White Blister. Handout. DPI, IHD Knoxfield, 2pp.

Minchinton, E., Kita, N., Nguyen, N. and Murdoch, C. (2002). White blister/rust. In 'Improving interaction and communication between RIRDC Asian foods program leaders and industry (DNT-28a)'. Minutes of meetings held in Melbourne and Geelong, on June 19-21, 2002. Edt. Melinda Gosbee, Northern Territory Department of Business, Industry and Resource Development.

Minchinton, E., Kita, N., Villalta, O. and Galea, V. (2002). Field day notes, disease management strategies for downy mildew on spring onions DNRE, IHD Knoxfield, 16p.

Minchinton, E., Kita, N., Villalta, O. Galea, V., Mac Manus, G. and Thompson, L. (2002). Disease management strategies for downy mildew on spring onions (shallots). Report on field days. DNRE, IHD Knoxfield, 18p.

Minchinton, E., Porter, I. and Ellement, D. (2001). Tackling disease in bunching vegetables. WA Grower, Vegelink, Issue 9: p3.

Minchinton, E.J., Galea, V., Trapnell, Thomson, F., Nadesan, S., and Murdoch, C. (July 2004). Management of diseases in bunching vegetable crops. Workshop notes for Victorian growers meeting. DPI, PIRVic, Knoxfield Centre. 30pp.

Minchinton, E.J., Thomson, F., Nadesan, S., Kita, N., Galea, and Murdoch, C. (August 2004). Management of diseases in bunching vegetable crops. Workshop notes for WA growers meeting DPI, PIRVic, Knoxfield Centre. 15pp.

Minchinton, E.J., Thomson, F., Nadesan, S., Kita, N., Galea, V., and Murdoch, C. (2004). Management of diseases in bunching vegetable crops (Tasmanian grower's workshop notes). DPI, PIRVic, Knoxfield Centre, 9pp.

Thompson, L., MacManus, G., Kita, K. and Minchinton, E. (2001). Field day notes, disease management strategies for bunching vegetables. DNRE, IHD Knoxfield, 11p.

Villalta, O., Geitz, G., Minchinton, E. and Kita, N. (2003). Controlling diseases in spring onions. Workshop Notes, Cranbourne TAFE, 19 September 2003. DPI Knoxfield, 41pp.

Meetings, field days and conferences

Meeting Bunching Vegetables Project. Muirs Cranbourne 25/7/01.

Field day 27/11/01 at P J & J Cochranes, Devon Meadows.
Field day 2/7/02 at A & D Lamattina & Sons, Clyde.
Field day 28/2/03 at Cranbourne TAFE.
Field day 19/9/03 at Cranbourne TAFE.

Workshop, Kemps Creek Sporting and Bowling Club, NSW, 12/8/02
Workshop, Danny DeIeso's Farm, Virginia, SA, 21/8/02.
Workshop, Queensland Clunies Ross Centre, Eight Mile Plain, QLD, 26/8/02.
Workshop, Longford RSL, Longford, Tasmania, 26/2/04.
Workshop, Wynyard, Federal Hotel, Wynyard, Tasmania, 27/2/04.
Workshop, Forth, Forthside Vegetable Research Station, Forth, Tasmania, 27/2/04.
Workshop, Amstel Golf Club, Cranbourne, Vic, 8/7/04.
Workshop, Wanneroo Tavern, Waneroo, WA, 26-27/8/04.

Conference (attendance)
Onions 2002. Yanco Agriculture Institute. 3-5 June 2002.
8th International Congress of Plant Pathology. Sunday 2 to Friday 7 February 2003, Christchurch, New Zealand

Steering committee meetings
25/7/01 Muirs Cranbourne
10/7/02 Amstel Golf Club, Cranbourne
12/3/03 Amstel Golf Club, Cranbourne
24/6/03 Amstel Golf Club, Cranbourne
14/10/03 Amstel Golf Club, Cranbourne
10/3/04 Amstel Golf Club, Cranbourne