Developing alternate fungicides to control white blister disease in Brassica crops

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Peracto Pty Ltd

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HAL Project VG04061

Final Report

15 May 2007

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MEDIA SUMMARY

White blister (*Albugo candida*) is the most important foliar disease of brassica crops in Australia. The disease can affect all stages of plant growth, but its greatest impact is on infected flower heads, resulting in substantial losses to yield and higher costs in sorting. This Horticulture Australia project aimed to evaluate fungicides for white blister control (*Albugo candida*) and to expedite the registration of suitable fungicides in Australia for white blister control on brassica and leafy brassica crops.

- In these studies, Ridomil Gold MZ and Ridomil Gold Plus at 2.5 kg/ha and 2.2 kg/ha, respectively, were effective for white blister control. The systemic fungicides, Amistar and BAS 500 or Cabrio, were also effective ; however, Penncozeb, Bravo, Filan and phosphorous acid had no effect on the disease.

- Amistar SC at 0.25 and 0.5 L/ha appeared to be adequate for effective disease control, when disease pressure was low and/or when field conditions were not favourable for the disease. Higher rates of Amistar SC at 1.0 and 2.0 L/ha gave better disease control, when the disease pressure was high and field conditions were favourable to the disease.

- Amistar SC or Ridomil MZ must be applied early, at the first sign of infection, for effective disease control. Less effective control by Amistar SC or Ridomil MZ was noted when they were applied later, long after the onset of the disease.

- Copper fungicides based on copper hydroxide or copper oxychloride tend to be less effective than the systemic fungicides in preventing leaf infection, but are effective in reducing head infections. They should be considered for use on crops that are approaching maturity in order to prevent head infections, following early systemic fungicide applications.

- In Tasmania and Victoria, favourable field conditions, consecutive plantings and multiple plantings combine to create a constant disease pressure over a prolonged period of time, as well as prolonged exposure of fungal populations to a fungicide. The systemic fungicides, Amistar, Cabrio, Ridomil Gold MZ and Ridomil Gold Plus have a high risk of resistance development if they are exposed to constant disease pressure. Failure to follow resistance management guidelines carefully will likely result in the loss of these new fungicides as effective control measures. Growers should adopt an integrated disease management strategy that incorporates the use of fungicides, along with other management practices such as resistance cultivars, crop rotations and reducing multiple plantings, for long-term and sustainable disease control.

TECHNICAL SUMMARY

Fungicide efficacies

White blister (*Albugo candida*) is the most important foliar disease of brassica crops in Australia. The disease can affect all stages of plant growth, but its greatest impact is on infected flower heads, resulting in substantial losses to yield and higher costs in sorting. This Horticulture Australia project aimed to evaluate fungicides for white blister control (*Albugo candida*) and to expedite the registration of suitable fungicides in Australia for white blister control on brassica and leafy brassica crops.

Six efficacy trials were conducted to evaluate azoxystrobin (Amistar SC), chlorothalonil (Bravo Weather Stik), metalaxyl-M + mancozeb (Ridomil Gold MZ) and metalaxyl-M + copper hydroxide (Ridomil Gold Plus) and to determine suitable rates, application timing and programs for white blister control. Another two field trials were conducted to evaluate the alternative fungicides pyraclostrobin (BAS 500 or Cabrio), boscalid (BAS 510 or Filan), BAS 516 (pyraclostrobin + boscalid), BAS 536 (pyraclostrobin + dimethomorph), copper hydroxide (Flo-Bordo) and phosphorous acid (Agri-Fos), for white blister control.

- In these studies, Amistar SC, Ridomil Gold MZ and Ridomil Gold Plus were found to be effective in protecting leaves and heads from white blister.

- Amistar SC was evaluated at rates of 0.25, 0.5, 1.0 and 2.0 L/ha for white blister control. Under high disease pressure, Amistar SC at 1.0 and 2.0 L/ha gave the best disease control. It also gave relatively effective disease control at 0.25 and 0.5 L/ha, which indicates that the lower rates may provide adequate control in situations where disease pressure is low and/or when field conditions are not favourable for the disease

- Ridomil Gold MZ and Ridomil Gold Plus at 2.5 kg/ha and 2.2 kg/ha, respectively, are effective for white blister control. The efficacy of Ridomil Gold MZ was found to be dependent on its history of previous use, locations and farm practices.

- BAS 500 was also found to be effective against white blister. Disease control by the combinational fungicide mixtures BAS 516 and BAS 536 appeared to be due to pyraclostrobin alone. Penncozeb, Bravo, Filan and phosphorous acid had no effect on white blister.

- The contact fungicides based on copper hydroxide or copper oxychloride tended to be less effective than the systemic fungicides in preventing leaf infection under high disease pressure . They were, however, effective in preventing head infections.

Fungicide use

AUSVEG applied for emergency and temporary permits for the use of chlorothalonil, mancozeb, boscalid and phosphorous acid for white blister control in 2003 to 2005. However, in this project, all of these fungicides were found to have no effect against the disease, and growers have since stopped using them for white blister control.

- The temporary permit use of Ridomil Gold MZ, copper oxychloride and Amistar SC expires in March 2008. Ridomil Gold MZ and Amistar SC must be registered with the APVMA for long-term use in brassica crops. In this project, Syngenta Crop Protection Pty Ltd funded a series of residue and efficacy studies in order to generate the data required for the registration of Ridomil Gold MZ and Amistar SC for use on brassica and leafy brassica vegetable crops.

- Copper fungicides based on copper hydroxide or copper oxychloride are alternatives to the systemic fungicides, Amistar and Ridomil Gold MZ, and are already registered for use in Australia for the control of other brassica diseases. They should be considered for use on crops that are approaching maturity in order to prevent head infections, following early systemic fungicide applications. Amistar SC or Ridomil MZ must be applied early, at the first sign of infection in the crop at the pre-button stage, for effective disease control. In this project, Amistar SC or Ridomil MZ sprays were less effective when applied later, long after the onset of the disease.

- In Tasmania and Victoria, favourable field conditions, consecutive plantings and multiple plantings combine to create a constant disease pressure over a prolonged period of time, as well as prolonged exposure of fungal populations to a fungicide. The systemic fungicides, Amistar, BAS 500 and Ridomil Gold MZ have a high risk of resistance development, if they are exposed to the constant disease pressure. Failure to follow resistance management guidelines carefully will likely result in the loss of these new fungicides as effective control measures. Growers should adopt an integrated disease management strategy that incorporates the use of fungicides with other management practices, such as resistance cultivars, crop rotations and reducing multiple planting, for long-term and sustainable disease control.

RECOMMENDATIONS

- For long-term and sustainable white blister control growers should adopt an integrated disease management strategy that incorporates the use of fungicides along with other management practices such as using disease tolerant cultivars, crop rotations, management of crop debris, avoid consecutive brassica crops and reducing multiple planting.

- Currently, the most effective fungicides for white blister control are phenylamide (metalaxyl-M) and strobilurin (azoxystrobin and pyraclostrobin). These fungicides have a high risk of resistance development. It is essential to use a management program to prevent or delay the build-up of resistant fungal populations, in order to maintain and prolong the useful life of the most effective fungicides. Attempting to manage resistance after it has developed is far more difficult than prevention.

- Systemic fungicides should be used early in the epidemic when the pathogen population is low. High-risk fungicides should be used at the manufacturer's recommended full rate and application interval. Therefore, Amistar, Cabrio, Ridomil Gold MZ and Ridomil Gold Plus should be used early; when infections are first noted or when field conditions are conducive to infections.

- A spray mixture of Amistar or Cabrio with copper fungicide should also be considered for fungicide resistance management.

- It is best to limit high-risk fungicide to no more than two consecutive sprays during the crop or as recommended by their manufacturers.

- Copper fungicides applications should be considered, following the early systemic fungicide applications, in order to prevent head infections.

- The number of spray applications will depend on locations, disease pressure, climatic conditions, cultivar susceptibility and crop growth. The disease risk prediction model that was developed in UK based on the temperature and duration of leaf wetness has been shown to have the potential to improve fungicide application timing for white blister control in Australia.

- In commercial practice, it is typical to apply up to two systemic fungicide applications in each planting at the initial flower head formation. Therefore, in order to reduce long-term exposure of the pathogen to a fungicide and hence reduce the risk of fungicide resistance, a block of two spray applications of a systemic fungicide should be considered. For example, apply two applications of Ridomil Gold MZ in one planting, followed by two applications of Amistar SC in the next planting.

INTRODUCTION

Background

White blister (*Albugo candida*) is a fungal disease that became commercially important in Australia in 2002 when the disease became widespread in many broccoli crops in Victoria. The disease can affect all stages of plant growth and can result in substantial losses to yield. Generally, the tolerance level for broccoli head infections in a fresh market broccoli crop is 10%, with increased costs in sorting during and after harvest, and potential losses if the disease develops on heads in storage and in transit to their market. *A. candida* belongs to the same group of fungi, classified as *Oomycetes,* as other fungal pathogens such as *Peronospora*, *Pythium* and *Phytophthora.* Fungicides that are active against the latter pathogens may also have activity against *A. candida*.

When white blister first became widespread in Victoria in 2002, quarantine restrictions were implemented on the interstate movement of broccoli and cauliflower plant material, in order to prevent its spread to other states in Australia. However, these attempts to prevent and eradicate the disease in early 2003 were unsuccessful due to the rapid spread of the disease. The disease is now present in all major brassica production regions throughout Australia. White blister is now considered to be the most important foliar disease on brassicas, namely broccoli, cauliflowers and brussel sprouts. White blister also affects leafy brassica vegetables. The disease is most widespread and severe in Werribee South, Victoria, and in northern Tasmania. Therefore, all fungicide evaluation studies in this project were conducted in these two regions.

Azoxystrobin and metalaxyl-M + mancozeb are systemic fungicides that were identified as being highly effective against *A. candida* on broccoli in Victorian trials in 2003/04, in HAL project VG02118, as well as in a field efficacy trial conducted in 2004 by H. Pung, Peracto Pty Ltd. Growers in Tasmania regularly used chlorothalonil for white blister control in 2003 and 2004, even though no efficacy study has been conducted to establish that chlorothalonil is effective against white blister. No fungicides are currently registered for control of white blister on these crops. Initially, emergency permits were issued by the Australian Pesticides & Veterinary Medicines Authority (APVMA) for copper oxychloride, chlorothalonil and metalaxyl + mancozeb use in Australia, on broccoli and cauliflower, in 2003. These permits have been renewed and are scheduled to expire in March 2008, subject to an understanding that in the interim period, the product manufacturers must make progress in generating the scientific data necessary to support full product registrations for their continued and long-term use in Australia. Brassica is considered to be a major crop and only registered products can be used, and only for the approved purposes that are specific on the fungicide label. This project was, therefore, carried out with voluntary funding and in-kind support from Syngenta Crop Protection Pty Ltd, in order to expedite the product registrations of suitable fungicides in Australia for white blister control on brassica crops. Alternative fungicides, which may also have been effective for white blister control from Nufarm Australia Ltd and Agrichem Industries Pty Ltd, were also examined in initial studies in 2005.

Currently, the lack of choices in fungicides, as well as lack of an informed and proven use of fungicide products, poses a serious threat of their misuse and/or overuse, which could jeopardise their long-term availability and effectiveness. Therefore, regulated and proper use of these products, with full support from the manufacturers, is seen as a vital step in ensuring the long-term efficacy of these products in integration with other non-chemical measures identified in other studies in project VG02118.

Aims

The first aim of this project was to evaluate fungicides for their effectiveness for white blister control on broccoli. If proven to be effective and if considered by the product manufacturer to be feasible for full product registration, further trial studies were conducted to generate all necessary efficacy and residue data required for registering the fungicides with the APVMA.

This project consisted of three main areas:

Section A: Evaluation and development of effective fungicides from Syngenta Crop Protection for white blister control on brassica crops in Australia. Field trials were conducted to evaluate Amistar, Bravo, Ridomil Gold MZ and Ridomil Gold Plus, and to determine suitable rates, application timing and programs for white blister control. Data generated from the trial studies are also being used to support product registrations and to develop recommendations for label use by Syngenta Crop Protection.

Section B: Preliminary evaluations of alternative fungicides for white blister control. This study aimed to identify fungicides from other chemical groups that may be effective against white blister and that could be used for fungicide resistance management programs with fungicides identified in Section A.

Section C: Studies on residues of azoxystrobin, metalaxyl-M and mancozeb in brassica vegetables. This study included residue trials and analysis conducted under GLP (Good Laboratory Practice), and data generated will be used to register Amistar SC, Ridomil Gold MZ and Ridomil Gold Plus for use on brassicas for white blister control in Australia.

SECTION A: EVALUATION AND DEVELOPMENT OF EFFECTIVE FUNGICIDES FROM SYNGENTA CROP PROTECTION FOR WHITE BLISTER CONTROL ON BRASSICA CROPS IN AUSTRALIA

Introduction

All efficacy and residue studies conducted in this section were funded by Syngenta Crop Protection Pty Ltd, with matching funds from the Australian Government, with the aim of identifying effective fungicides for white blister control, optimising application methods and generating all essential scientific data to support product registration for long-term legal use of the effective fungicides on brassica crops in Australia.

Six field efficacy trials were conducted within commercial broccoli crops at Forth and Harford in Tasmania, and at Werribee South in Victoria, in 2005 to 2007, to evaluate the efficacy of fungicides for white blister (*Albugo candida*) control. Broccoli crops planted in Werribee South, Victoria, are subjected to constant and high disease pressure due to consecutive and multiple plantings throughout the year, with little or no break. In contrast, in Tasmania, broccoli crops are typically planted in a paddock, once a year and in a three or four year rotation with non-brassica crops. Crops in both regions usually have multiple plantings. White blister is also widespread in Tasmania, particularly in summer and autumn, when warm, wet and humid conditions favour the disease.

The fungicides examined were azoxystrobin (Amistar), chlorothalonil (Bravo), metalaxyl-M + mancozeb (Ridomil Gold MZ or Ridomil MZ), metalaxyl-M + copper hydroxide (Ridomil Gold Plus or Ridomil Plus), mancozeb (Penncozeb or Mancozeb) and copper oxychloride.

Fungicide Product List

PRODUCT	ACTIVE INGREDIENT (AI)	CONCENTRATION OF AI	FORMULATION
Amistar SC	azoxystrobin	250 g/L	Suspension concentrate
Bravo Weather Stik	chlorothalonil	720 g/L	Suspension concentrate
Copper oxychloride	copper oxychloride	500 g/kg	Wettable powder
Ridomil Gold MZ	metalaxyl-M + mancozeb	40 g/kg + 640 g/kg	Wettable granules
Ridomil Gold Plus	metalaxyl-M + copper hydroxide	50 g/kg + 390 g/kg	Wettable powder
Penncozeb DF	mancozeb	750 g/kg	Dry flowable

Trial Summary

Trial	#1	#2	#3	#4	#5	#6
Location	Werribee South, Victoria	Werribee South, Victoria	Forth, Tasmania	Werribee South, Victoria	Werribee South, Victoria	Harford, Tasmania
Soil Type	Silty loam	Silty loam	Ferrosol	Silty loam	Silty Loam	Black cracking clay
Crop	Broccoli	Broccoli	Broccoli	Broccoli	Broccoli	Broccoli
Variety	cv. Legacy	cv. Legacy	cv. Marathon	cv. Legacy	cv. Legacy	cv. Shamrock
Trial Design	Randomised complete block	Randomised complete block	Randomised complete block	Randomised complete block	Randomised complete block	Randomised complete block
Replicates	5 for all treatments except for untreated control, which had 10 replicate plots	5 for all treatments except for untreated control, which had 10 replicate plots.	5 for all treatments except for untreated control, which had 10 replicate plots.	5 for all treatments except for untreated control, which had 16 replicate plots.	4	4 for all treatments, except for untreated control, which had 8 replicate plots.
Plot Size	10 x 1.6 m 2 plant rows	10 m x 1.6 m 2 plant rows	7 m x 3.2 m 4 plant rows	10.5 m x 1.8 m 3 plant rows	10 m x 2 m 3 plant rows	7 m x 3.2 m 4 plant rows
Sowing Date	30/10/04	30/10/04	07/02/05	02/08/05	05/04/06	24/01/07
Harvest Date	12/01/05	12/01/05	30/04/05	26/10/05	24/07/06	19/04/07

Trial 1: Evaluation of Amistar SC, Bravo, Ridomil Gold MZ and Penncozeb for white blister control in Werribee, Victoria (2004/05)

Summary

A trial was conducted within a commercial broccoli crop in December 2004 - January 2005 at Werribee, Victoria, to evaluate the efficacy of fungicides for white blister (*A. candida*) control. The fungicides examined were azoxystrobin (Amistar), chlorothalonil (Bravo), and metalaxyl + mancozeb (Ridomil Gold MZ or Ridomil MZ). These fungicides were compared against mancozeb (Penncozeb). Fungicide treatments consisted of four sprays at 200 L water/ha applied at 33, 40, 47 and 55 days after broccoli seedlings were transplanted. The first spray application was approximately one week before initial flower heads formed or initial button stage. Broccoli plants were assessed for infections of top leaves on plants and head infections.

Most of the white blister and severity levels recorded were due to leaf infections, with very few head infections. Amistar was highly effective in reducing white blister, while Bravo and Penncozeb were not effective. Amistar applied at 0.5, 1.0 and 2.0 L reduced disease incidence and severity by 62% to 92% at 18 days after the fourth foliar application in comparison to levels in the untreated control. Two early Bravo applications followed by two Amistar or Ridomil MZ applications also did not reduce white blister incidence and severity. In contrast, two sprays of Amistar at 1.0 L followed by two sprays of Ridomil MZ reduced disease incidence and severity by 64% and 62%, respectively, in comparison to the untreated control. These findings indicated that systemic fungicides such as Amistar or Ridomil MZ must be applied early, at the first sign of infection at the pre-button stage, for effective disease control. Two early Bravo applications, followed by two Ridomil MZ, were the standard industry practice used by broccoli growers in Tasmania for white blister control in 2004 and 2005.

Aims

This study was conducted to identify effective fungicides, and their appropriate rates and application timings, for control of the pathogen *A.candida* (white blister) in broccoli.

Materials & Methods

Treatment List

No.	Treatment*	Product Rate (L or kg/ha)	Active Ingredient (ai/ha)	Application Schedule
1 & 2	Untreated control	Nil	Nil	Nil
3	4 x Bravo Weather Stik	1.8 L	1295 g chlorothalonil	4 applications at 7 day intervals. 1st spray at initial button stage.
4	4 x Amistar	0.5 L	125 g azoxystrobin	
5	4 x Amistar	1.0 L	250 g azoxystrobin	
6	4 x Amistar	2.0 L	500 g azoxystrobin	
7	2 x Amistar / 2 x Ridomil	1.0 L / 2.5 kg	250 g azoxystrobin / 40 g metalaxyl + 640 g mancozeb	
8	2 x Bravo / 2 x Amistar	1.8 L / 1.0L	-	
9	2 x Bravo / 2 x Ridomil	1.8 L / 2.5 kg	-	
10	4 x Penncozeb	2.2 kg	1650 g mancozeb	

Trial 1: Werribee, Victoria (2004/05)

Chronology of Events

Date	Days after planting (DAP)	Days after application (DAA)	Event
30/10/04	0	-	Seedlings planted.
02/12/04	33	0	1st foliar fungicide application, pre button crop stage.
09/12/04	40	7DAA1	2nd foliar fungicide application, button crop stage. Spray may have been severely compromised by a rainstorm not long after application.
16/12/04	47	7DAA2	3rd foliar fungicide application. Head size 10 - 15 mm; white blister first noted on plants.
24/12/04	55	8DAA3	4th foliar fungicide application. Head size 10 - 30 mm.
05/01/05	67	12DAA4	Disease assessment for white blister leaf and head infection.
11/01/05	73	18DAA4	Disease assessment for white blister leaf and head infection.

Results

Table 1.1 - White blister disease assessment on top leaves and broccoli heads

No.	Treatment*	Product Rate (L or kg/ha)	White blister[3]			
			67DAP (12DAA4)		73DAP (18DAA4)	
			Incidence[1]	Severity[2]	Incidence[1]	Severity[2]
1 & 2	Untreated control	Nil	2.0	3.8	3.9 b	5.2 b
10	4 x Penncozeb	2.2 kg	3.9	5.6	4.8 b	8.4 c
3	4 x Bravo Weather Stik	1.8 L	2.8	3.8	4.8 b	6.4 bc
8	2 x Bravo / 2 x Amistar	1.8 L / 1.0 L	3.1	4.4	4.8 b	6.2 bc
9	2 x Bravo / 2 x Ridomil	1.8 L / 2.5 kg	3.1	4.6	4.8 b	5.8 bc
7	2 x Amistar / 2 x Ridomil	1.0 L / 2.5 kg	1.4	2.0	1.4 a	2.0 a
4	4 x Amistar	0.5 L	1.1	1.4	1.4 a	2.0 a
5	4 x Amistar	1.0 L	0.6	0.8	1.4 a	2.0 a
6	4 x Amistar	2.0 L	1.4	2.0	0.3 a	0.4 a
p-value			0.095	0.084	0.003	0.001

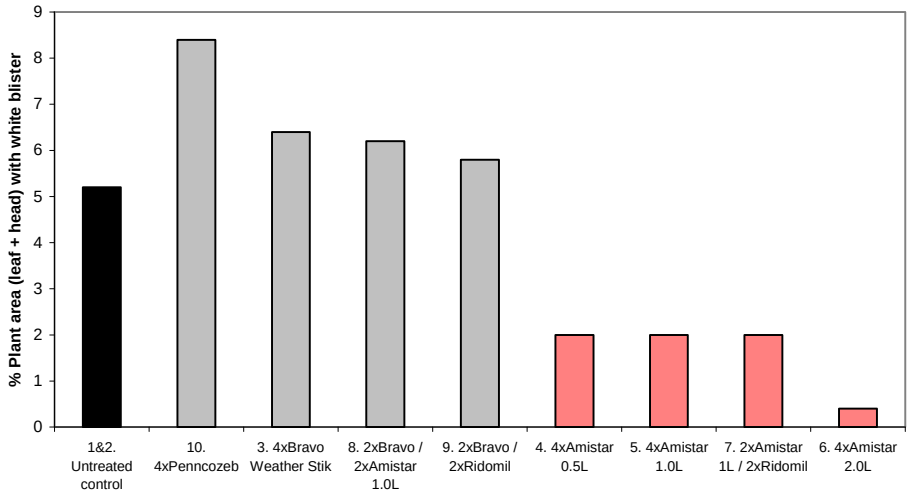
[1] % plants infected ; [2] % area of total leaf & head with white blister

[3] DAA = days after application number, DAP = days after planting
Means in the same column followed by the same letter do not differ significantly (P = 0.05) according to the Fisher's LSD test

Trial 1: Werribee, Victoria (2004/05)

Results (Cont.)

Figure 1.1 - Treatment effects on white blister severity (73 DAP, 18DAA4)



Discussion

- White blister incidence and disease severity (infected plant area) were recorded based on the presence of lesions over the top parts of the plant foliage. Most of the white blister incidence and severity recorded was due to leaf infections, with very few flower head infections. The disease incidences were relatively low, ranging from 0.3% to 4.8%.

- There were significant differences between treatments on the white blister incidence and severity at 73DAP or 18DAA4 ($P < 0.05$) (Table 1.1).

- Amistar SC applied at 0.5, 1.0 and 2.0 L (Treatments 4, 5 and 6) significantly reduced disease incidence by 64% to 92% and disease severity by 62% to 92% at 18DAA4, in comparison to levels in the untreated control. An alternate fungicide program of two sprays of Amistar SC at 1.0 L followed by two sprays of Ridomil MZ (Treatment 7) reduced disease incidence and severity by 64% and 62% respectively, in comparison to the untreated control.

- There were no significant differences in disease incidence and severity between the Amistar SC rates or the alternate fungicide program of 2 x Amistar / 2 x Ridomil MZ. The disease was too low to enable comparisons of the different Amistar SC rates.

- Bravo or Penncozeb, applied in four applications, did not reduce white blister incidence or severity. Penncozeb treated plants also had higher disease severity than the untreated control plants, indicating that the treatment may predispose plants to more severe infections.

- Two early Bravo applications followed by two Amistar SC or Ridomil MZ applications did not reduce disease incidence or severity. Two early Bravo applications, followed by two Ridomil MZ, were the standard industry practice, as recommended by farm consultants and field officers to broccoli growers, in Tasmania in 2004 and 2005. This finding indicates that Amistar SC or Ridomil MZ sprays were less effective when applied later, long after the onset of the disease. Amistar SC or Ridomil MZ must be applied early, at the first sign of infection in the crop at the pre-button stage, for effective disease control.

Trial 2: Evaluation of alternate fungicide application programs with Amistar, Bravo and Ridomil Gold MZ for white blister control at Werribee, Victoria (2004/05)

Summary

A trial was conducted within a commercial broccoli crop from December 2004 - January 2005 at Werribee, Victoria, to evaluate the timing of alternate fungicide application programs for white blister (*Albugo candida*) control. The fungicides in this study included azoxystrobin (Amistar), chlorothalonil (Bravo), and metalaxyl + mancozeb (Ridomil Gold MZ or Ridomil MZ). These fungicides were compared against Mancozeb. Fungicide treatments consisted of early transplant application at 2 days after transplanting with 956 L water/ha, and four foliar sprays at 200 L water/ha applied at 33, 40, 47 and 55 days after transplanting. The first foliar spray application was approximately one week before initial flower heads formed or initial button stage. White blister incidence and severity were recorded based on the presence of lesions over the top parts of the plant foliage and broccoli heads.

There was no significant disease control by all fungicide treatments in the trial. The lack of disease control appeared to be due to non-effective fungicides such as Bravo and Mancozeb, as well as the use of two early Bravo foliar applications in all the fungicide treatments. The early transplant treatments, applied at 2 days after transplanting, did not appear to contribute to any significant disease control, due to constant disease pressure throughout the trial and poor disease control by the follow up foliar fungicide applications. Following the outcomes of this study and those of Trial #1, which showed that Bravo and Mancozeb did not prevent white blister infections, broccoli growers stopped using these products for white blister control.

Aims

This study was conducted to compare the efficacies of Amistar and Ridomil Gold MZ for white blister control, when they are applied following two early foliar applications of Bravo at first sign of leaf infections, at about button crop stage. Two early Bravo applications, followed by two Ridomil MZ, were standard industry practice, as recommended by farm consultants and field officers to broccoli growers, in Tasmania in 2004 and 2005. This study was conducted at the same time as Trial #1.

Materials & Methods

Treatment List

No.	Treatment Early transplant / Foliar spray	Early transplant application (Product Rate/ha)	Foliar spray at button stage (Product Rate/ha)
1&2	Untreated control	Untreated control	Untreated control
3	- / B B A A	Nil	2 x Bravo (1.8 L) 2 x Amistar (1.0 L)
4	- / B B R R	Nil	2 x Bravo (1.8 L) 2 x Ridomil (2.5 kg)
5	- / B B B B	Nil	4 x Bravo (1.8 L)
6	- / M M M M	Nil	4 x Mancozeb (2.5 kg)
7	A / B B A A	Amistar (100 mL/100 L)	2 x Bravo (1.8 L) 2 x Amistar (1.0 L)
8	A / B B R R	Amistar (100 mL/100 L)	2 x Bravo (1.8 L) 2 x Ridomil (2.5 kg)
9	R / B B A A	Ridomil (250 g/100 L)	2 x Bravo (1.8 L) 2 x Amistar (1.0 L)
10	R / B B R R	Ridomil (250 g/100 L)	2 x Bravo (1.8 L) 2 x Ridomil (2.5 kg)

A = Amistar ; B = Bravo ; R = Ridomil MZ; M = Mancozeb
Transplant application: Applied with 956 L water using a watering can
Foliar sprays: 1st spray at first sign of infection in crop, just before and during button stage, with 2 - 4 foliar applications at 7 day intervals with a backpack air-pressurized sprayer at 200 L water/ha and 250 kPa.

Trial 2: Werribee, Victoria (2004/05)

Chronology of Events

Date	Days After Planting (DAP)	Days after Application (DAA)	EVENT
30/10/04	0	-	Trial planted.
01/11/04	2	-	Early transplant application applied to Treatments 7 - 10.
02/12/04	33	0DAA1	1st foliar fungicide application, pre button crop stage.
09/12/04	40	7DAA1	2nd foliar fungicide application, button crop stage.
16/12/04	47	7DAA2	3rd foliar fungicide application. Head size 10 – 15 mm; white blister first noted on plants.
24/12/04	55	8DAA3	4th foliar fungicide application. Head size 10 – 30 mm.
24/12/04	55	8DAA3	Disease assessment for white blister leaf infection.
02/01/05	64	9DAA4	Disease assessment for white blister leaf and head infection.
05/01/05	67	12DAA4	Disease assessment for white blister leaf and head infection.
11/01/05	73	18DAA4	Disease assessment for white blister leaf and head infection.

Results

Table 2.1 - White blister disease assessment on top leaves and broccoli heads

No.	Treatment (Transplant / Foliar sprays)	White blister[3]			
		67DAP (12DAA4)		73DAP (18DAA4)	
		Incidence[1]	Severity[2]	Incidence[1]	Severity[2]
1 & 2	Untreated control	2.4	3.4	3.4	4.6
3	- / B B A A	3.6	5.2	4.2	6.0
4	- / B B R R	1.7	4.4	4.2	5.8
5	- / B B B B	3.1	4.2	4.5	6.2
6	- / M M M M	3.4	4.8	4.5	6.2
7	A / B B A A	1.1	1.6	2.8	4.0
8	A / B B R R	2.0	2.8	5.3	7.6
9	R / B B A A	2.2	3.2	3.4	4.8
10	R / B B R R	2.5	3.6	3.6	5.2
p-value		0.49	0.67	0.88	0.88

[1] % plants infected ; [2] % area of total leaf & head with white blister

[3] DAA = days after foliar application number, DAP = days after planting

Trial 2: Werribee, Victoria (2004/05)

Discussion

- White blister incidence and severity were recorded based on the presence of lesions over the top parts of the plant foliage and broccoli heads. Most of the white blister and severity levels recorded were due to leaf infections, with very few head infections.

- There were negligible levels of disease incidence with the first two disease assessments at 55DAP and 64DAP. At 67DAP and 73DAP, the disease incidence and severity were also relatively low, and there were no significant differences between all treatments on the white blister incidence and severity (p-value > 0.05) (Table 2.1).

- The lack of significant disease control in this trial appeared to be due to ineffective fungicides such as Bravo and Mancozeb, as well as the use of two early Bravo foliar applications in all the fungicide treatments. The two early Bravo foliar applications were used in this trial because Bravo was believed to have activity against *A. candida* and was used as an industry standard for white blister control in Tasmania in 2004 and early 2005.

- In Trial 1, the two early Bravo applications followed by two Amistar or Ridomil MZ applications did not reduce white blister infections. The results in Trial 1 as well as this trial also indicated that at least two early foliar sprays of Amistar, at the first sign of infection in the crop at the pre-button stage, was essential for effective disease control.

- The early transplant treatments applied at 2DAP (Treatments 7-10) did not appear to contribute to any significant disease control. This may be due to constant disease pressure throughout the crop period in a high disease pressure area and poor disease control by the follow up foliar Bravo fungicide applications.

Trial 3: Timing and spray programs with Amistar, Ridomil Gold MZ and copper fungicides for white blister control at Forth, Tasmania (2005)

Summary

A trial was conducted within a commercial broccoli crop from February - April 2005 at Forth, Tasmania, to evaluate the timing and spray program of suitable fungicides for white blister (*Albugo candida*) control. The fungicides examined were azoxystrobin (Amistar), metalaxyl + mancozeb (Ridomil Gold MZ or Ridomil MZ) and Copper oxychloride. Fungicide treatments consisted of early application at 31 days after planting with 944 L water/ha and/or 2-4 foliar sprays at 50, 57, 64 and 71 days after planting. The first foliar spray application was just before the initial button stage (pre-button stage), with 400 L water/ha.

At harvest, the disease incidence on leaves was relatively low, ranging from 0% to 8% plants with leaf infections. There was no head infection in the trial. Under low disease pressure, only one early treatment application at 31DAP, Ridomil MZ, was shown to be effective in reducing plant infection by 88% in comparison to levels in the untreated control. The early Amistar application at 31DAP, however, had no effect on white blister. All treatments with two or four foliar sprays of Amistar or Ridomil MZ gave effective disease control, reducing plant infection by approximately 58% to 100% in comparison to levels in the untreated control. Ridomil MZ appeared to be more effective than Amistar in this trial.

Aims

This study was conducted to evaluate the timing and spray program of Amistar and Ridomil Gold MZ for white blister control.

Materials & Methods

Treatment List

No.	Treatment	Early application at 33 days after transplanting (Product Rate/ha)	Foliar spray at button stage (Product Rate/ha)
1&2		Untreated control	Untreated control
3	- / A A A A	Nil	4 x Amistar (1.0 L)
4	- / R R R R	Nil	4 x Ridomil MZ (2.5 kg)
5	A / -	Amistar (100 mL/100 L)	Nil
6	R / -	Ridomil (250 g/100 L)	Nil
7	A / R R	Amistar (100 mL/100 L)	2 x Ridomil MZ (2.5 kg)
8	A / A A	Amistar (100 mL/100 L)	2 x Amistar (1.0 L)
9	A / A A R R	Amistar (100 mL/100 L)	2 x Amistar (1.0 L) 2 x Ridomil MZ (2.5 kg)
10	A / R C R C	Amistar (100 mL/100 L)	Ridomil MZ (2.5 kg) alternated with copper oxychloride (2.5 kg)

A = Amistar 250 SC (product rate at 1L/ha)
R = Ridomil Gold MZ (product rate at 2.5 kg/ha)
C = Copper oxychloride (product rate at 2.5 kg/ha)

Early application: Applied with 944 L water using a knapsack sprayer fitted with drift guard nozzles.
Foliar sprays: Sprays applied with 400 L water/ha and 400 kPa, with 2 to 4 sprays at 7-day intervals. First spray applied at the first sign of infection in the crop and just before the initial button stage.

Trial 3: Forth, Tasmania (2005)

Chronology of Events

Date	Days After Planting (DAP)	Days After Application (DAA)	Event
07/02/05	0	-	Trial planted.
09/03/05	30	-	Trial pegged.
10/03/05	31	-	Early treatments applied.
15/03/05	36	-	Vegetative crop stage.
21/03/05	42	-	Two plants noticed with white blister near the trial.
29/03/05	50	0	1st foliar fungicide application, plants are not yet at button stage.
05/04/05	57	7DAA1	2nd foliar fungicide application.
12/04/05	64	7DAA2	3rd foliar fungicide application.
19/04/05	71	7DAA3	4th foliar fungicide application.
25/04/05	77	6DAA4	First commercial harvest outside trial area.
26/04/05	78	7DAA4	Disease assessment for white blister on leaves for replicates 1-3.
27/04/05	79	8DAA4	Disease assessment for white blister on leaves for replicates 4-5.
29/04/05	81	10DAA4	Disease assessment for white blister on heads.

Photographs

Crop stage at the early fungicide applications at 31DAP (Photograph 3.1) and at the 1st foliar applications at 50DAP (Photograph 3.2)

3.1

3.2

Trial 3: Forth, Tasmania (2005)

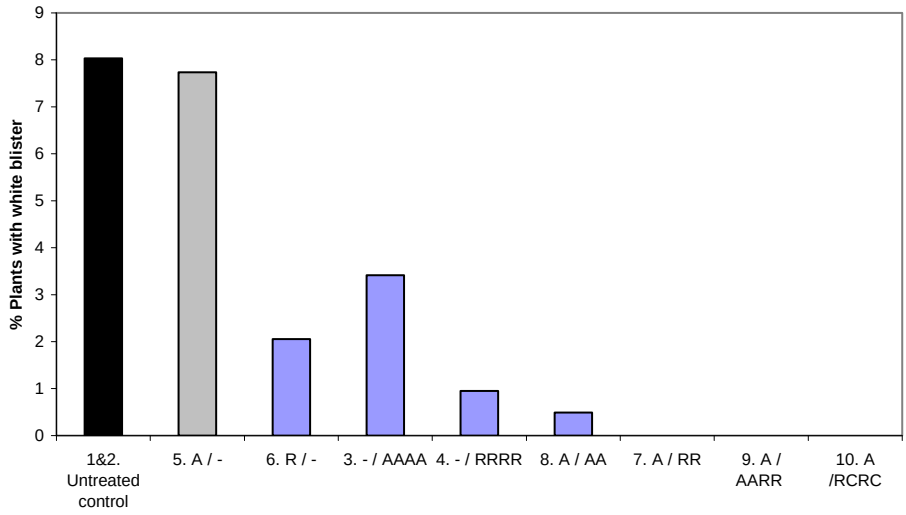
Results

Table 3.1 - White blister disease assessment on leaves and broccoli heads, 78-81DAP

No.	Treatment* Early application / Foliar sprays at button stage	% Plants with white blister on leaves** 78-79DAP	% Broccoli heads with white blister 81DAP
1 & 2	Untreated control	8.0 d	0
5	A / -	7.7 cd	0
6	R / -	2.1 ab	0
3	- / A A A A	3.4 bc	0
4	- / R R R R	1.0 ab	0
8	A / A A	0.5 ab	0
7	A / R R	0.0 a	0
9	A / A A R R	0.0 a	0
10	A / R C R C	0.0 a	0
p-value		< 0.0001	-

* A = Amistar SC; R = Ridomil Gold MZ; C = Copper oxychloride
** Means in the same column followed by the same letter do not differ significantly (P = 0.05) according to the Fisher's LSD test
DAP = days after planting

Figure 3.1 - White blister disease assessment on all plant leaves, 78-79DAP



Trial 3: Forth, Tasmania (2005)

Discussion

- White blister incidence on leaves was recorded based on the presence or absence of lesions on all plant leaves. At 78-79DAP, the disease incidence on leaves was relatively low, ranging from 0% to 8% plants with leaf infections. Disease severity was considered mild, with less than 1% leaf area infected. There was no head infection in the crop at harvest.

- Except for the early Amistar treatment (Treatment 5), all fungicide treatments significantly reduced the percentage of plants with leaf infections in comparison to the untreated control at 78-79DAP ($P < 0.0001$) (Table 3.1, Figure 3.1).

- For early treatment application, at 31 days after transplanting, Ridomil MZ (Treatment 6) reduced plant infection by 88% in comparison to levels in the untreated control. Early Amistar treatment had no effect on the disease. The differences between the fungicides might be affected by Amistar sensitivity to UV light and low plant canopy on small plants.

- All foliar spray treatments applied at pre-button stage gave effective disease control, reducing plant infection by approximately 58% to 100% at 7DAA4, in comparison to levels in the untreated control. Although not significant, Ridomil MZ appeared to be more effective than Amistar in four foliar spray applications.

- Fungicide spray programs of early Amistar applications, at 31 days after planting, followed by spray treatments at pre-button stage with 2 x Amistar, 2 x Ridomil MZ, 2 x Amistar & 2 x Ridomil MZ, and Ridomil MZ alternated with copper oxychloride, also gave effective control of white blister, reducing the disease severity by approximately 94% to 100% in comparison to the untreated control.

Trial 4: Fungicide timing and spray program with Amistar, Ridomil Gold MZ and Ridomil Gold Plus for white blister control at Werribee, Victoria (2005)

Summary

A trial was conducted within a commercial broccoli crop from September - November 2005 at Werribee South, Victoria, to evaluate the timing and spray program of suitable fungicides for white blister (*Albugo candida*) control. The fungicides examined were azoxystrobin (Amistar SC), metalaxyl-M + mancozeb (Ridomil Gold MZ or Ridomil MZ) and metalaxyl-M + copper hydroxide (Ridomil Gold Plus or Ridomil Plus). Fungicide treatments consisted of early transplant application at 14 days after planting and/or four foliar sprays at 63, 71, 78 and 87 days after broccoli seedlings were planted. The first foliar spray was applied when initial flower heads formed or initial button stage. All fungicide treatments were applied with 385 L water/ha and with a non-ionic surfactant Activator at 125 mL/100 L. Broccoli plants were assessed for leaf and head infections at crop maturity.

Very high incidences of leaf and head infections were recorded in the untreated control plots, with 98% infected plants at 63 days after planting and before the foliar spray applications, and 73% infected heads at 91 days after planting. Under the high disease pressure, only one early transplant application of Ridomil MZ at 14 days after planting was inadequate for control of white blisters on broccoli heads. At least two foliar applications of Amistar and Ridomil MZ at the initial button stage were necessary for effective head infection control. In alternate spray programs, treatments consisting of one or two Amistar sprays at the initial button stage generally gave better head infection control compared to Ridomil MZ sprays, indicating that there might be populations of metalaxyl resistant fungal strains in the trial area.

Aims

This study was conducted to determine the optimum spray programs with Amistar and Ridomil Gold MZ for white blister control. Ridomil Gold MZ, which contains metalaxyl + mancozeb, was also compared against Ridomil Gold Plus, which contains metalaxyl + copper hydroxide.

Materials & Methods

Treatment List

No.	Treatment (transplant / foliar sprays)	Early transplant application	Foliar application (just before and after button stage)
1&2	Untreated control	Nil	Nil
3	R / -	R	-
4	R / A R	R	A R
5	R / R A	R	R A
6	R / R R A A	R	R R A A
7	R / A A R R	R	A A R R
8	- / A A A A	-	A A A A
9	- / R R R R	-	R R R R
10	- / P P P P	-	P P P P

A = Amistar SC applied at 1 L/ha
R = Ridomil Gold MZ applied at 2.5 kg/ha
P = Ridomil Gold Plus applied at 2.0 kg/ha

Transplant application: Applied as high volume spray application 14 days after transplanting.
Foliar sprays: Sprays applied with 385 L water/ha and 150 kPa, with 2 to 4 sprays at 7-day intervals. 1st spray applied at the first sign of infection in crop, at initial button stage.
Spray surfactant: Activator, a non-ionic surfactant, was added to all fungicide spray applications at 125 ml/100 L.

Trial 4: Werribee, Victoria (2005)

Chronology of Events

Date	Days After Planting (DAP)	Days After Application (DAA)	Event
02/08/05	0		Trial planted.
16/08/05	14		Early transplant application on to 2-3 true leaf transplants.
04/10/05	63	0	1st foliar fungicide application, initial button stage.
04/10/05	63	0	Assessment for white blister incidence and severity on leaves.
12/10/05	71	8DAA1	2nd foliar fungicide application, immature heads of 5 - 10 mm.
19/10/05	78	7DAA2	3rd foliar fungicide application, immature heads of 20 - 40 mm.
26/10/05	85	7DAA3	4th foliar fungicide application, immature heads of 50 - 130 mm.
26/10/05	85	7DAA3	1st disease assessment for head infections. First harvest of heads by grower outside trial area.
30/10/05	89	4DAA4	2nd disease assessment for head infections.
01/11/05	91	6DAA4	3rd disease assessment for head infections.

Photographs

Size of transplants at the early transplant applications at 14DAP (Photograph 4.1) and the initial button crop stage at the 1st foliar application at 63DAP (Photograph 4.2)

4.1

4.2

Trial 4: Werribee, Victoria (2005)

Results

Table 4.1 - White blister disease assessment for leaf infections, 63DAP

No.	Treatment (transplant / foliar sprays)	Incidence % Plants with white blister	Severity on leaves % leaf area infected
1 & 2	Untreated control	97.5	1.8
3	R / -	100.0	2.6
4	R / A R	97.2	2.4
5	R / R A	96.8	2.0
6	R / R R A A	100.0	2.0
7	R / A A R R	97.2	1.4
8	- / A A A A	99.2	2.4
9	- / R R R R	96.8	2.4
10	- / P P P P	96.8	1.6
p-value		0.308	-

DAP = Days after planting

Table 4.2 - White blister disease assessment for head infections, 85-91DAP*

No.	Treatment (transplant / foliar sprays)	% Broccoli heads with white blister**		
		85DAP	89DAP	91DAP
1 & 2	Untreated control	25.3 b	54.6 b	73.0 c
3	R / -	2.7 a	62.3 b	81.0 c
4	R / A R	0.0 a	1.6 a	1.2 a
5	R / R A	0.0 a	10.9 a	13.6 ab
6	R / R R A A	0.0 a	3.4 a	6.6 ab
7	R / A A R R	0.0 a	0.0 a	0.8 a
8	- / A A A A	0.0 a	0.0 a	0.8 a
9	- / R R R R	0.7 a	10.1 a	18.4 b
10	- / P P P P	0.4 a	7.1 a	11.4 ab
p-value		< 0.0001	< 0.0001	< 0.0001

* DAP = Days after planting
** Means in the same column followed by the same letter do not differ significantly (P = 0.05) according to the Fisher's LSD test

Trial 4: Werribee, Victoria (2005)

Figures 4.1a & 4.1b - White blister incidence on broccoli heads, 91DAP

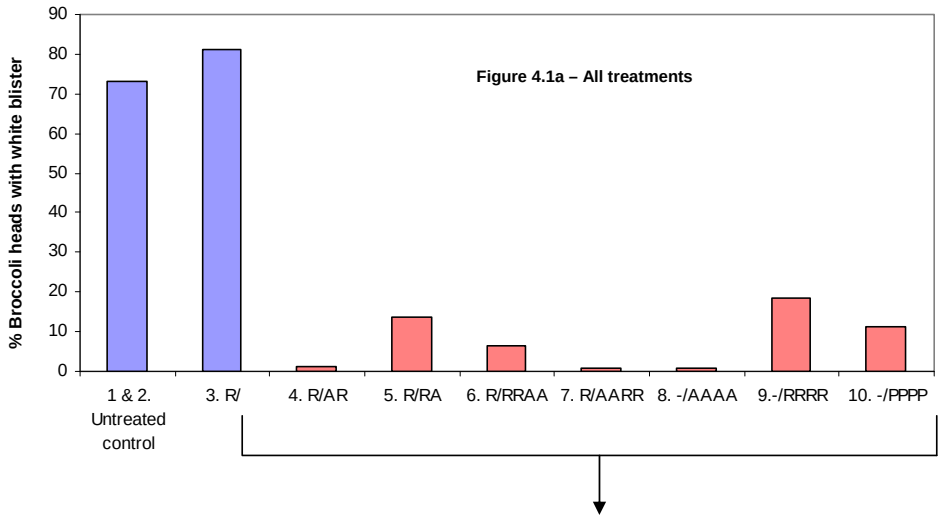
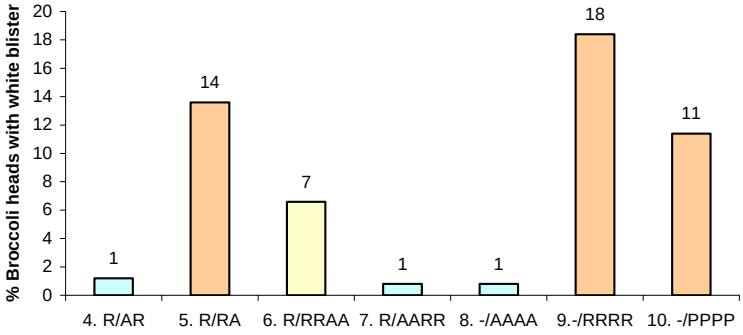


Figure 4.1b – Excludes Treatments 1-3



Trial 4: Werribee, Victoria (2005)

Discussion

Leaf infection

- White blister incidence on leaves was recorded at the beginning of the foliar spray applications at the initial button stage at 63DAP. The disease incidence on leaves was very high, where almost all plants had infected leaves.

- There was no significant treatment effect on the disease incidence (P = 0.308) (Table 4.1). The leaf disease severity ranged from 1.4% to 2.6% leaf area infected.

- The early transplant applications with Ridomil MZ at 14DAP did not reduce the disease incidence on leaves at 63DAP. This lack of disease control might be related to the poor efficacy of Ridomil MZ. Reduced or loss of efficacy by Ridomil MZ has been noted in several farms in Werribee South, indicating that there may have been a selection of fungal populations that are more tolerant to metalaxyl due to its previous use at the farm site.

Head infection

- The levels of head infection in the untreated control plots were very high, with approximately 73% infected heads (Table 4.2, Figure 4.1). At 85DAP, all fungicide treatments significantly reduced the percentage of broccoli heads with white blister in comparison to the untreated control (Table 4.2). One early transplant application of Ridomil MZ (Treatment 3) reduced head infections by 89% compared to levels in the untreated control. All other fungicide treatments reduced head infections by 97% to 100% compared to levels in the untreated control.

- At 89DAP, all fungicide treatments except for the one early transplant application of Ridomil MZ (Treatment 3) significantly reduced the percentage of broccoli heads with white blister in comparison to the untreated control (Table 4.2, Figure 4.1a). The level of head infection in Treatment 3 was similar to that of the untreated control. There was a sharp increase in the percentage of infected heads in Treatment 3, from 2.7% at 71 days after the early fungicide application to 62.3% at 75 days after its application. This indicated that the interval between the transplant fungicide treatment and head maturity might have been too long for effective control of head infections.

- At 91DAP, all fungicide treatments except for Treatment 3 significantly reduced the percentage of broccoli heads with white blister in comparison to the untreated control (Table 4.2, Figure 4.1a). Treatments consisting of one or two Amistar sprays at the initial button stage (Treatments 4, 7, 8) generally gave better head infection control when compared to Ridomil MZ sprays (Treatments 5, 6, 9) (Figure 4.1b).

- The lower efficacy shown by the treatments containing early Ridomil MZ sprays at the initial button stage at 91DAP compared to Amistar might be due to development or selection of fungal strains that are resistant to metalaxyl-M. The practice of consecutive and multiple plantings of broccoli crops throughout the year since the disease appeared in Werribee in early 2002, as well as the early reliance and overuse of Ridomil MZ, is likely to favour the selection of fungal strains that are resistant to metalaxyl-M in the region.

Trial 5: Evaluation of Amistar rates for white blister control at Werribee, Victoria (2006)

Summary

A trial was conducted in Werribee, Victoria, in 2006, to determine the optimum rate of the fungicide Amistar 250 SC for crop safety, and for efficacy on white blister (*Albugo candida*) on broccoli cv. Legacy. The rates of Amistar 250 SC were 62.5, 125, 250 and 500 g ai/ha. All fungicides were foliar applied four times on a 7-10 day application schedule beginning at the button crop stage. All fungicide treatments were applied with 385 L water/ha.

At the commencement of the trial, 100% of plants across the trial site were infected with white blister on the lower leaves; with an average of 5% of the lower leaf area infected. However, the dry and cold conditions throughout the trial period were unsuitable for the spread of the disease onto upper leaves or broccoli heads, resulting in very low disease incidence. All fungicide treatments in the trial were shown to be effective in preventing upper leaf infections and completely prevent head infections. However, no comparisons could be made between the different Amistar rates due to low white blister incidence, as a result of unfavourable disease conditions.

Aims

This study was conducted to determine the optimum application rates of azoxystrobin (Amistar SC) for crop safety and efficacy on white blister (*Albugo candida*) in broccoli.

Materials and Methods

Treatment List

No.	Treatment	Active ingredient rate (g ai/ha)	Product Rate /ha	Application Schedule
1	Untreated control	-	-	N/A
2	Amistar 250 SC	62.5	0.25 L	Foliar applied four times, on a 7-10 day application schedule beginning at button stage
3	Amistar 250 SC	125	0.50 L	
4	Amistar 250 SC	250	1.00 L	
5	Amistar 250 SC	500	2.00 L	

Trial 5: Werribee, Victoria (2006)

Chronology of Events

Date	Days after planting (DAP)	Days after foliar application (DAFA)	Crop stage	Event
05/04/06	0		Transplants	Crop planted.
06/06/06	62	0DAFA1	5 mm heads	1st foliar fungicide application.
13/06/06	69	7DAFA1	12 mm heads	2nd foliar fungicide application.
20/06/06	76	7DAFA2	15 to 20 mm heads	3rd foliar fungicide application.
30/06/06	86	10DAFA3	25 to 50 mm heads	4th foliar fungicide application.
06/06/06 30/06/06 06/07/06 12/07/06 19/07/06 23/07/06	62 86 92 98 105 109	0DAFA1 10DAFA3 6DAFA4 12DAFA4 19DAFA4 23DAFA4		Leaf disease assessments.
30/06/06 06/07/06 12/07/06 19/07/06 23/07/06	86 92 98 105 109	10DAFA3 6DAFA4 12DAFA4 19DAFA4 23DAFA4		Head disease assessments.

Trial 5: Werribee, Victoria (2006)

Results

Table 5.1 - White blister incidence on lower leaves at the first fungicide spray application

No.	Treatment	Active ingredient rate (g ai/ha)	Product Rate (L/ha)	Incidence of leaf infection (% of plants with lower leaves infected with white blister)
				06/06/06 0DAFA1
1	Untreated control	-	-	100
2	Amistar 250 SC	62.5	0.25	100
3	Amistar 250 SC	125	0.50	100
4	Amistar 250 SC	250	1.0	100
5	Amistar 250 SC	500	2.0	100

DAFA = Days after foliar application number

Table 5.2 - White blister incidence on upper leaves after 3 and 4 fungicide spray applications

No.	Treatment	Active ingredient rate (g ai/ha)	Product Rate (L/ha)	Incidence of leaf infection (% plants with top leaves infected with white blister)				
				30/06/06 10DAFA3	06/07/06 6DAFA4	12/07/06 12DAFA4	19/07/06 19DAFA4	23/07/06 23DAFA4
1	Untreated control	-	-	0.3	0.0	0.0	0.3	0.3
2	Amistar 250 SC	62.5	0.25	0.0	0.0	0.0	0.0	0.0
3	Amistar 250 SC	125	0.50	0.3	0.0	0.0	0.0	0.0
4	Amistar 250 SC	250	1.0	0.0	0.0	0.0	0.0	0.0
5	Amistar 250 SC	500	2.0	0.0	0.0	0.0	0.0	0.0
p-value				0.740	N/A	N/A	0.443	0.443

DAFA = Days after foliar application number
N/A = Not applicable due to all means being the same.

Table 5.3 - White blister incidence on broccoli heads after 4 fungicide spray applications

No.	Treatment	Active ingredient rate (g ai/ha)	Product Rate (L/ha)	Head infections (% broccoli heads assessed)			
				06/07/06 6DAFA4	12/07/06 12DAFA4	19/07/06 19DAFA4	23/07/06 23DAFA4
1	Untreated control	-	-	0.0	0.0	2.7a	6.4a
2	Amistar 250 SC	62.5	0.25	0.0	0.0	0.0 b	0.0 b
3	Amistar 250 SC	125	0.50	0.0	0.0	0.0 b	0.0 b
4	Amistar 250 SC	250	1.0	0.0	0.0	0.0 b	0.0 b
5	Amistar 250 SC	500	2.0	0.0	0.0	0.0 b	0.0 b
p-value				N/A	N/A	0.0057	0.0025

DAFA = Days after foliar application number
Means within columns followed by the same letter are not significantly different at the 5% level according to LSD test.

Trial 5: Werribee, Victoria (2006)

Discussion

- At the commencement of the trial, 100% of broccoli plants across the trial site were infected with white blister (*Albugo candida*) on the lower leaves; with an average of 5% of lower leaf area infected. However, dry and cold conditions throughout the trial period were unsuitable for the spread of the disease on to new top leaves. At the first assessment timing, 10 days after the third foliar application (10DAFA3), less than 1% of broccoli plants in the untreated control had top leaves infected with white blister.

- Four disease assessments were conducted after the fourth and final fungicide application; there were no more than 0.3% of broccoli in the untreated control with top leaves infected with white blister at any of these assessment timings.

- White blister incidence on broccoli heads was relatively low at 2.7% and 6.4% of heads infected in the untreated control at 19DAFA4 and 23DAFA4, respectively. These percentages were significantly higher than all fungicide treatments, which had no disease present on heads at either of the two assessment dates.

- No comparisons could be made on the level of disease control between the different Amistar rates, because of the low disease incidence in the crop.

- Crop safety was checked for all treatments at each assessment date; all fungicide treatments were safe to the crop.

Trial 6: Evaluation of Amistar rates for white blister control at Harford, Tasmania (2007)

Summary

A trial was conducted at Harford, Tasmania, in 2007, to determine the optimum rate of the fungicide Amistar 250 SC for efficacy on white blister (*Albugo candida*) on broccoli cv. Shamrock. Amistar SC was also compared against Ridomil Gold MZ, Ridomil Gold Plus and Copper oxychloride. The product rates of Amistar SC were 0.25, 0.5, 1.0 and 2.0 L/ha (62.5, 125, 250 and 500 g ai/ha), Ridomil Gold MZ at 2.5 kg/ha and Ridomil Gold Plus 2.2 kg/ha. All fungicides were applied in four foliar applications on a 6-9 day application schedule beginning at the button initiation crop stage, with approximately 400 L water/ha.

At the commencement of the trial, white blister was noted on the lower leaves of approximately 80% of the plants across the trial site. At harvest, there were high levels of white blister incidence and severity on new top leaves on the untreated control plants. There were obvious differences between treatments in white blister incidence and severity on the new and fully expanded top leaves that had formed since the first fungicide application. With the untreated control, there were 98% plants infected, 87% top leaves infected and a maximum leaf coverage severity rating of 5.

All fungicide treatments with Amistar SC, Ridomil Gold MZ, Ridomil Gold Plus and Copper oxychloride substantially reduced the white blister incidence on the top leaves by 29% to 96% compared to the untreated control. However, the greatest differences in disease control by the fungicide treatments were in the reduction in the severity of the leaf infections, reducing the proportion of top leaves infections by 72% to 99% compared to the untreated control. They also reduced infected leaf coverage severity from a maximum of 5 in the untreated control to a minimum of 1.

An increase in the rates of Amistar SC resulted in a significant decrease in the leaf infection incidence and severity. Amistar SC applied at the highest rate of 250 and 500 g ai/ha gave the best disease control. At the lower rates of 62.5 and 125 g ai/ha, it also gave relatively effective disease control. Amistar SC at 125, 250 and 500 g ai/ha were shown to be more effective in reducing white blister infections on leaves than Ridomil Gold MZ, Ridomil Gold Plus and Copper oxychloride. Ridomil Gold MZ, Ridomil Gold Plus and Copper oxychloride gave similar levels of white blister control on leaves.

There were little or no broccoli head infections in the crop at harvest, and therefore no comparisons could be made between the different fungicide treatments on head infections. All fungicide treatments were safe to the crop.

Trial 6: Harford, Tasmania (2007)

Aims

This trial was conducted primarily to determine the optimum application rates of azoxystrobin (Amistar SC) for crop safety and efficacy on white blister (*Albugo candida*) in broccoli. This study also compares the efficacies of Amistar SC, Ridomil Gold MZ and Ridomil Gold Plus for white blister control.

Materials & Methods

Treatment List

No.	Treatment	Active ingredient rate (g ai/ha)	Product Rate /ha	Application Schedule
1	Untreated control	-	-	N/A
2	Untreated control	-	-	N/A
3	Amistar 250 SC	62.5	0.25 L	Four spray applications at 6-9 day intervals with 398 - 425 L water/ha. First spray just before button stage.
4	Amistar 250 SC	125	0.50 L	
5	Amistar 250 SC	250	1.00 L	
6	Amistar 250 SC	500	2.00 L	
7	Ridomil Gold MZ	1600 + 100	2.5 kg	
8	Ridomil Gold Plus	1320 + 110	2.2 kg	
9	Copper oxychloride	1250	2.5 kg	

Agral, a non-ionic surfactant was applied at as a spray adjuvant for all fungicide treatments

Chronology of Events

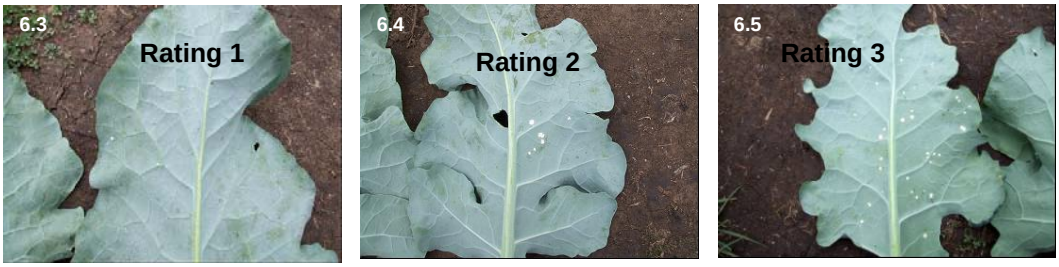
Date	Days after planting (DAP)	Days after foliar application (DAA)	Crop stage	Event
24/01/07	0		Seedlings	Broccoli seedlings (cv Shamrock) transplanted
01/02/07	8		Vegetative	Trial plots marked. Soil and air temperature and soil moisture sensors installed. 74% of plants have white blister on lower leaves.
09/03/07	44	0DAA1	Vegetative - head initiation	1st foliar fungicide application. Leaf wetness sensor installed.
14/03/07	49	5DAA1		Pirimor and Success insecticides applied.
15/03/07	50	6DAA1	Vegetative - head initiation	2nd foliar fungicide application.
22/03/07	57	7DAA2	Vegetative - head initiation	3rd foliar fungicide application.
31/03/07	66	9DAA3	Button stage to early head (~19 mm wide)	4th foliar fungicide application.
17/04/07	83	17DAA4	Early to matured heads	1st disease assessments for leaf infections.
20/04/07	86	20DAA4	Early to matured heads	2nd disease assessments for broccoli head infections.
23/04/07	89	23DAA4	Early to matured heads	3rd disease assessments for broccoli head infections.

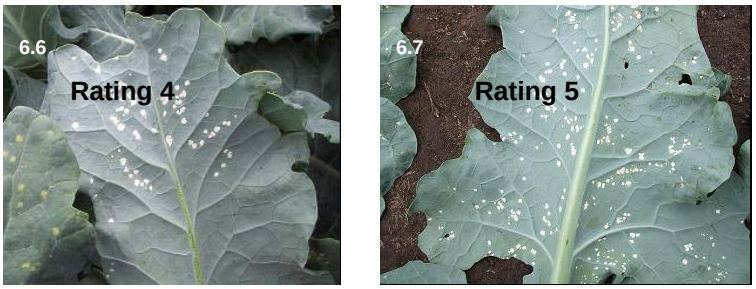
Trial 6: Harford, Tasmania (2007)

Photographs

The crop at the 1st foliar fungicide application stage (Photograph 6.1) and at the 4th foliar fungicide application (Photograph 6.2)

Disease severity rating based on percentage leaf coverage by white blisters (Photographs 6.3-6.7)





Trial 6: Harford, Tasmania (2007)

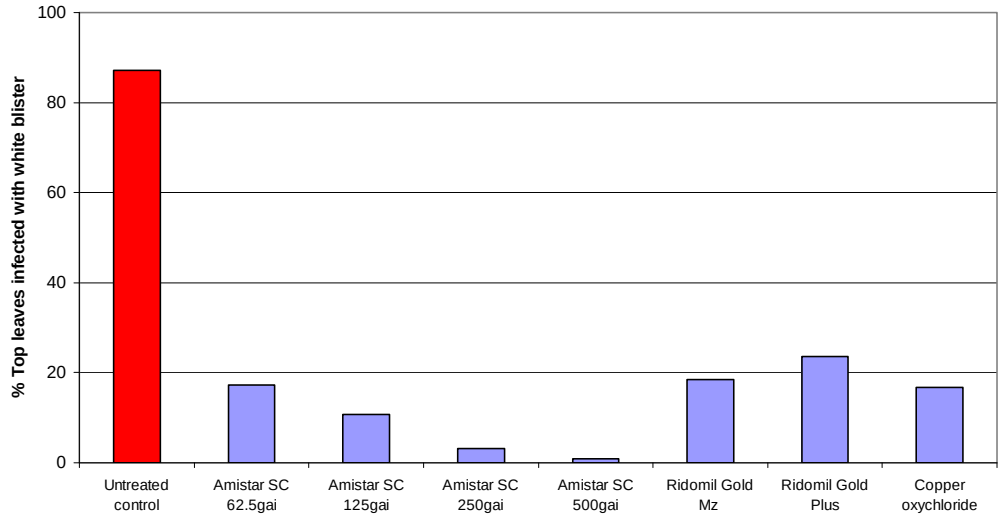
Results

Table 6.1 - White blister on top leaves after four fungicide applications (83DAP, 17DAA4)

No.	Treatment	Active ingredient rate (g ai/ha)	Product Rate	White blister infections on the top five fully expanded leaves		
				Disease incidence	Leaf infection severity	
				% Plants with infected top leaves	% Top leaves infected	Leaf coverage severity rating (0-5)
1 & 2	Untreated control	-	-	98a	87a	4.9a
3	Amistar SC 62.5 g ai	62.5	0.25 L	55 c	17 cd	1.3 b
4	Amistar SC 125 g ai	125	0.5 L	42 d	11 d	1.3 b
5	Amistar SC 250 g ai	250	1.0 L	15 e	3 e	1.0 bc
6	Amistar SC 500 g ai	500	2.0 L	4 f	1 f	0.8 c
7	Ridomil Gold MZ	1600 + 100	2.5 kg	61 bc	18 bc	1.0 bc
8	Ridomil Gold Plus	1320 + 110	2.2 kg	70 b	24 b	1.0 bc
9	Copper oxychloride	1250	2.5 kg	60 bc	17 c	1.0 bc
p-value				< 0.0001	< 0.0001	< 0.0001

DAP = days after planting; DAA = days after fungicide application number #
Means within columns followed by the same letter are not significantly different at the 5% level according to Least Significant Difference (LSD) test.

Figure 6.1 - The severity of white blister leaf infection on top leaves (83DAP, 17DAA4)



Trial 6: Harford, Tasmania (2007)

Results (Cont.)

Table 6.2 - White blister incidence on broccoli heads

No.	Treatment	Active ingredient rate (g ai/ha)	Product Rate	% Heads with white blister	
				20/04/07, 86DAP, 20DAA4	23/04/07, 89DAP, 23DAA4
1 & 2	Untreated control	-	-	0.0	0.9
3	Amistar SC 62.5 g ai	62.5	0.25 L	0.0	0.0
4	Amistar SC 125 g ai	125	0.5 L	0.0	0.0
5	Amistar SC 250 g ai	250	1.0 L	0.0	0.0
6	Amistar SC 500 g ai	500	2.0 L	0.0	0.0
7	Ridomil Gold MZ	1600 + 100	2.5 kg	0.0	0.0
8	Ridomil Gold Plus	1320 + 110	2.2 kg	0.9	0.9
9	Copper oxychloride	1250	2.5 kg	0.0	0.6
p-value				N/a	N/a

DAP = days after planting; DAA = days after fungicide application number #

Trial 6: Harford, Tasmania (2007)

Discussion

This trial was conducted within a late commercial broccoli crop cv. Shamrock, grown for processing into frozen vegetables, at Harford, Tasmania. All fungicide treatments were found to be safe to the crop.

Leaf infections

- At the commencement of the trial, an average of 80% of broccoli plants across the trial site already had white blister (*A. candida*) on their lower leaves; with an average leaf cover severity rating of 2. At close to harvest, 100% of the broccoli plants had white blister on their lower leaves. However, there were obvious differences between treatments in white blister incidence and severity on the new and fully expanded top leaves that had formed since the first fungicide application. Therefore, in the leaf disease assessment, the top five fully expanded leaves were examined for white blister incidence on plants, the proportion of infected top leaves (or leaf infection severity) and white blister coverage on leaves (Table 6.1). The treatment differences were best demonstrated by the leaf infection severity assessments (Figure 6.1). Even though many fungicide treated plants had infected top leaves, almost all of the infected leaves had a leaf coverage severity rating of 1 (Photograph 6.3), compared to a severity rating of 5 in the untreated controls (Photograph 6.7).

- In the untreated control plants, white blister incidence on the top leaves was very high, affecting 97% to 99% of plants. Leaf infection severity of the untreated plants was also very high, with 87% of the top leaves infected and with a maximum leaf coverage severity rating of 5 (Photograph 6.7). All fungicide treatments significantly reduced the white blister incidence and severity on the top leaves when compared to the untreated control ($p = 0.0001$).

- There were significant differences in the percentages of plants and top leaves infected between the different rates of Amistar SC. An increase in the rates of Amistar resulted in a significant decrease in the percentages of plants with infected top leaves and percentages of top leaves infected. Amistar SC applied at the highest rate of 250 and 500 g ai/ha gave the best disease control. In comparison to the untreated control, Amistar SC applied at 62.5 and 125 g ai/ha also gave relatively effective disease control, reducing the incidence and severity of leaf infections. Therefore, in situations where disease pressure is low and/or when field conditions are not favourable for the disease, low rates of Amistar SC at 62.5 and 125 g ai/ha may be adequate for effective disease control. Whereas, if disease pressure is very high and field conditions are favourable to the disease, higher rates of Amistar SC at 250 and 500 g ai/ha should be considered.

- Amistar SC at 125, 250 and 500 g ai/ha were significantly more effective in reducing white blister infections on leaves than Ridomil Gold MZ, Ridomil Gold Plus and Copper oxychloride. This is an interesting development, as in previous trials conducted in north-west Tasmania in 2005 and 2006, Ridomil Gold MZ was shown to be more effective than Amistar SC at 250 g ai/ha (see Trial 3 and Trial 7). In contrast, trials conducted in Werribee, Victoria, had shown that Amistar was more effective than Ridomil Gold MZ. It is possible that the reliance on Ridomil Gold MZ as a curative fungicide in recent years in Tasmania may have helped select and increase populations of fungal isolates that are more resistant to metalaxyl. There is also a high risk of selection for fungicide resistant isolates as a result of the common practice of consecutive plantings of several broccoli crops adjacent to one another, thereby ensuring a constant disease pressure over a prolonged period of time. In commercial practice, it is typical to apply up to two systemic fungicide applications in each planting during the head formation. Therefore, in order to reduce long term exposure of the pathogen to a fungicide and hence reduce the risk of fungicide resistance, a block of two spray applications of a systemic fungicide such as Ridomil Gold MZ in one planting, followed by Amistar SC in the next planting, should be considered. A spray mixture of Amistar SC with copper fungicide should also be considered for fungicide resistance management.

- Ridomil Gold MZ, Ridomil Gold Plus and Copper oxychloride gave similar levels of white blister control. Although applications of these products resulted in relatively high disease incidence, ranging from 60% to 70% plants infected, there were substantial reduction in the levels of leaf infection severity. The percentages of top leaves infection by these treatments ranged from 17% to 24% compared to 87% with the untreated control. Many of these infected leaves had relatively new and small white blister lesions and a leaf coverage rating of 1.0, i.e. with 3 or less white blister lesions on each infected leaf. These findings indicate that Ridomil Gold MZ and Ridomil Gold Plus are still effective in the control of white blister, particularly in reducing leaf infection severity.

Head infections

- There was little or no white blister infection found on matured broccoli heads in the two head infection assessments (Table 6.2). Only five infected heads were found in the whole trial, resulting in slight head infection averages in the untreated control, Ridomil Gold Plus and Copper oxychloride treatments. The

incidence of head infection was too low for statistical analysis.

SECTION B. INVESTIGATIONS ON THE EFFICACIES OF ALTERNATIVE FUNGICIDES FOR WHITE BLISTER CONTROL ON BROCCOLI CROPS IN AUSTRALIA

Introduction

Two field trials were conducted to evaluate alternative fungicides for white blister control. This study aimed to identify fungicides from other chemical groups and fungicide mixtures that may be effective against white blister and could be used in fungicide resistance management programs with fungicides identified in Section A. Both trials were conducted during the months when crops are most susceptible to high levels of infection in the regions.

Fungicide Product List

Product Name	Active Ingredient (ai)	Concentration of active ingredient	Formulation
Agri-Fos 600	phosphorous acid	600 g/L	Suspension concentrate
Amistar SC	azoxystrobin	250 g/L	Suspension concentrate
BAS 500	pyraclostrobin	250 g/L	Emulsifiable concentrate
BAS 510	boscalid	500 g/kg	Water dispersible granule
BAS 516	boscalid + pyraclostrobin	252 g/kg + 120 g/kg	Water dispersible granule
BAS 536	pyraclostrobin + dimethomorph	67 g/kg + 120 g/kg	Water dispersible granule
Copper oxychloride	copper oxychloride	500 g/kg copper oxychloride	Wettable powder
Flo-Bordo	copper hydroxide	50 g/L	Liquid concentrate
Ridomil Gold MZ	metalaxyl-M + mancozeb	40 g/kg + 640 g/kg	Water dispersible granule

Trial Summary

Location	Forth, NW Tasmania	Werribee South, Victoria
Soil Type	Ferrosol	Silty loam
Crop	Broccoli	Broccoli
Variety	cv. Marathon	cv. Legacy
Trial Design	Randomised complete block	Randomised complete block
Replications	5	5
Plot Size	7 m x 3.2 m	9 m x 1.8 m
Plant Spacing	0.4 cm	1.8 m wide with 3 plant rows
Planting Date	05/02/05	06/06/05
Harvest Date	30/04/05	First harvest - 04/09/05 Last harvest - 13/09/05

Trial 7: Comparisons of alternative fungicides for white blister control on broccoli at Forth, Tasmania (2005)

Summary

A trial was conducted within a commercial broccoli crop in February - April 2005, at Forth, Tasmania, to evaluate the efficacy of alternative fungicides for white blister (*Albugo candida*) control. The alternative fungicides in this study included pyraclostrobin (BAS 500), boscalid (BAS 510 or Filan), BAS 516 (a combination of pyraclostrobin and boscalid), copper hydroxide (Flo-Bordo) and phosphorous acid (Agri-Fos). These alternatives were compared with Copper oxychloride and Ridomil Gold MZ (Ridomil MZ), which have temporary permits issued by APVMA for white blister control on broccoli. Flo-Bordo was applied in conjunction with Agri-Fos (phosphorous acid), as well as being an alternate spray with Ridomil MZ, BAS 500 and BAS 516. Fungicide treatments consisted of three sprays with 400 L water/ha applied at 47, 54 and 65 days after broccoli seedlings were transplanted. The first spray application was approximately one week before initial flower heads formed or initial button stage. Broccoli plants were assessed for leaf and head infections at crop maturity and harvest.

Except for BAS 510, all fungicide treatments significantly reduced the incidence of white blister on broccoli heads at harvest. Ridomil MZ, BAS 500, BAS 516, Flo-Bordo and Copper oxychloride reduced white blister incidence by greater than 89% on broccoli heads compared to the untreated control at 15 days after the third spray application and 80 days after planting.

Among the alternative fungicides examined in this study, BAS 500 has a similar level of efficacy to Ridomil MZ in providing the most effective control of white blister on leaves. BAS 516 was the second most effective fungicide, but has a lower level of efficacy compared to BAS 500. BAS 510 had no effect on the disease. The lower efficacy by BAS 516 compared to BAS 500 appeared to be related to its lower pyraclostrobin level (120g vs 250g in BAS 516 and BAS 500, respectively).

The two copper products, Flo-Bordo and Copper oxychloride, gave similar levels of white blister control on leaves. It is noteworthy that the level of copper active ingredient in the Copper oxychloride treatment is 1250 g ai/ha compared Flo-Bordo at 400 g ai/ha. As broccoli heads are susceptible to phytotoxic damage by high rates of copper under certain field conditions, the low level of copper application with Flo Bordo might be considered. There was no improvement in white blister control with the mixture of Flo-Bordo + Agri-Fos compared to Flo-Bordo alone. Flo-Bordo is a suitable substitute for Copper oxychloride for use in spray program as a contact fungicide along with a more effective systemic fungicide such as Ridomil MZ or BAS 500.

Trial 7: Forth, Tasmania (2005)

Aims

This study aimed to identify effective fungicides, and their appropriate rates and application timings, for control of the pathogen *A.candida* (white blister) in broccoli.

Materials and Methods

Treatment List

No.	Treatment	Product Rate/ha	Active Ingredient (g ai/ha)	Application Schedule
1	Untreated control	Nil	Nil	Nil
2	3 x Ridomil MZ	2.5 kg	100 g metalaxyl-M + 1.6 kg mancozeb	3 applications at 7-day intervals (a 4th application was cancelled due to rapid maturity of crop)
3	3 x BAS 500 (Cabrio)	1.0 L	250 g pyraclostrobin	
4	3 x BAS 510 (Filan)	1.0 kg	500 g boscalid	
5	3 x BAS 516	1.0 kg	252 g boscalid + 120 g pyraclostrobin	
6	3 x Flo-Bordo	8.0 L	400 g copper hydroxide	
7	3 x Flo-Bordo + Agri-Fos	8.0 L + 3.5 L	400 g copper hydroxide + 2.1 kg phosphoric acid	
8	BAS 516/ Flo-Bordo/ BAS 516*	1.0 kg / 8.0 L	252 g boscalid + 120 g pyraclostrobin / 400 g copper hydroxide	
9	BAS 510/ Flo-Bordo/ BAS 510*	1.0 kg / 8.0 L	500 g boscalid / 400 g copper hydroxide	
10	Ridomil MZ/ Flo-Bordo/ Ridomil MZ*	2.5 kg / 8.0 L	100 g metalaxyl-M + 1.6 kg mancozeb / 400 g copper hydroxide	
11	3 x Copper oxychloride	2.5 kg	1250 g copper oxychloride	

* alternate spray applications
Flo-Bordo application rate was based on 2 L/100 L water

Trial 7: Forth, Tasmania (2005)

Chronology of Events

Date	Days after planting (DAP)	Days after application (DAA#)	Crop Stage	Event
05/02/05	0		Seedling	Broccoli transplanted.
15/03/05	38		Vegetative	Vegetative crop stage.
21/03/05	44			Two plants observed to have white blister in the buffer rows in the trial area.
24/03/05	47	0 DAA1	Pre-button	1st application of fungicide treatments.
31/03/05	54	7 DAA1	Initial button	2nd application of foliar fungicide treatments.
11/04/05	65	11 DAA2	Average head size 35 mm	3rd application of foliar fungicide treatments (spray delayed due to showers and windy conditions). White blister obvious on many plants along the commercial spray track through the trial.
18/04/05	72	7 DAA3		Fourth spray cancelled due to rapid crop maturity; some head sizes were close to harvest.
19/04/05	73	8 DAA3		Disease assessment 1 for leaf infections (Replicate 1).
20/04/05	74	9 DAA3		Disease assessment 2 for leaf infections (Replicates 2 - 5).
22/04/05	76	11 DAA3	Head sizes ranged from 50-150 mm	First commercial harvest of heads outside the trial area.
26/04/05	80	15 DAA3		Disease assessment 3 for head infections (All replicates).
30/04/05	84	19 DAA3		Second commercial harvest of heads outside the trial area.

Photographs

Photographs 7.1a & 7.1b: Crop stage at the first fungicide spray application.

Trial 7: Forth, Tasmania (2005)

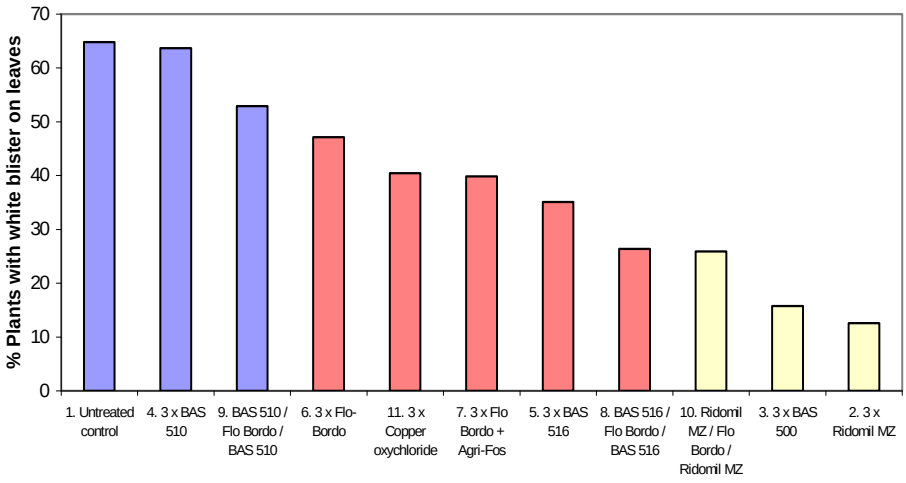
Results

Table 7.1 - White blister disease assessment on broccoli leaves, 8-9 DAA3 (73-74 DAP)

No.	Treatment	Product Rate/ha	Mean % of plants with white blister on leaves**
1	Untreated control	Nil	66 a
4	3 x BAS 510 (Filan)	1.0 kg	64 a
9	BAS 510/ Flo-Bordo/ BAS 510*	1.0 kg & 8.0 L	53 ab
6	3 x Flo-Bordo	8.0 L	47 bc
11	3 x Copper oxychloride	2.5 kg	40 bc
7	3 x Flo-Bordo + Agri-Fos	8.0 L + 3.5 L	40 bcd
5	3 x BAS 516	1.0 kg	35 cde
8	BAS 516/ Flo-Bordo/ BAS 516*	1.0 kg & 8.0 L	26 def
10	Ridomil MZ/ Flo-Bordo/ Ridomil MZ*	2.5 kg & 8.0 L	26 efg
3	3 x BAS 500 (Cabrio)	1.0 L	16 fg
2	3 x Ridomil MZ	2.5 kg	13 g
p-value			< 0.0001

Treatments are sorted according to the mean percentage of plants with white blister in a descending order, with poor control treatments on top and the best treatments at the bottom.
* alternate spray applications; DAA = Days after application #; DAP = Days after planting
** Means in the same column followed by the same letter do not differ significantly (P = 0.05) according to the Fischer's least significant difference (LSD) test.

Figure 7.1 - White blister disease incidence assessment on broccoli leaves, 8-9 DAA3 (73-74 DAP)



Trial 7: Forth, Tasmania (2005)

Results (Cont.)

Table 7.2 - White blister disease assessment on broccoli heads, 15 DAA3 (80 DAP)

No.	Treatment	Product Rate/ha	Percentage of heads infected **
1	Untreated control	Nil	4.5 a
4	3 x BAS 510 (Filan)	1.0 kg	3.1 a
9	BAS 510/ Flo-Bordo/ BAS 510*	1.0 kg & 8.0 L	0.5 b
6	3 x Flo-Bordo	8.0 L	0.5 b
11	3 x Copper oxychloride	2.5 kg	0.0 b
7	3 x Flo-Bordo + Agri-Fos	8.0 L + 3.5 L	0.0 b
5	3 x BAS 516	1.0 kg	0.0 b
8	BAS 516/ Flo-Bordo/ BAS 516*	1.0 kg & 8.0 L	0.0 b
10	Ridomil MZ / Flo-Bordo/ Ridomil MZ *	2.5 kg & 8.0 L	0.0 b
3	3 x BAS 500 (Cabrio)	1.0 L	0.0 b
2	3 x Ridomil MZ	2.5 kg	0.0 b
p-value			0.0001

Treatments are sorted according to the mean percentage of plant heads with white blister in a descending order, with poor control treatments on top and best treatments at the bottom.
* alternate spray applications; DAA = Days after application #; DAP = Days after planting
** Means in the same column followed by the same letter do not differ significantly (P = 0.05) according to the Fischer's LSD test.

Discussion

Leaf infection

- There was a significant fungicide treatment effect on the percentage of plants with white blister at 8-9 DAA3 (p-value <0.0001) (Table 7.1 & Figure 7.1). Although the disease incidence in the untreated control plots was relatively high, almost all of the leaf infections covered less than 1% of the leaf area, and only a few leaves were infected per plant.

- Except for treatments with BAS 510 (Treatments 4 and 9), all other fungicide treatments significantly reduced the number of broccoli plants with white blister leaf infection in comparison to the untreated control at 8-9 DAA3. BAS510 had no effect on white blister.

- BAS 500 (Treatment 3) and Ridomil MZ (Treatment 2), applied in three repeated applications, gave the most effective control of white blister leaf infection, reducing infection by approximately 76% and 80% respectively, in comparison to levels in the untreated control. There was no significant difference in efficacy between the two fungicide treatments. BAS 516 was the second most effective fungicide, reducing infection by 47%.

- The two copper products, Flo-Bordo (Treatment 6) and Copper oxychloride (Treatment 11), applied in three repeated applications, were the third most effective fungicides in this study on white blister leaf infection, reducing infection by approximately 27% and 39% respectively, in comparison to levels in the untreated control. There was no significant difference in efficacy between the two copper products.

- It is noteworthy that the level of copper active ingredient in the Copper oxychloride treatment was applied at a much higher rate at 1250 g ai/ha compared to the level of active in Flo-Bordo at 400 g ai/ha. Flo-Bordo is based on 50 g/L copper hydroxide in a liquid concentrate, and Copper oxychloride is based on 500 g/kg copper oxychloride in a wettable powder. Broccoli heads are susceptible to phytotoxic damage by copper under certain field conditions; therefore, a low level of copper application is preferable in spray applications.

Trial 7: Forth, Tasmania (2005)

Leaf infection (Cont.)

- There was no improvement in white blister control with the mixture of Flo-Bordo + Agri-Fos (Treatment 7) compared to Flo-Bordo alone. Therefore, there is no additive or synergistic effect with the copper hydroxide + phosphorous acid mixture.

- BAS 516, which contains a mixture of BAS 500 (pyraclostrobin) and BAS 510 (boscalid), was less effective than BAS 500. Therefore, there is no synergistic effect by a mixture of the two fungicides. The lower efficacy by BAS516 appeared to be related to its lower rate of pyraclostrobin compared to BAS 500 (120g vs 250 g pyraclostrobin in BAS 516 and BAS 500, respectively).

- An alternate fungicide program of two sprays BAS 516 or Ridomil MZ with a third spray of Flo-Bordo also gave relatively effective control of white blister on leaves (Treatments 10 and 3), reducing the leaf infection incidence by approximately 60% and 76% respectively, in comparison to the untreated control.

Head infection

- At 80 DAP, the level of white blister infection on broccoli heads was very low in comparison to the incidence of infection on broccoli leaves, with 4.5% infected heads in the untreated control. Head infections, however, could increase exponentially within a few days if conditions are highly favourable to the disease.

- Except for BAS 510 applied in three applications (Treatment 4), all fungicide treatments with BAS 500, Ridomil MZ, Flo Bordo and Copper oxychloride significantly reduced the incidence of white blister on broccoli heads (Table 7.2).

Trial 8: Evaluation of fungicides for white blister control at Werribee, Victoria (2005)

Summary

A trial was conducted within a commercial broccoli crop in August - September 2005 at Werribee, Victoria, to evaluate the efficacy of alternative fungicides for white blister (*Albugo candida*) control. The alternative fungicides in this study included pyraclostrobin (BAS 500), BAS 536 (a combination of pyraclostrobin and dimethomorph), copper hydroxide (Flo-Bordo) and phosphorous acid (Agri-Fos). These alternatives were compared with Amistar and Ridomil Gold MZ (Ridomil MZ). Flo-Bordo or Flo-Bordo + Agri-Fos were applied in alternate late applications after Ridomil MZ or BAS 500. Fungicide treatments consisted of four sprays at 385 L water/ha applied at 63, 71, 78 and 87 days after broccoli seedlings were transplanted. The first spray application was approximately one week before initial flower heads formed or initial button stage. Broccoli plants were assessed for top leaves and head infections at crop maturity and harvest.

Poor efficacies were shown by the treatments containing Ridomil MZ (in four applications or in two applications followed by Flo-Bordo or Flo-Bordo + Agri-Fos). This indicated the development of fungal populations that are resistant to metalaxyl-M at this site.

Amistar, BAS 500 and BAS 536 gave the most effective control of white blister head infection, reducing infection by 81% to 91% in comparison to levels in the untreated control. There was no significant difference in efficacies between the three fungicides. There appeared to be a trend of better performance by the high rate of BAS 500 at 0.250 g ai/ha compared to 0.125 g ai/ha

Under very high disease pressure, Flo-Bordo appeared to be less effective against white blister, in comparison to the systemic fungicides Amistar, BAS 500 and BAS 536. Agri-Fos, applied in a mixture with Flo-Bordo and applied in two sprays after two Ridomil MZ sprays, did not improve white blister control on broccoli heads.

Materials and Methods

Treatment List

No.	Treatment	Product Rate/ha	Active ingredient ai/ha
1&2	Untreated control	-	-
3	4 x Amistar SC	1.0 L	250 g azoxystrobin
4	4 x Ridomil Gold MZ	2.5 kg	100 g metalaxyl-M + 1.6 kg mancozeb
5	4 x BAS 500	0.25 L	62.5 g pyraclostrobin
6	4 x BAS 500	0.50 L	125 g pyraclostrobin
7	4 x BAS 536	1.0 kg	67 g pyraclostrobin + 120 g dimethamorph
8	4 x BAS 500 + Flo-Bordo	0.25 L + 22 L	62.5 g pyraclostrobin + 1.10 kg copper hydroxide
9	2 x BAS 500 / 2 x Flo-Bordo	0.25 L / 22 L	62.5 g pyraclostrobin fb 1.10 kg copper hydroxide
10	2 x Ridomil Gold MZ / 2 x Flo-Bordo	2.5 kg / 22 L	100 g metalaxyl-M + 1.6 kg mancozeb fb 1.10 kg copper hydroxide
11	2 x Ridomil Gold MZ / 2 x Flo-Bordo + Agri-Fos	2.5 kg / 22 L + 3.5 L	100 g metalaxyl + 1.6 kg mancozeb fb 1.10 kg copper hydroxide

Activator, a non-ionic surfactant, was added to all fungicide treatments at 125 mL/100 L

Trial 8: Werribee, Victoria (2005)

Chronology of Events

Date	Days after planting (DAP)	Days after application (DAA#)	Crop Stage	Event
06/06/05			Seedling	Broccoli transplanted.
08/08/05	63	0 DAA1	Pre-button to initial button	1st application of fungicide treatments.
16/08/05	71	8 DAA1	Immature head sizes 20-30 mm	2nd application of foliar fungicide treatments.
23/08/05	78	7 DAA2	Immature head sizes 50-100 mm	3rd foliar fungicide treatments. Showers just prior to spraying.
01/09/05	87	9 DAA3	Immature head sizes 75-120 mm	4th foliar foliar fungicide treatments. Showers just prior to spraying.
04/09/05	90	3 DAA4		First harvesting of heads outside trial area.
05/09/05	91	4 DAA4		1st disease assessment for leaf and head infections.
08/09/05	94	7 DAA4		2nd disease assessment for leaf and head infections.
13/09/05	99	12 DAA4		3rd disease assessment for leaf and head infections.
13/09/05	99	12 DAA4		Finish commercial harvest of crop outside trial area.
15/09/05	101			Crop mulched into soil

Photographs

Crop stage at the first fungicide spray application (Photograph 8.1) and distorted florets on broccoli head due to white blister infections (Photograph 8.2)

Trial 8: Werribee, Victoria (2005)

Results

Table 8.1 - White blister disease assessment on broccoli leaves, 4-12 DAA4 (91-99 DAP)

No.	Treatment#	Percentage of plants with infected top leaves (top five leaves per plant examined)*		
		4 DAA4 (91 DAP)	7 DAA4 (94 DAP)	12 DAA4 (99 DAP)
1&2	Untreated control	0.0	0.0	0.2
3	4 x Amistar SC	0.0	0.0	0.2
4	4 x Ridomil MZ	0.0	0.0	0.0
5	4 x BAS 500 @ 0.25 L	0.0	0.0	0.0
6	4 x BAS 500 @ 0.5 L	0.0	0.0	0.0
7	4 x BAS 536	0.0	0.0	0.0
8	4 x BAS 500 + Flo-Bordo	0.0	0.0	0.4
9	2 x BAS 500 / 2 x Flo-Bordo	0.0	0.0	0.4
10	2 x Ridomil MZ / 2 x Flo-Bordo	0.0	0.0	0.0
11	2 x Ridomil MZ / 2 x Flo-Bordo + Agri-Fos	0.0	0.0	0.4

Activator, a non-ionic surfactant, was added to all fungicide treatments at 125 mL/100 L
* DAA = Days after application #; DAP = Days after planting

Table 8.2 - White blister disease assessment on broccoli heads, 4-12 DAA4 (91-99 DAP)

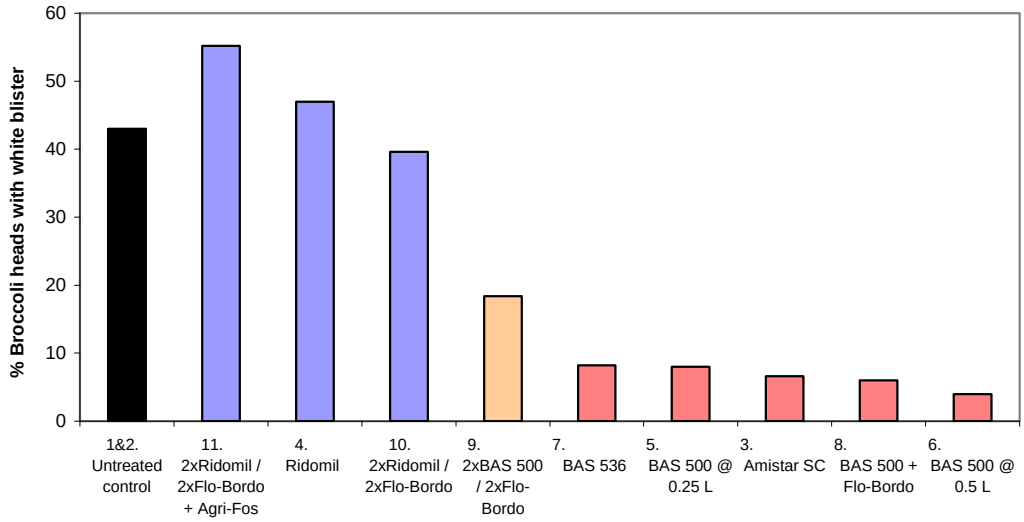
No.	Treatment#	Percentage of heads infected		
		4 DAA4 (91 DAP)	7 DAA4 (94 DAP)	12 DAA4 (99 DAP)
1&2	Untreated control	6.8 c	15.7 b	44.3 c
11	2 x Ridomil MZ / 2 x Flo-Bordo + Agri-Fos	2.0 ab	20.2 b	55.2 c
4	4 x Ridomil MZ	2.8 b	13.6 b	47.0 c
10	2 x Ridomil MZ / 2 x Flo-Bordo	4.2 b	18.6 b	39.6 c
9	2 x BAS 500 / 2 x Flo-Bordo	0.0 a	3.6 a	18.4 b
7	4 x BAS 536	0.0 a	1.0 a	8.2 ab
5	4 x BAS 500 @ 0.25 L	0.0 a	0.6 a	8.0 ab
3	4 x Amistar SC	0.0 a	0.6 a	6.6 a
8	4 x BAS 500 + Flo-Bordo	0.0 a	0.8 a	6.0 ab
6	4 x BAS 500 @ 0.5 L	0.0 a	0.6 a	4.0 a
p-value		< 0.0001	< 0.0001	< 0.0001

Activator, a non-ionic surfactant, was added to all fungicide treatments at 125 mL/100 L
Treatments are sorted according to the mean percentage of plants with white blister in a descending order, with poor control treatments on top and best treatments at the bottom.
* DAA = Days after application #; DAP = Days after planting
** Means in the same column followed by the same letter do not differ significantly (P = 0.05) according to the Fischer's LSD test.

Trial 8: Werribee, Victoria (2005)

Results Cont.)

Figure 8.1 - White blister disease assessment on broccoli heads at 12 DAA4 (91-99 DAP)



Discussion

Leaf infection

- Prior to the start of applications, white blister was observed on lower leaves of 75% of plants in the trial area, with a low disease severity of less than 1% plant area infection. Later in the trial, little or no white blister was found on the newer top leaves (Table 8.1). Assessments of the top five leaves of each plant in the trial showed that plants had little or no white blister on their new top leaves, even when head infections were noted on maturing broccoli heads.

Head infection

- Harvesting of broccoli heads outside the trial area commenced at 90 DAP and concluded at 99 DAP, and the crop was cultivated and mulched into the soil two days later. Significant head infection was recorded on the first head assessment at 91 DAP, and it increased rapidly at 94 and 99 DAP (Table 8.2). There was a significant fungicide treatment effect on the percentage of broccoli heads infected with white blister at 4-12 DAA4 (p-value <0.0001) (Table 8.2, Figure 8.1).

- At four days after the last fungicide applications (4 DAA4), all fungicide treatments including treatments with Ridomil MZ significantly reduced the percentage of broccoli heads with white blister, in comparison to the untreated control.

- At 7 DAA4 and 12 DAA4, all treatments with Ridomil MZ (Treatments 4, 10 and 11) did not control head infections. Agri-Fos + Flo-Bordo or Flo-Bordo applied following two early applications of Ridomil MZ did not improve the control of head infections. The poor efficacy shown by Ridomil MZ indicated that *A. candida* populations at the trial site are highly resistant to metalaxyl-M.

- In contrast, four spray applications of Amistar, BAS 500, BAS 536, BAS 500 + Flo-Bordo, and BAS 500 alternated with Flo-Bordo significantly reduced head infections.

Trial 8: Werribee, Victoria (2005)

Discussion (Cont.)

Head infection

- At 12 DAA4, two applications of BAS 500 at 0.25 L/ha followed by two applications of Flo-Bordo (Treatment 9) were shown to be less effective than four applications of Amistar, BAS 500, BAS 536, and BAS 500 + Flo-Bordo (Table 8.2, Figure 8.1). This indicated that the 12 day interval between the last spray application of Flo-Bordo and the head harvest period might have been too long for effective protection by a contact fungicide like Flo-Bordo. It is also possible that the disease pressure might have been too high in the crop for Flo Bordo to be effective. There was no improvement in white blister control with the mixture of Flo-Bordo + Agri-Fos compared to Flo-Bordo alone.

- Four applications of the systemic fungicides Amistar, BAS 500 and BAS 536 gave a more effective protection of the treated broccoli heads from infections until the final harvest. Therefore, for effective control throughout the harvesting period and under high disease pressure and favourable conditions, it would appear that more than two spray applications were required, starting from just before to initial button stage and continuing until harvest.

- There was no obvious difference in the head infection control between Amistar at 250 g ai/ha and the two rates of BAS 500 at 62.5 g ai/ha and 125 g ai/ha.

- The systemic fungicides, Amistar, BAS 500 and BAS 536, are effective alternative fungicides for white blister control. Amistar and BAS 500 belong to the same fungicide chemical group, strobilurins. There was no difference in the performance of BAS500 at 0.25 L/ha and BAS536 at 1.0 kg/ha.

SECTION C: STUDIES ON THE RESIDUES OF AZOXYSTROBIN, METALAXYL-M AND MANCOZEB IN BRASSICA VEGETABLES

Summary

This study was conducted to determine the presence and persistence of azoxystrobin, metalaxyl-M and mancozeb residues in brassica vegetables following various applications of Amistar 250 SC, Ridomil Gold Plus and Ridomil Gold MZ at various timings before harvest to generate data to set or confirm Maximum Residue Levels (MRLs) to support registration or permit applications. All residue trials and chemical analyses were conducted under GLP (Good Laboratory Practice), as required by APVMA.

The field phase was conducted by Peracto Pty Ltd at five (5) locations as follows:

Site 1 – South East Queensland
Site 2 – Tasmania
Site 3 – Tasmania
Site 4 – Tasmania
Site 5 – Victoria

The analytical phase of the study was conducted by AgriSolutions Australia at their Brisbane Laboratory.

Site Locations and Details

Site	**1**	**2**	**3**	**4**	**5**
Location	Mulgowie, QLD 4341	Don, TAS 7310	Forth, TAS 7310	Don, TAS 7310	Lovely Bank, VIC 3221
Soil Type	Medium Clay	Ferrosol	Ferrosol	Ferrosol	Clay Loam
Crop	Broccoli	Broccoli	Cauliflower	Brussels sprouts	Bok Choy (leafy brassica)
Cultivar	Greenbelt	Atomic	Atlantis	Brolin	7-hybrid
Date Planted	02/06/06	08/03/06	15/02/06	10/12/05	18/07/06
Planting Method	Direct seeded	Transplanted	Transplanted	Transplanted	Sowed seed
Plot Size	2 Rows x 10 m	16 m x 1.5 m	22.5 m x 1.5 m	10 m x1.5 m	5 m x 1 m
Plot Design	Unreplicated	Unreplicated	Unreplicated	Unreplicated	Unreplicated

Test Item

Product Name	Amistar	Ridomil Gold Plus	Ridomil Gold MZ
Active Ingredient	azoxystrobin	metalaxyl-M + copper hydroxide	metalaxyl-M + mancozeb
Nominal Concentration	250 g/kg	50 g/kg + 390 g/kg	40 g/kg + 640 g/kg
Formulation	Suspension Concentrate	Wettable Powder	Wettable Powder
Batch Number	GRA4C113C	YGM 5G01005	SSP2A505

Treatment Information

Treatment Number	Test Item	Rate (mL/100 L)	AI Rate (g a.i./100 L)	Number of spray applications at 7 day intervals
1	Untreated Control	Nil	Nil	-
2	Amistar 250 SC	1 L/ha	250	2
3	Ridomil Gold MZ	2.5 kg/ha	100 + 1600	2
4	Ridomil Gold Plus	2 kg/ha	100 + 780	2
5	Amistar 250 SC	1 L/ha	250	4
6	Ridomil Gold MZ	2.5 kg/ha	100 + 1600	4

Application Details

Trial Sites	1	2	3	4	5
Type of Application	Foliar	Foliar	Foliar	Foliar	Foliar
No. of Applications	2 - Trt 2, 3 & 4 4 - Trt 5 & 6	2 - Trt 2, 3 & 4 4 - Trt 5 & 6	2 - Trt 2, 3 & 4 4 - Trt 5 & 6	2 - Trt 2, 3 & 4 4 - Trt 5 & 6	2 - Trt 2, 3 & 4 4 - Trt 5 & 6
Dates of Applications	17/07/06 24/07/06 31/07/06 07/08/06	13/06/06 20/06/06 26/06/06 03/07/06	20/06/06 26/06/06 03/07/06 10/07/06 17/07/06 24/07/06	06/06/06 13/06/06 20/06/06 26/06/06	08/08/06 15/08/06 22/08/06 29/08/06
Growth Stage at Application	10 leaves Bud formation Buds 3-5 cm Buds 5-10 cm	Prior to buttoning 20% heads up to 4 cm Heads 3-6 cm Heads 3-10 cm	Heads enclosed Heads approx 5cm Heads to 10 cm Heads to 15 cm Heads to 25 cm Heads to 25 cm	Early buttoning Buttoning 2-3 cm Buttons 2-4 cm Buttons 2-5 cm	5 cm diameter 20 cm diameter of outer leaves Maturing Mature

Sampling Details

Trial Sites	1	2	3	4	5
Specimen Collection Dates	07/08/06 10/08/06 14/08/06 21/08/06	03/07/06 06/07/06 10/07/06 17/07/06	26/6/06 - T2, 3, 4 29/6/06 - T2, 3, 4 3/7/06 - T2, 3, 4 10/7/6 - T2, 3, 4 24/7/06 - T5, 6 27/7/06 - T5, 6 31/7/06 - T5, 6 7/6/06 - T5, 6	26/06/06 29/06/06 03/07/06 10/07/06	29/08/06 01/09/06 05/09/06 12/09/06
Sampling Intervals (DALA)	7 0 3 7 14	7 0 3 7 14	7 0 3 7 14	7 0 3 7 14	7 0 3 7 14
Crop Part Sampled	Head	Head	Head	Buttons	Whole above ground part of plant
Order of Sampling	T1, 2, 5, 3, 6, 4 T2, 5, 3, 6, 4 T2, 5, 3, 6, 4 T2, 5, 3, 6, 4 T2, 5, 3, 6, 4	T2, 5, 3, 6, 4 T1, 2, 5, 3, 6, 4 T2, 5, 3, 6, 4 T2, 3, 6, 5, 4 T2, 5, 3, 6, 4	T2, 3, 4 T1, 2, 3, 4 T2, 3, 4 T2, 3, 4 T2, 3, 4 T5, 6 T5, 6 T5, 6 T5, 6 T5, 6	T2, 5, 3, 6, 4 T2, 5, 3, 6, 4, 1 T2, 5, 3, 6, 4 T2, 5, 3, 6, 5, 4 T2, 5, 3, 6, 4	T2, 5, 3, 6, 4 T1, 2, 5, 3, 6, 4 T2, 5, 3, 6, 4 T2, 5, 3, 6, 4 T2, 5, 3, 6, 4

T = Treatment; DALA = Days after last application

Table C1 – Summary of Results

Site No.	Crop	Specimen Number	Sample Timing	Application Rate[1] (g a.i./ha)			Azoxystrobin Residues[2] (mg/kg)	Metalaxyl-M Residues[2] (mg/kg)	Mancozeb Residues[3] (mg CS_2/kg)
				AZ	MM	MZ			
1	Broccoli	SYN-WBLISTER-S1-T2-7DAA2	7DAA2[4]	250	-	-	0.03	-	-
1	Broccoli	SYN-WBLISTER-S1-T3-7DAA2	7DAA2	-	100	1600	-	0.01	-
1	Broccoli	SYN-WBLISTER-S1-T4-7DAA2	7DAA2	-	100	780	-	0.02	-
1	Broccoli	SYN-WBLISTER-S1-T5-7DAA4	7DAA4	250	-	-	0.03	-	-
1	Broccoli	SYN-WBLISTER-S1-T6-7DAA4	7DAA4	-	100	1600	-	0.01	-
3	Cauliflower	SYN-WBLISTER-S3-T2-7DAA2	7DAA2	250	-	-	<LOQ	-	-
3	Cauliflower	SYN-WBLISTER-S3-T3-7DAA2	7DAA2	-	100	1600	-	0.02	-
3	Cauliflower	SYN-WBLISTER-S3-T4-7DAA2	7DAA2	-	100	780	-	<LOQ	-
3	Cauliflower	SYN-WBLISTER-S3-T5-7DAA4	7DAA4	250	-	-	<LOQ	-	-
3	Cauliflower	SYN-WBLISTER-S3-T6-7DAA4	7DAA2	-	100	1600	-	0.02	-
5	Bok Choy	SYN-WBLISTER-S5-T2-7DAA2	7DAA2	250	-	-	0.07	-	-
5	Bok Choy	SYN-WBLISTER-S5-T3-7DAA2	7DAA2	-	100	1600	-	0.04	1.65
5	Bok Choy	SYN-WBLISTER-S5-T4-7DAA2	7DAA2	-	100	780	-	0.03	-
5	Bok Choy	SYN-WBLISTER-S5-T5-7DAA4	7DAA4	250	-	-	0.05	-	-
5	Bok Choy	SYN-WBLISTER-S5-T6-7DAA4	7DAA2	-	100	1600	-	0.02	0.94

1. Application Rate Codes: AZ = Azoxystrobin, MZ = Mancozeb, MM = Metalaxyl-M.
2. LOQ = 0.01 mg/kg for azoxystrobin and metalaxyl-M in brassica crops
3. LOQ = 0.01 mg/kg for carbon disulphide (mancozeb) in brassica crops
4. #DAA# = '*number*' Days After Application '*Number*'

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GENERAL DISCUSSION

Efficacy of azoxystrobin, chlorothalonil, metalaxyl-M + mancozeb and metalaxyl-M + copper hydroxide

- Six efficacy trials were conducted to evaluate azoxystrobin (Amistar SC), chlorothalonil (Bravo Weather Stik), metalaxyl-M + mancozeb (Ridomil Gold MZ) and metalaxyl-M + copper hydroxide (Ridomil Gold Plus) and to determine suitable rates, application timing and programs for white blister control.

- Amistar SC, Ridomil Gold MZ and Ridomil Gold Plus were found to be effective in protecting leaves and heads from white blister. The efficacy of Ridomil Gold MZ may be dependent on its previous use, locations and farm practices.

- Amistar SC was evaluated at different rates of 0.25, 0.5, 1.0 and 2.0 L/ha for white blister control. Under high disease pressure, Amistar SC applied at the highest rate of 1.0 and 2.0 L/ha gave the best disease control. At the lower rates of 0.25 and 0.5 L/ha, it also gave relatively effective disease control. Therefore, in situations where disease pressure is low and/or when field conditions are not favourable for the disease, low rates of Amistar SC at 0.25 and 0.5 L/ha may be adequate for effective disease control. Whereas, if disease pressure is very high and field conditions are favourable to the disease, higher rates of Amistar SC at 1.0 and 2.0 L/ha should be considered.

- Ridomil Gold MZ and Ridomil Gold Plus at 2.5 kg/ha and 2.2 kg/ha respectively, are effective for white blister control.

- Amistar SC or Ridomil MZ must be applied early, at the first sign of infection in the crop, at about initial button stage, for effective disease control. Less effective control by Amistar SC or Ridomil MZ was noted when they were applied later, long after the onset of the disease.

- Penncozeb applied at 2.2 kg/ha Bravo Weather Stik applied at 1.8 L/ha did not control white blister.

Alternative fungicides for white blister control

- Two field trials were conducted at Forth, Tasmania, and Werribee South, Victoria, to evaluate alternative fungicides for white blister control. The alternative fungicides were pyraclostrobin (BAS 500 or Cabrio), boscalid (BAS 510 or Filan), BAS 516 (pyraclostrobin + boscalid), BAS 536 (pyraclostrobin + dimethomorph), copper hydroxide (Flo-Bordo) and phosphorous acid (Agri-Fos).

- BAS 500 and BAS 536 were effective against white blister. BAS 510 has no effect on white blister. There was no synergistic or additive effect in disease control by the combinational mixture of BAS 516, indicating that only its pyraclostrobin active ingredient was effective against white blister.

- Phosphorous acid did not control white blister on broccoli leaves or heads. It also did not improve white blister control, when applied in a mixture of copper hydroxide + phosphorous acid, when compared to copper hydroxide alone.

- The systemic fungicides, BAS 500 and BAS 536, are suitable alternative fungicides for white blister control. There was no difference in the performance of BAS 500 at 0.25 L/ha and BAS 536 at 1.0 kg/ha. However, the combinational mixtures of BAS 536 may offer advantages in reducing the risk of fungicide resistance.

- Copper fungicides based on copper hydroxide or copper oxychloride are suitable additions to the systemic fungicides, Amistar and Ridomil Gold MZ. When the disease pressure is very high, copper fungicides tend to be less effective than the systemic fungicides in preventing leaf infection. They are, however, very effective in preventing head infections. Therefore, copper fungicides should be considered for use on crops that are approaching maturity in order to prevent head infections, following early systemic fungicide applications to reduce disease pressure to a level that can be readily controlled.

GENERAL DISCUSSION (Cont.)

Permit use and fungicide registrations

- AUSVEG applied for emergency and temporary permits for the use of chlorothalonil, mancozeb, boscalid and phosphorous acid for white blister control in 2003 to 2005. However, in this project, all of these fungicides were found to have no effect against the disease, and growers have since stopped using them for white blister control.

- The temporary permit use of Ridomil Gold MZ, copper oxychloride and Amistar SC expires in March 2008. Ridomil Gold MZ and Amistar SC must be registered by the APVMA for long-term use in brassica crops. In this project, Syngenta Crop Protection Pty Ltd has funded a series of residue and efficacy studies in order to generate the essential data for the registration of Ridomil Gold MZ and Amistar SC for use on brassica and leafy brassica vegetable crops.

- The alternative fungicide, pyraclostrobin or BAS 500 belongs to the same strobilurin chemical group as azoxystrobin (Amistar), and therefore is not a suitable alternative to Amistar. As a result, the product manufacturer and distributor decided not to register it for use on brassicas against white blister in Australia.

- Copper fungicides based on copper hydroxide or copper oxychloride are alternatives to the systemic fungicides, Amistar and Ridomil Gold MZ. Copper fungicides are already registered for use on brassicas for disease control in Australia. They should be considered for use on crops that are approaching maturity in order to prevent head infections, following early systemic fungicide applications.

Fungicide resistance management

- White blister is most common and severe in northern Tasmania and Werribee South, Victoria, due to field conditions that are highly favourable to the spread of the disease. In northern Tasmania, broccoli is typically planted once a year and in 3-4 year rotations with non-brassica crops, and disease pressure ranged from low to moderate. In contrast, at Werribee South, Victoria, broccoli is typically planted throughout the year with or without a short break with a lettuce crop, and disease pressure is usually high.

- In both northern Tasmania and Werribee South, it is a common practice to have consecutive plantings of several broccoli crops adjacent to one another. Under favourable field conditions, the disease incidence and severity can increase in the later plantings as disease pressure increases with each crop. Consecutive plantings and multiple plantings help create a constant disease pressure over a prolonged period of time, as well as prolonged exposure of fungal populations to a fungicide.

- When the disease first became widespread in both regions, growers initially relied solely on Ridomil Gold MZ for disease control. Ridomil Gold MZ is also often used as a curative fungicide, after the disease has become widespread and severe. These practices have resulted in substantial variations in the efficacy Ridomil Gold MZ, depending on the locations, disease pressure and history of fungicide use.

- The link between leaf infections and head infections is unclear and may be related to environmental conditions and cultivar susceptibility. High levels of leaf infections do not always result in high levels of head infections, and vice versa. However, if leaf infections are not controlled and the pathogen populations become very high, resistance to fungicides can develop quickly because higher numbers of the pathogen are available for selection.

- Currently, the most effective fungicides for white blister control are phenylamide (metalaxyl-M) and strobilurin (azoxystrobin and pyraclostrobin) fungicides. Phenylamides are very systemic compared with other fungicides but most of this mobility is in the xylem. As a result, most of the movement is upwards and outwards in plant tissue. Strobilurin fungicides are strongly held by the waxy layer of leaves and tend to be released gradually over a period of time resulting in useful product redistribution on plant surfaces not directly sprayed. Some strobilurins redistribute internally via the xylem and others externally. Unfortunately, both of these fungicide groups have a high risk of resistance development because they have very specific modes of action. Failure to follow resistance management guidelines carefully will likely result in the loss of these new fungicides as effective control measures.

GENERAL DISCUSSION (Cont.)

- It is essential to use a management program to prevent or delay the buildup of resistant strains, in order to maintain and prolong the useful life of the most effective fungicides. Attempting to manage resistance after it has developed is far more difficult than prevention.

- Phenylamide and strobilurin are “single site” fungicides, because they interfere with a single metabolic pathway in the pathogen. In this case, only a single mutation in the pathogen population is needed for resistance to develop. The development of resistance to this type of fungicide can be extremely rapid.

- Copper fungicides are “multi site” fungicides because they interfere with multiple metabolic sites in the pathogen. Several mutations must occur simultaneously before resistance to fungicides of this type can develop. The resistance results from the modification of several genes, and develops somewhat gradually over time. Increasing the fungicide application rate or the frequency of application improves performance, but continued use could eventually result in complete loss of control.

- It is best to limit high-risk fungicides to no more than two consecutive sprays during the crop or as recommended by their manufacturers.

- High-risk fungicides should be used early in the epidemic when the pathogen population is low. The tactic of using high-risk fungicides as curatives (eradicants) is inconsistent with good resistance management. Resistance can develop quickly when fungicides are used curatively because far higher numbers of the pathogen are available for selection and survival, and intermediate resistance can more easily be selected.

- High-risk fungicides should be used at the manufacturer’s recommended full rate and application interval. Reduced rates could increase the populations of pathogen strains that are of intermediate resistance.

Fungicide use and timing

- Systemic fungicides such as Amistar, Cabrio, Ridomil Gold MZ and Ridomil Gold Plus should be used early, when infections are first noted, usually at the initial flower head formation or initial button stage. A spray mixture of Amistar or Cabrio with copper fungicide should also be considered for fungicide resistance management.

- The number of spray applications will depend on locations, disease pressure, climatic conditions, cultivar susceptibility and crop growth.

- Under low disease pressure and conditions that are not favourable to the disease, one to two systemic fungicide applications applied at the initial button stage appear to be sufficient for white blister control. Under high disease pressure and favourable conditions, at least four fungicide applications may be required for effective control of leaf and head infections.

- In commercial practice, it is typical to apply up to two systemic fungicide applications in each planting at the initial flower head formation. Therefore, in order to reduce long-term exposure of the pathogen to a fungicide and hence reduce the risk of fungicide resistance, a block of two spray applications of a systemic fungicide should be considered. For example, apply two applications of Ridomil Gold MZ in one planting, followed by two applications of Amistar SC in the next planting.

- Copper fungicides should be considered on crops that are approaching maturity in order to prevent head infections, following the early systemic fungicide applications.

- Apart from fungicide control methods, growers should also adopt an integrated disease management strategy that incorporates the use of fungicides along with other management practices such as resistance cultivars, crop rotations and reducing multiple planting for long-term and sustainable disease control.

TECHNOLOGY TRANSFER

- Detailed efficacy trial reports were sent to the appropriate agricultural chemical companies in 2005, 2006 and 2007.
- Workshop meeting held with Dr. Elizabeth Minchinton at Werribee on 6 May 2005 to review and extend project studies and exchange information.
- Project outcomes were presented at a Tasmanian vegetable extension day held at Devonport on 27 July 2005.
- Project outcomes were presented at the Brassica Disease Workshop on 10 November 2005 at Forth, Tasmania.
- A flyer on white blister - fungicide resistance management that was prepared in consultations with Syngenta Crop Protection Pty Ltd and Nufarm Australia Limited, was distributed to growers and consultants in 2005 and 2006.
- Progress of the project studies was presented and discussed at the Brassica Review Meeting with HAL and industry representatives on 13th March 2006 at Coogee, NSW.
- Project outcomes presented at a Tasmanian vegetable extension day held at Ulverstone on 25 July 2006.