VG96014
Management of Pest Constraints to quality and production of melon

J Brown, H Martin, L Vawdrey
Queensland Horticulture Institute

Know-how for Horticulture™

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MANAGEMENT OF PEST CONSTRAINTS TO QUALITY AND PRODUCTION OF MELONS

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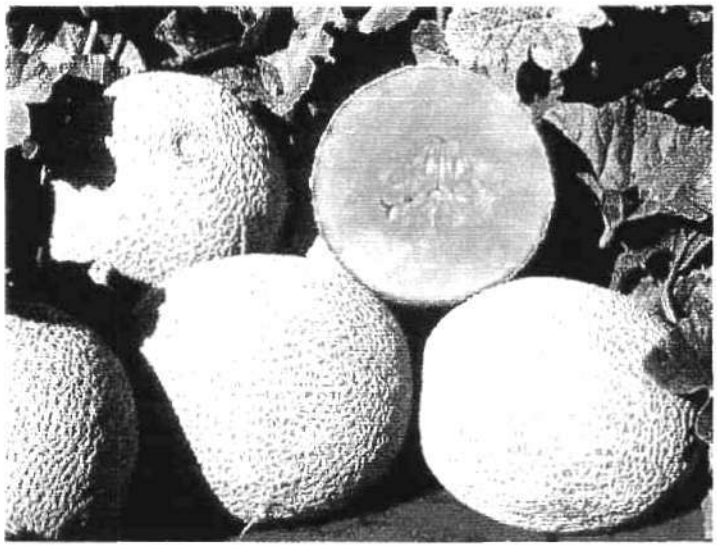

Final Report

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1. INDUSTRY SUMMARY

1.1 Introduction

The project involved field, laboratory and glasshouse studies towards the development of sound pest management systems for melons. Emphasis was focus on three major pest problems. Two are major diseases, downy mildew and gummy stem blight and the third component on fruit chewing caterpillars. All of these pests cause yield losses and reduce quality of fruit in cucurbit crops grown in all districts.

1.2 Downy mildew

Resistance to phenylamide fungicides (Ridomil®MZ, Galben®M, Recoil®, Fruvit®) was found to be widespread in the Burdekin/Bowen district. Phenylamides were ineffective for control of all except one of the downy mildew isolates collected from cucurbit crops during this study. Resistance was confined to the phenylamides. No resistance to alternative registered and experimental systemic fungicides (Acrobat®MZ, Azoxystrobin WG) was detected.

Glasshouse trials identified Acrobat®MZ and Azoxystrobin WG as highly effective alternative systemic fungicides to Ridomil®MZ for control of phenylamide-sensitive and resistant downy mildew.

Dimethomorph has recently been registered as an alternative systemic fungicide and several other products are currently pending registration for control of this disease.

Recommendations for a downy mildew anti-resistance management strategy include:

1. Phenylamide fungicide (Ridomil®MZ, Galben®M, Recoil®, Fruvit®) use should be discontinued in the Burdekin/Bowen district for control of cucurbit downy mildew
2. Protectant fungicides should form the basis of spray programs (application at 7 day intervals). Systemic fungicides (Acrobat®MZ and Azoxystrobin WG (pending registration)) should be used sparingly (not more than 4 sprays per crop), in rotation, and timed to combat early infection following periods of rain or heavy dew.

1.3 Gummy stem blight

Under conditions of a severe disease epiphytotic, weekly applications of azoxystrobin (300g a.i./ha) alone were superior to all other spray schedules for the control of gummy stem blight. Azoxystrobin (300g a.i./ha) alone and azoxystrobin (300g a.i./ha) alternated with chlorothalonil (1500 g a.i./ha) produced more marketable fruit than all other treatments.

1.4 Fruit chewing caterpillars

Heliothis and Cucumber Moth are considered to be the main insect pests of cucurbit crops. Damage to the vegetative parts of the crop are caused by Cucumber Moth, flowers are damaged by Heliothis and both insect pests cause major damage to the fruit. The value of beneficial insects in controlling these pests is limited and only the egg parasites of Heliothis (*Trichogrammatoidea spp.* and *Trichogramma spp.*) were found in numbers to be of value.

Control by pesticides identified that the biological pesticide MPV mixed with a oil DC Tron Plus and a powdered milk supplement Daisyvite and the synthetic pesticides Orthene and Bifenthrin gave adequate control of Cucumber Moth. These pesticides are also effective against Heliothis and should fit into a program to control Silverleaf Whitefly, a new pest in these crops.

A scouting method to monitor insect pests in crops has been developed around the different growth stages. This method in conjunction with an economic threshold level for vegetative loss gives a more accurate measurement as to when control by pesticides is warranted.

2. TECHNICAL SUMMARY

2.1 Downy mildew

Azoxystrobin WG reduced disease severity more effectively than any other fungicide and it provided long-term residual control. The systemic component of Acrobat®MZ (dimethomorph) was found to be significantly enhanced by the addition of Synertrol® Oil as a spray-tank adjuvant in glasshouse grown cucurbits. The experimental systemic acquired resistance compound CGA245704, was generally highly phytotoxic at concentrations that controlled the disease. In the field, the protectant fungicides, Rover® (chlorothalonil) and Manzate®DF (mancozeb) controlled downy mildew as well as Acrobat®MZ, the most effective systemic fungicide. Agri-Fos® performed comparatively poorly as a foliar spray, both in the glasshouse and the field.

The minimum inhibitory concentrations (MICs) of nine fungicides were established for 12 *P. cubensis* isolates (a known metalaxyl sensitive isolate, a known metalaxyl resistant isolate, and 10 isolates of unknown sensitivity collected from affected cucurbit crops in the Burdekin/Bowen district) in drench trials using cucumber seedlings. The phenylamide fungicides metalaxyl and furalaxyl were ineffective for control of all except one of the *P. cubensis* isolates collected during this study, suggesting that phenylamide-insensitive strains of the pathogen are widespread in this region. No evidence of resistance to effective alternative systemic fungicides (dimethomorph or azoxystrobin) was obtained.

Glasshouse efficacy trials identified Acrobat®MZ and Azoxystrobin WG as highly effective alternative systemic fungicides to Ridomil®MZ for control of phenylamide-sensitive and resistant *P. cubensis* isolates. Azoxystrobin WG reduced disease severity more effectively than any other fungicide ($P<0.05$) when applied as a post-inoculation treatment. Synertrol®Oil, an emulsifiable vegetable oil formulation, significantly ($P<0.01$) enhanced the therapeutic activity of dimethomorph (the systemic component of Acrobat®MZ) when applied as a spray-tank adjuvant to glasshouse-grown cucumbers. The experimental systemic acquired resistance compound CGA245704 caused a severe phytotoxic response in rockmelon cv. Eastern Star at concentrations that afforded control of *P. cubensis*.

In field evaluations, routine applications of the protectant fungicides, chlorothalonil and mancozeb, significantly improved mean rockmelon fruit weights ($P<0.05$) to levels equivalent to Acrobat®MZ, the most effective systemic fungicide. Agri-Fos® performed relatively poorly as a foliar spray, both in the glasshouse and in the field.

2.2 Gummy stem blight

Seven fungicides from different chemical groups were evaluated in 3 field experiments with rockmelons and watermelons for control of gummy stem blight caused by the fungus *Didymella bryoniae*. These experiments were conducted during 1997 and 1998. Gummy stem blight failed to develop in an experiment with rockmelons however the fungicides (g a.i./ha) azoxystrobin (300), procymidone (500) chlorothalonil (1500), metalaxyl plus mancozeb (200+1600) and metiram (160) reduced the severity of downy mildew compared with an unsprayed treatment. Total weight and number of marketable fruit in plots treated with these fungicides increased significantly compared with

untreated plots. Cyproconazole (100) and benomyl (500) were ineffective in reducing the severity of downy mildew compared with an unsprayed treatment.

In an experiment with watermelons, all the previously mentioned fungicides except cyproconazole reduced the severity of gummy stem blight compared with an unsprayed treatment. Cyproconazole was excluded from this experiment as it was shown to be phytotoxic in the experiment with rockmelons. Azoxystrobin was the superior chemical and increased the weight of marketable fruit by 46% compared with untreated plots.

Weekly and fortnightly spray strategies involving the fungicides azoxystrobin (300 and 150 g a.i./ha) and chorothalonil (1500 g a.i /ha) used alone or as mixtures were evaluated in an experiment with watermelons for control of gummy stem blight

2.3 Fruit chewing caterpillars

Sampling of melon crops throughout the Dry Tropics has revealed that a large number of insects from many families within a number of Orders can be found in melon crops. Differences in the types and number of insects collected in melon crops is not influenced by melon varieties to the same extent as to whether and how often the crop is sprayed.

From these collections it has revealed that there are no predators or parasites that are causing a major control of these melon pests other than the egg parasites which can have up to 51% parasitism of *Helicoverpa spp.* eggs. The combination of all of these groups that do feed on these melon pests could be having an overall affect but it is too difficult to measure. Independent measurements of the different insect groups will need to be made under different spraying regimes and using different pesticides to measure the affect of these sprays in managing these insect populations. It has been noted that in crops that are not sprayed frequently, the population of spiders is high and these spiders are feeding on the adult whitefly populations that are beginning to infest melon crops and are becoming a major pest in this area.

The pesticide MPV mixed with a oil DC Tron Plus and a powdered milk supplement Daisyvite and the synthetic pesticides Orthene and Bifenthrin were shown to give adequate control of Cucumber Moth. As these insecticides are also known to be effective against Heliothis in other crops it can be assumed that the if both pests were present then an application of these chemicals should have given control. Of interest is that the biological insecticide Gemstar did not perform as well as the formulation of Bt, another biological insecticide, with similar additives. Also of interest is that Bifenthrin which gave good control of Cucumber moth and is known to control Heliothis has also shown to be effective against Silverleaf Withefly in another study. This will give added support for this chemical to be registered in melon crops.

Monitoring of crops can be time consuming with uncertain results, while the structure sampling method developed, based on 20 points throughout a crop, will offer comparable results over time. A method has been developed for each of the different growth stages, nursery, and transplant to 2 weeks, flowering and fruiting. These methods offer a high degree of certainty to the growers in that the results from the inspections will improve their management of insect pests. Users of this method will

also need to consider the effect of pesticide applications if required during the flowering period on the bee populations.

Results from varying the amount of leaf removed from plants following transplanting on production is not clear-cut. In the *nil* leaf remove treatment where the plants in the three leaf removal periods were of the same age, there was a significant difference in the total number of fruit harvested at the second leaf removal period. Also the results showed that there was no significant difference between the treatments, nil leaf removed 25%, 50%, 75% and 100% leaf removed, in the average total number of fruit harvested. The average total number of fruit harvested ranged from 19.2 in the nil leaf removed treatment to 16.0 in the treatment with all leaf removed.

The time of plant manipulation, at the first true leaf stage and then 1 and 2 weeks later, had no affect on the number of fruit harvested or weight of fruit other than in the treatment with all of the leaf removed. In this treatment the average number of green fruit harvested was significantly higher in the third leaf removal period. As mentioned earlier the control treatment did show a significant difference between the leaf removal periods.

A trend that can be seen from the results, is that the removal of all of the leaf did cause a significant reduction in the number of mature fruit harvested compared to the other treatments. This also showed up in the lower weight of these fruit. This suggests that removal of leaf material from the plants can cause a delay in fruit maturity and size. If harvesting in this trial was delayed then this fruit may have developed to maturity with no difference from the nil leaf removed plants in the number of mature fruit. A problem with having a delay is that the longer the plants are in the field the more exposure they are subjected to by pests, especially diseases.

3. GENERAL INTRODUCTION

3.1 General

In Queensland, melons are an important horticultural industry ($45 million) comprising approximately 63% of total melon production in Australia.

This project was undertaken in three separate sections, downy mildew management, gummy stem blight management and fruit chewing caterpillar management. Each of these sections has been researched independently by three researchers with different expertise.

3.1.1 Downy Mildew

Downy mildew is a constrain to melon production through resistance of the disease to the fungicide Metalaxy. The resistant strains of the disease is found in populations throughout the melon growing areas of Queensland. Metalaxyl and some related chemicals are the only registered systemic chemicals available.

3.1.2 Gummy Stem Blight

Gummy stem blight has also been a continuing constraint to melon production and fruit quality. Current chemical controls recommended the use of protectant fungicides but results are often unsatisfactory when disease pressure is high.

3.1.3 Fruit chewing insects

Cucumber moth and Heliothis continue to cause fruit damage by their direct feeding on the fruit and this contributes to fruit quality problems. Cucumber moth can also cause vine damage especially in young crops.

3.2 Pests

3.2.1 Downy Mildew

Cucurbit downy mildew caused by the fungal pathogen *Pseudoperonospora cubensis* (Berk. et Curt.) Rost. is a common and severe foliar disease of cucurbits in Australia. Rockmelon (*Cucumis melo* L. var. *reticulatus*) and honeydew melon (*C. melo* L. var. *inodorus*) are highly susceptible hosts. Watermelon (*Citrullis lanatus* (Thumb.) Matsum. & Nakai) is affected to a lesser extent.

3.2.2 Gummy Stem Blight

Gummy stem blight (GSB) caused by the fungus *Didymella bryoniae* is an important disease affecting rockmelon, honey-dew (*Cucumis melo.*), and watermelon (*Citrullus lanatus*).

3.2.3 Fruit chewing insects

Information on the ecology of fruit chewing caterpillars Cucumber Moth (*Diaphania indica* (Saunders) and Heliothis (*Helicoverpa armigera* (Hubner) and *H. punctigera*

(Wallengren) in melon crops grown in the dry tropics is lacking and there is a need to formulate a management strategy.

3.3 Symptoms

3.3.1 Downy Mildew

Downy mildew produces small pale, yellow areas on leaves, which enlarge to form brown, angular spots. Affected leaves curl and die. The associated reduction in plant foliage exposes fruit to sunburn and results in poor fruit development. Downy mildew is most severe following warm showery weather or when heavy dews lead to extended periods of leaf wetness.

3.3.2 Gummy Stem Blight

Gummy stem blight causes leaf spots, hypocotyl and stem cankers and fruit rot (Schenck 1968; Persley *et al* 1989). Yield losses of 30% or more have been encountered following prolonged showery weather conditions conducive to the disease.

3.3.3 Fruit chewing insects

Fruit chewing caterpillars feed on the surface of the fruit causing scarring to the skin which downgrades the fruit. In some cases the larvae enter the fruit and this fruit is rejected at harvest. One of the fruit caterpillars, Cucumber Moth is also responsible for vegetative loss and often requires chemical control.

3.4 Controls

3.4.1 General

The availability of cultivar resistance is still many years off, so research is required to evaluate chemicals with curative and systemic activity against these diseases in melon crops.

Routine chemical spraying is currently the primary tactic adopted by cucurbit growers for control of downy mildew, gummy stem blight and fruit chewing insects in the field. Recently, melon growers in the Burdekin/Bowen district of north Queensland have reported poor field control of downy mildew despite adherence to spray programs and control of gummy stem blight is often unsatisfactory when disease pressure is high (Fletcher and Preece 1966), suggesting more effective chemicals need to be found. The lack of different insecticide groups registered to control the fruit chewing insects in melon crops has contributed to unsatisfactory control levels being achieved. This has lead to an increase in the amount of fruit being damaged in the field.

3.4.2 Downy Mildew

Effective control of *P. cubensis* epidemics in the field demands regular applications of both protectant and systemic fungicides. In particular, fungicide mixtures containing phenylamides as their systemic component have been widely used since their registration nearly 20 years ago. Isolates of *P. cubensis* with resistance to the phenylamide fungicide metalaxyl, were first reported in plastic-house grown cucumbers

in Israel (Reuveni *et al.*, 1980), and have since been found in Greece (Georgopoulos and Grigoriu, 1981), Italy (D'Ercole and Nipoti, 1985), the USA (Moss, 1987) and Russia (Grin'ko, 1992). In 1995, resistance to phenylamide fungicides, specifically metalaxyl, was reported in isolates of *P. cubensis* from the Burdekin district of north Queensland and the Murrumbidgee Irrigation Area (MIA) of New South Wales (O'Brien and Weinert, 1995). Since this time melon growers in the Burdekin/Bowen district have reported poor control of the disease in the field.

3.4.3 Gummy Stem Blight

Control of gummy stem blight in field-grown melons is presently based on regular applications of protectant dithiocarbamate and phthalimide fungicides. However, results are often unsatisfactory when disease pressure is high (Fletcher and Preece 1966), suggesting more effective chemicals need to be found

3.4.4 Fruit chewing insects

Control of fruit chewing insects has been restricted to the use of Endosulfan and Carbaryl. Both of these insecticides have limitations in that Endosulfan is being restricted in its use and Carbaryl has little effect against Heliothis.

3.5 Objectives

3.5.1 Downy Mildew

Fungicide resistance screening and fungicide efficacy evaluations were completed in a research program aimed at developing an anti-resistance management strategy for downy mildew. The research reported here aimed to:

- Provide information on resistance to fungicides in cucurbit downy mildew in the Burdekin/Bowen district.
- Assess fungicides for efficacy in control of cucurbit downy mildew.
- Develop an anti-resistance strategy for management of cucurbit downy mildew

3.5.2 Gummy Stem Blight

Examine the efficacy of a range of fungicides from different chemical groups and the strategic use of one of these chemicals in the control of gummy stem blight of watermelon.

3.5.3 Control of fruit chewing caterpillars

To reduce the amount of pesticides by developing components that will fit into an IPM strategy. Some of the research that will add to this strategy included:

- Monitoring of the insects groups in crops and determining their role as beneficials or pests.
- Evaluate insecticides that could fit into this strategy.
- Develop scouting methods that will aide in determining pesticide applications.
- Develop threshold levels on the vegetative growth phase.

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4.1. FUNGICIDE RESISTANCE EVALUATIONS

4.1.1 Fungicide resistance screening of downy mildew from the Burdekin/Bowen district

4.1.1 .1 Introduction

Since O'Brien and Weinert first identified metalaxyl-insensitive strains of cucurbit downy mildew in the Burdekin (1995), no subsequent resistance monitoring program has been completed in this district. Knowledge of the status of fungicide resistance within populations of this pathogen will facilitate the judicious use of fungicides which may help to retard the rate of development of fungicide resistance. This experiment was conducted to determine the current status of fungicide resistance in populations of downy mildew in the Burdekin/Bowen district.

4.1.1.2 Materials and Methods

The minimum inhibitory concentrations (MICs) of nine fungicides for control of *Pseudoperonospora cubensis* isolates were established in drench trials using cucumber seedlings. The minimum inhibitory fungicide concentrations were defined as the lowest concentration of fungicide inhibitory to both disease lesion development and fungal sporulation. Seed of cucumber cv. Crystal Salad was germinated, two seeds per cell, in peat vermiculite mix (1:2) in speedling trays. Seedlings were thinned out, one per cell, and when the first true leaves were emerging, fungicide solutions were applied as soil drenches using syringes, 10mL per cell. Twelve isolates were screened, each in a separate trial.

Each trial comprised nine fungicides applied at nine concentrations and replicated four times as follows:

Treatments	Concentrations (ppm)
1. Metalaxyl (Ridomil®250WP)	1. 0
2. Dimethomorph (Dimethomorph 500WG)	2. 0.1
3. Phosphorous Acid (Agri-Fos®200)	3. 1.0
4. Azoxystrobin (Azoxystrobin 500WG)	4. 2.5
5. Propamocarb (Previcur®)	5. 10
6. Fotesyl-Al (Aliette®WG)	6. 25
7. CGA245704	7. 100
8. Benalaxyl + mancozeb (Galben®M)	8. 250
9. Furalaxyl (Fongarid® 250WP)	9. 1000

The experiments were set up as split-plot designs. Each speedling tray was divided into nine blocks of ten cells, and fungicides were assigned to the blocks at random, such that each tray contained all fungicide treatments. Within each block the fungicide concentrations were randomly assigned to cells.

Seedlings were inoculated with a sporangial suspension 24 h after the treatments were applied. Downy mildew isolates 4906 (collected in 1993 from Gympie ex cucumber) and 4031 (collected in 1993 from Ayr ex rockmelon) were recovered from liquid nitrogen storage at the Indooroopilly Plant Protection Unit. Isolate 4906 was used as a standard metalaxyl-sensitive isolate and isolate 4031 was used as a standard metalaxyl-resistant isolate. All other isolates were collected from a range of cucurbit crops in the Burdekin/Bowen district throughout the 1998-1999 production season. Inoculum was prepared following the method of O'Brien and Weinert (1995).

Inoculum was standardised to 1.0×10^4 sporangia/mL and applied until runoff to all foliar surfaces using a jet-pak spraygun. The speedling trays were incubated in moist plastic bags for 24 h under controlled conditions (22°C, 80%R.H.). Seven days later the plants were again enclosed in bags overnight, after which the two most severely affected leaves from each plant were rated for disease severity. Each leaf was given a rating on a 0-3 scale both for sporulation and % leaf area affected, as follows:

%Leaf Area Affected	Sporulation Index
0 nil disease	0 nil disease
1 <10% leaf area	1 sparse/low
2 10-50% leaf area	2 moderate
3 >50% leaf area	3 intense

4.1.1.3 Results

For the standard sensitive isolate (4906), the minimum inhibitory concentration for metalaxyl fell within the range >2.5-<10ppm (Figure 1, Plate 1) and furalaxyl was effective at >25 - <100ppm. In comparison, at concentrations up to and including 1000ppm, metalaxyl (Figure 1) and furalaxyl (Figure 2) were found to be ineffective for control of the standard resistant isolate 4031 and 7 other isolates collected from affected crops in the Burdekin/Bowen district (120, 196, 205, 200, 202, 216, 288). Two isolates (189, 201) displayed intermediate levels of resistance, being completely inhibited by furalaxyl at 1000ppm (Figure 2), and significantly inhibited (compared to the known resistant isolate 4031) by >250-<1000ppm metalaxyl (Figure 1). A single isolate from a Bowen cucumber crop (208) was controlled by metalaxyl and furalaxyl at 1.0ppm. No shifts in effective concentrations of dimethomorph or azoxystrobin were detected, with concentrations of >250-<1000ppm dimethomorph and >25 - <100ppm azoxystrobin being sufficient to inhibit all isolates (Table 1). Phosphorous acid, propamocarb, fotesyl-Al, CGA245704 and benalaxyl + mancozeb were ineffective for complete control of any of the isolates at fungicide concentrations ≤ 1000ppm (data not presented).

Table 1: MIC Values for *Pseudoperonospora cubensis* isolates

Isolate Number	Minimum Inhibitory Fungicide Concentration (ppm)*			
	Metalaxyl	Furalaxyl	Dimethomorph	Azoxystrobin
Standard sensitive (4906)	>2.5-<10	>25-<100	>250-<1000	>25-<100
Standard Resistant (4031)	-	-	>250-<1000	>25-<100
Isolates 120, 196, 205, 200, 202, 216, 288	-	-	>250-<1000	>25-<100
Isolates 189 and 201	-	>250-<1000	>250-<1000	>25-<100
Isolate 208	>0.1-<1.0	>0.1-<1.0	>250-<1000	>25-<100

*The lowest concentration of fungicide inhibitory to both disease lesion development and fungal sporulation

- Control not achieved at any concentration

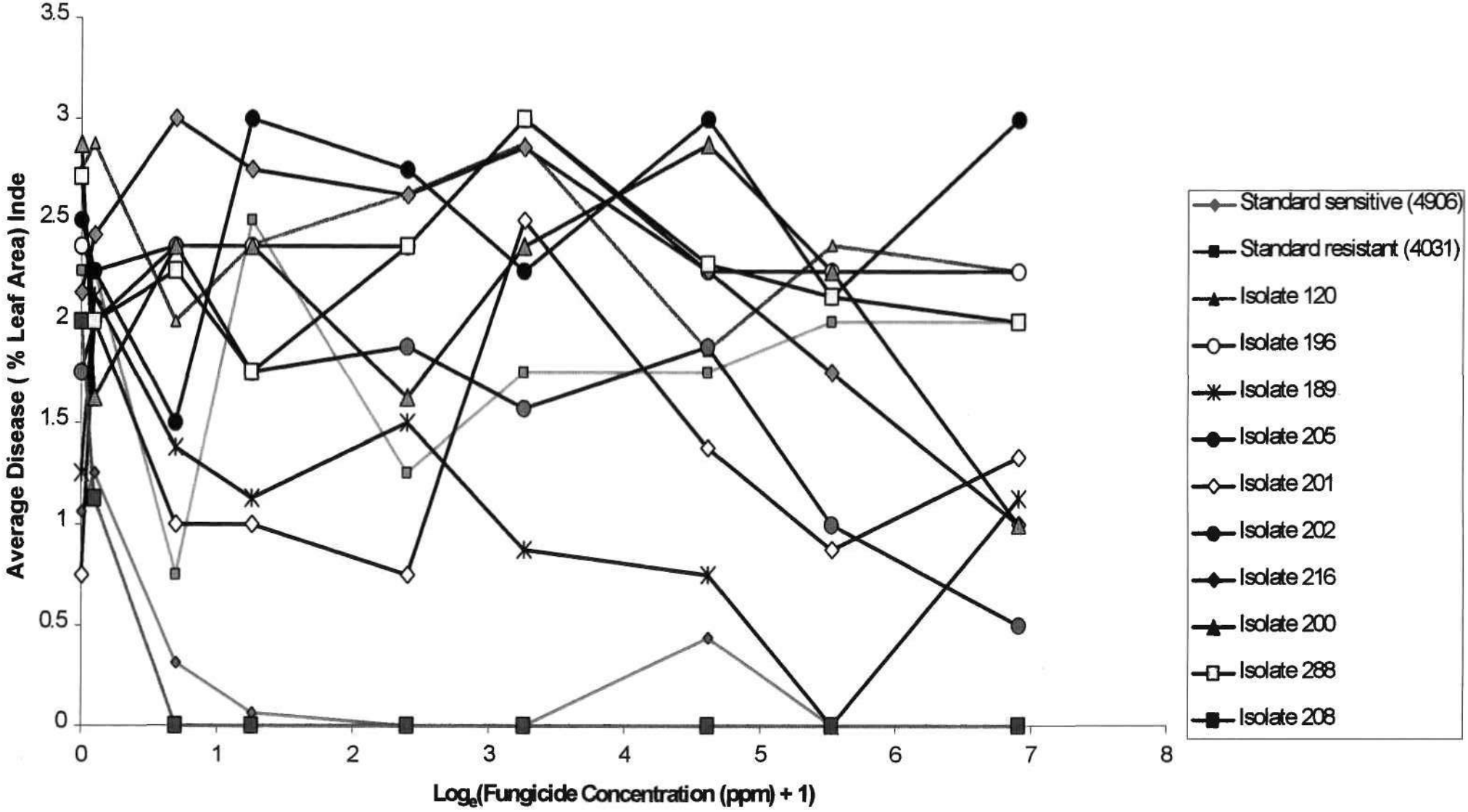

Figure 1: Sensitivity of *Pseudoperonospora cubensis* isolates to metalaxyl

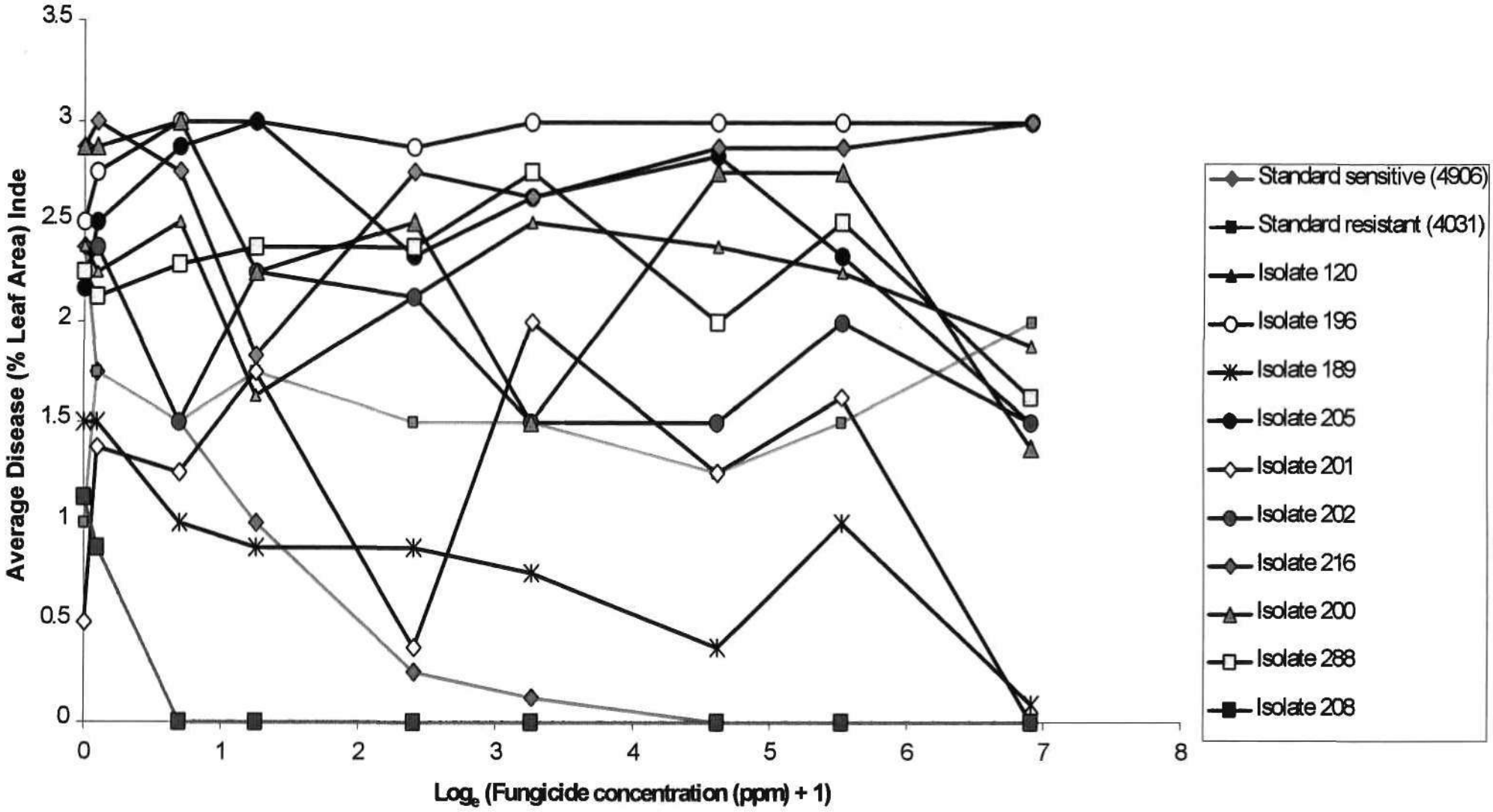

Figure 2: Sensitivity of *Pseudoperonospora cubensis* isolates to furalaxyl

Plate 1. Cucumber seedlings drenched with 0ppm metalaxyl (left) and 25ppm metalaxyl (right) prior to inoculation with the metalaxyl-sensitive *P. cubensis* isolate (4906)

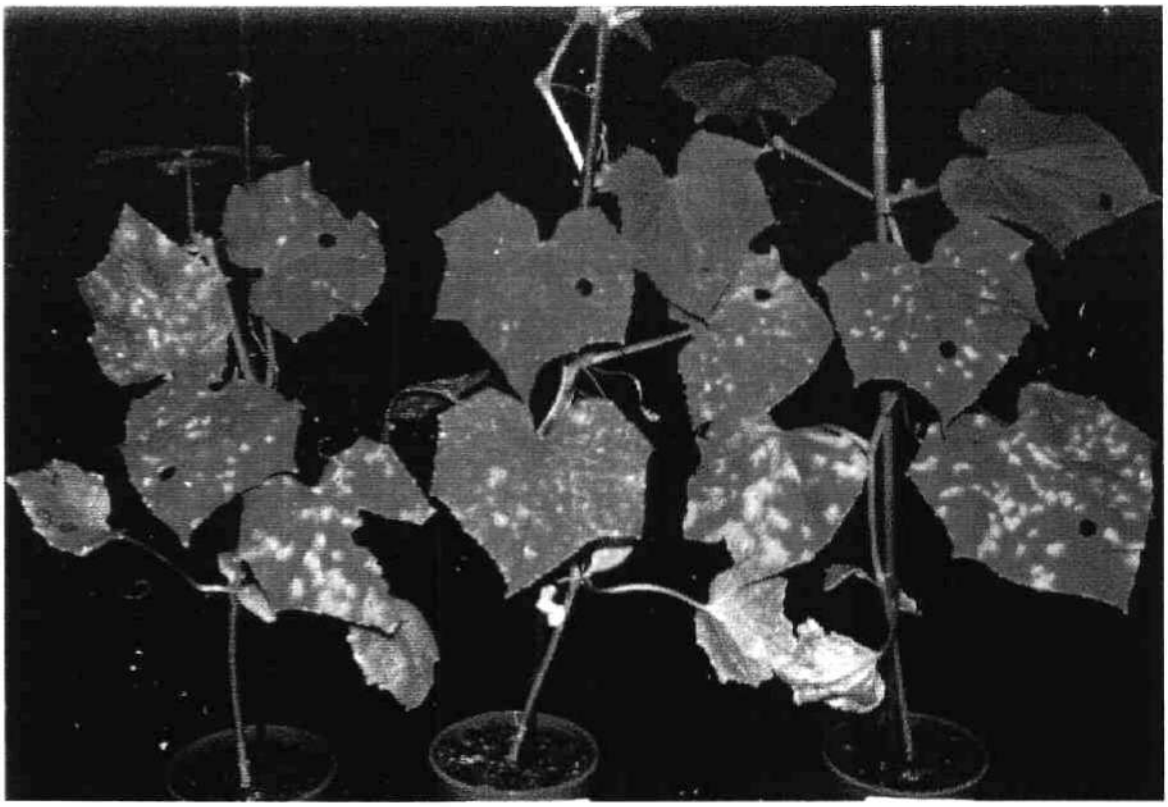

Plate 2. Disease symptom severity on cucumber plants treated with foliar sprays of Ridomil®MZ 720 (left), Acrobat®MZ 690 (centre) and water (right), following inoculation with the phenylamide-resistant *P. cubensis* isolate 196.

4.1.1.4 Discussion

These experiments indicate that resistance to phenylamide fungicides is widespread in the downy mildew populations of the Burdekin/Bowen district. Seven of the isolates were highly resistant to the phenylamide fungicides metalaxyl and furalaxyl. Isolates 189 and 201were resistant to a lesser extent, however it seems likely that the populations from which these isolates were derived are in a transitionary stage. Further selection of more highly resistant strains will occur in these populations if phenylamide fungicides continue to be used at sub-lethal rates in the field. For this reason, the use of phenylamides in downy mildew spray programs is discouraged in this district. The registered field application rate for Ridomil®MZ 720 (a fungicide containing metalaxyl) on cucurbit crops for *P. cubensis* is 2.5kg/ha (16ppm). For the metalaxyl-sensitive isolate 4906, control was achieved at concentrations between 2.5 and 10ppm, and for isolate 208, at 1.0ppm, indicating that field control of these isolates would have been possible with registered rates of this fungicide. In comparison, control of all other isolates was not achieved in our experiments, even at 1000ppm. This fungicide concentration is more than 60 times the registered field rate and therefore, Ridomil®MZ 720 applied at registered rates would not have afforded field control of any of these isolates. The consistent efficacies of both azoxystrobin (MIC: >25-<100ppm) and dimethomorph (MIC: >250-<1000ppm) across all isolates indicates that no resistance to these fungicides has developed in these populations, nor is there cross-resistance between these two fungicide types and the phenylamide fungicides.

4.1.2 Cross Resistance Evaluation

4.1.2.1 Introduction

The phenylamide group of fungicides contains six members, four of which are registered on vegetable crops in Australia (metalaxyl, benalaxyl, oxadixyl, furalaxyl). These fungicides are single-site inhibitors with a high specific efficacy against oomycete plant pathogens, including downy mildews. Cross-resistance within this group of fungicides is known to occur however this has not been formally established in Australia. This experiment was conducted to test whether metalaxyl-insensitive isolates display cross-resistance to other phenylamide fungicides or to other fungicide groups

4.1.2.2 Materials and Methods

Seed of cucumber cv. Crystal Salad was germinated one seed per cell, in peat vermiculite mix (1:2) in speedling trays. After one week seedlings were transplanted into individual five inch pots containing UC mix and were grown until the fifth true leaf was emerging. The plants were inoculated with a sporangial suspension of the metalaxyl-resistant downy mildew isolate 196, in the manner previously described (4.1.2). Each pot was then enclosed in a moist plastic bag and incubated overnight at 23°C and after 24 h 7 treatments were applied to the plants as foliar sprays. Six replicate pots were treated with each of the following:

1. Water control
2. Manzate®DF @ 2.0g/L (750g/kg mancozeb)
3. Ridomil®MZ 720 WP @ 2.5g/L (640g/kg mancozeb + 80g/kg metalaxyl)
4. Fongarid® 250 WP@ 2.5g/L (250g/kg furalaxyl)
5. Recoil® @ 2.5g/L (640g/kg mancozeb + 80g/kg oxadixyl)
6. Galben®M @ 2.5g/L (650g/kg mancozeb + 80g/kg benalaxyl)
7. Acrobat®MZ 690 @ 2.0g/L (600g/kg mancozeb + 90g/kg dimethomorph)

The plants were arranged at random on a glasshouse bench for 7 days, after which they were enclosed overnight in moist plastic bags to induce sporulation. The following day the three youngest leaves from each plant which were showing symptoms were rated for disease severity using a 0-6 scale for % leaf area affected:

0 – nil disease
1 – few chlorotic spots, < 1% leaf area affected
2 – 1-10%
3 - >10-25%
4 - >25-50%
5 - >50-75%
6 - >75%

In addition, three 1.4cm diameter leaf disks were cut one per leaf, from each leaf that was rated for disease severity. The adaxial surface of each disk was examined under a stereo-microscope and rated for sporulation intensity on a 0-3 scale:

0 – nil sporulation
1 – sparse sporulation
2 - moderate sporulation
3 - intense sporulation

4.1.2.3 Results and Discussion

None of the phenylamide fungicides (Ridomil® MZ, Galben® M, Fongarid®, Recoil®) caused significant ($P< 0.05$) reductions in downy mildew symptom development or sporulation intensity in this experiment. Acrobat® MZ (dimethomorph + mancozeb) was the only fungicide that significantly reduced sporulation intensity ($P<0.05$) (Table 2). Acrobat MZ also reduced disease severity more than any other treatment ($P<0.05$), however this reduction was also not significantly different to the control.

Table 2: Mean sporulation intensity on cucumber leaves treated after inoculation with *Pseudoperonospora cubensis* isolate 196

Treatment	Mean Sporulation Intensity (0-3)*
Control	2.40**bc**
Recoil®	2.60**c**
Fongarid®250 WP	2.33**bc**
Manzate® DF	2.27**bc**
Ridomil®MZ 720	2.20**bc**
Galben®M	2.00**b**
Acrobat®MZ 690	1.33**a**
LSD (P<0.05)	0.47

*Treatments followed by the same letters are not significantly different at the 5% level

In ongoing experiments to monitor resistance in Burdekin/Bowen isolates of downy mildew (MIC trials), no differences have been detected in the effective concentrations of dimethomorph or azoxystrobin needed for control of metalaxyl-sensitive or metalaxyl-insensitive isolates.

These results indicate that cross-resistance in downy mildew collected from the Burdekin/Bowen district is confined to fungicides in the phenylamide group.

4.2. FUNGICIDE EFFICACY EVALUATIONS

4.2.1 Glasshouse evaluation of spray adjuvant ability to enhance post-infectional activity of dimethomorph

4.2.1.1 Introduction

Acrobat®MZ, a new fungicide formulation containing dimethomorph as its systemic component, was recently registered for control of downy mildew on cucurbit crops. Spray-tank adjuvants have previously been reported to substantially increase post-infectional activity of dimethomorph against several downy mildew pathogens including *Plasmopara viticola* on glasshouse propagated vines (Grayson *et al.*, 1996) and *Peronospora destructor* on onion seedlings (MacManus *et al.*, 1997). This report details the results of an experiment conducted to examine the ability of a variety of spray adjuvants to enhance the therapeutic activity of dimethomorph for control of cucurbit downy mildew.

4.2.1.2 Materials and Methods

Seed of cucumber cv. Crystal Salad was germinated in flats containing vermiculite. After one week the seedlings were transplanted into individual five inch pots containing UC mix and grown until the third true leaf was emerging. The seedlings were then misted until runoff with a sporangial suspension (1.0×10^4 sporangia/mL) of the metalaxyl-sensitive *P. cubensis* isolate 4906 using a Preval® atomiser. Each pot was enclosed in a moist plastic bag and incubated overnight at 22°C. After 48 hours the treatments were applied until runoff to all foliar surfaces with a gas powered sprayer. Four replicate pots were treated with each of the following:

1. Dimethomorph 500WP @ 2g/L
2. Dimethomorph 500WP @ 2g/L + Pulse Penetrant® (1mL/L)
3. Dimethomorph 500WP @ 2g/L + Synertrol Oil® (2mL/L)
4. Dimethomorph 500WP @ 2g/L + Codacide® (1.5mL/L)
5. Dimethomorph 500WP @ 2g/L + DCTron Plus® (2mL/L)
6. Dimethomorph 500WP @ 2g/L + Agridex® (2mL/L)
7. Dimethomorph 500WP @ 2g/L + Agral® (2mL/L)
8. Dimethomorph 500WP @ 2g/L + Bond® (1mL/L)
9. H_2O Control

The plants were randomly arranged on a glasshouse bench and maintained at approximately 25°C for three days, after which they were enclosed overnight in moist plastic bags to induce sporulation. The following day, and again two days later, the two most severely affected leaves of each plant were rated for disease severity using a 0-6 scale for % leaf area affected, and a 0-3 rating for sporulation intensity:

% Leaf Area Affected	Sporulation Intensity
0 - nil	0 - nil
1 - few chlorotic spots, <1% leaf area affected	1 - sparse
2 - 1-10%	2 - moderate
3 - >10-25%	3 - intense
4 - >25-50%	
5 - >50-75%	
6 - >75%	

Data were analysed using the one-way analysis of variance (ANOVA) procedure of Genstat for Windows (3.2).

4.2.1.3 Results

Six days after the plants were inoculated, significant ($P<0.05$) reductions in sporulation were evident in plants treated with combinations of dimethomorph and Pulse Penetrant®, Synertrol Oil® or DCTron Plus®, compared to plants treated with dimethomorph alone (Table 3).

TABLE 3: Mean sporulation intensity on cucumber leaves infected with isolate 4906, six days after inoculation

Treatment	Mean Sporulation Intensity (0-3)*
H_2O Control	3.00**e**
Dimethomorph	1.38**cd**
Dimethomorph + Pulse Penetrant®	0.25**a**
Dimethomorph + Synertrol Oil®	0.50**ab**
Dimethomorph + DCTron Plus®	0.50**ab**
Dimethomorph + Codacide®	1.00**abc**
Dimethomorph + Agridex®	0.88**abc**
Dimethomorph + Agral®	1.33**bcd**
Dimethomorph + Bond®	1.88**d**
LSD ($P<0.05$)	0.85

* Treatments with the same letters are not significantly different at the 5% level

At a second rating time, eight days after inoculation, disease severity and sporulation were not significantly different on plants treated solely with dimethomorph and those to which no fungicide or adjuvant treatments had been applied (Table 4).

TABLE 4: Mean disease severity and sporulation on cucumber leaves infected with isolate 4906, eight days after inoculation

Treatment	Mean Rating	
	Disease Severity (%Leaf Area Affected) (0-6)	Sporulation Intensity (0-3)
Dimethomorph	4.75	2.25
H_2O Control	5.75	3.00
LSD (P<0.05)	1.74	0.77

However, the application of Synertrol Oil®, Pulse Penetrant®, Codacide®, DCTron Plus® or Agridex® along with dimethomorph, resulted in significant reductions in fungal sporulation and disease severity (Table 5). Synertrol Oil was the most effective adjuvant, causing reductions in disease severity which were significant at the 1% level.

TABLE 5: Mean disease severity and sporulation on cucumber leaves infected with isolate 4906, eight days after inoculation

Treatment	Mean Rating	
	Disease Severity (% Leaf Area Affected) (0-6)*	Sporulation Intensity (0-3)*
Dimethomorph	4.75**c**	2.25**bc**
Dimethomorph + Pulse Penetrant®	2.63**ab**	1.13**a**
Dimethomorph + Synertrol Oil®	1.88**a**	1.13**a**
Dimethomorph + Codacide®	2.75**ab**	1.25**a**
Dimethomorph + DCTron Plus®	2.50**ab**	0.88**a**
Dimethomorph + Agridex®	2.75**ab**	0.88**a**
Dimethomorph + Agral®	3.33**abc**	1.50**ab**
Dimethomorph + Bond®	4.13**bc**	2.50**c**
LSD (P<0.05)	1.74	0.77

* Treatments with the same letters are not significantly different at the 5% level

4.2.1.4 Discussion

Under field conditions the newly registered fungicide Acrobat®MZ will most commonly be applied as a curative chemical subsequent to downy mildew infection of cucurbit crops. When applied in this way, the efficacy of the fungicide will depend on the penetrative and translocative properties of dimethomorph, the systemic component of Acrobat®MZ. This experiment has identified several spray-tank adjuvants including Synertrol Oil®, Pulse Penetrant®, Codacide®, DCTron Plus® and Agridex® which show promise in enhancing the therapeutic activity of dimethomorph. These adjuvants tended to delay or inhibit sporulation of the pathogen, and hence may prove useful in slowing the development of disease epidemics in field plantings if applied routinely. Synertrol Oil®, an emulsifiable vegetable oil formulation, was particularly effective.

4.2.2 Comparison of fungicide pre and post-infection activity in combination with Synertrol Oil®

4.2.2.1 Introduction

A previous trial (5.1) identified Synertrol Oil® as a potentially useful spray adjuvant for increasing the post-inoculation efficacy of dimethomorph. This glasshouse experiment was designed to evaluate the systemic activities of a range of fungicides applied as foliar sprays, with or without Synertrol Oil® as a spray-tank adjuvant.

4.2.2.2 Materials and Methods

Seed of cucumber cv. Crystal Salad was germinated in flats containing vermiculite. After one week the seedlings were transplanted, one per pot, into 160 five inch pots containing UC mix and grown until the fourth true leaf was emerging. Treatments were applied at recommended rates until runoff to the foliar surfaces of half of the plants using a gas powered sprayer. Four replicate pots were treated with each of the following:

1. H_2O Control
2. H_2O Control + Synertrol Oil® (2mL/L)
3. Acrobat®MZ @ 2.0g/L
4. Acrobat®MZ @ 2.0g/L + Synertrol Oil® (2mL/L)
5. Ridomil® MZ @ 2.5g/L
6. Ridomil® MZ @ 2.5g/L + Synertrol Oil® (2mL/L)
7. Manzate®DF @ 2.0g/L
8. Manzate®DF @ 2.0g/L + Synertrol Oil® (2mL/L)
9. Agri-Fos®400 @ 6mL/L
10. Agri-Fos®400 @ 6mL/L + Synertrol Oil® (2mL/L)
11. Azoxystrobin WG @ 0.4g/L
12. Azoxystrobin WG @ 0.4g/L + Synertrol Oil® (2mL/L)
13. Aliette® WG @ 2.5g/L
14. Aliette® WG @ 2.5g/L + Synertrol Oil® (2mL/L)
15. Previcur® @ 4.0mL/L
16. Previcur® @ 4.0mL/L + Synertrol Oil® (2mL/L)
17. CGA245704 @ 0.05g/L
18. CGA245704 @ 0.05g/L + Synertrol Oil® (2mL/L)
19. Bravo® SC @ 3.0g/L
20. Bravo® SC @ 3.0g/L + Synertrol Oil® (2mL/L)

Once the treated plants were dry, all 160 plants were misted until runoff with a sporangial suspension (1.0×10^4 sporangia/mL) of the metalaxyl-sensitive *P. cubensis* isolate 4906 using a Preval® atomiser. Each pot was enclosed in a moist plastic bag and incubated overnight at 22°C. After 48 h treatments were applied, four replicates per treatment, to the remainder of the plants in the manner previously described.

All plants were randomly arranged on a glasshouse bench and maintained at approximately 25°C for four days, after which they were enclosed overnight in moist plastic bags to induce sporulation. The following day the two most severely affected leaves of each plant were rated for disease severity using a 0-6 scale for % leaf area affected:

0 - nil disease
1 - few chlorotic spots, < 1% leaf area affected
2 - 1-10%
3 - >10-25%
4 - >25-50%
5 - >50-75%
6 - >75%

Data were analysed using the analysis of variance (ANOVA) procedure of Genstat for Windows (3.2).

4.2.2.3 Results

All the fungicides caused significant ($P<0.05$) reductions in disease severity when applied as pre-inoculation treatments, however, Acrobat® MZ, Ridomil® MZ, Manzate®DF, Azoxystrobin WG, Previcur® and Bravo®SC gave significantly better ($P<0.05$) control than Agri-Fos®, Aliette®WG or CGA245704 (Table 6, Plate 3).

TABLE 6: Mean disease severity on cucumber leaves treated prior to infection with *Pseudoperonospora cubensis* isolate 4906

Treatment	Mean Disease Severity (% Leaf Area Affected) (0-6)*
H_2O Control	4.63e
Acrobat®MZ	0a
Ridomil®MZ	0a
Manzate®DF	0a
Azoxystrobin WG	0a
Previcur®	0a
Bravo®SC	0.17a
Agri-Fos®	1.04b
Aliette®WG	1.67c
CGA245704	3.58d
LSD ($P<0.05$)	0.52

* Treatments followed by the same letters are not significantly different at the 5% level

Azoxystrobin WG displayed the best systemic activity, resulting in significantly ($P<0.05$) better post-inoculation control than Acrobat®MZ or Ridomil®MZ, both of which gave better control when applied post-inoculation than any of the other fungicides (Table 7, Plate 4).

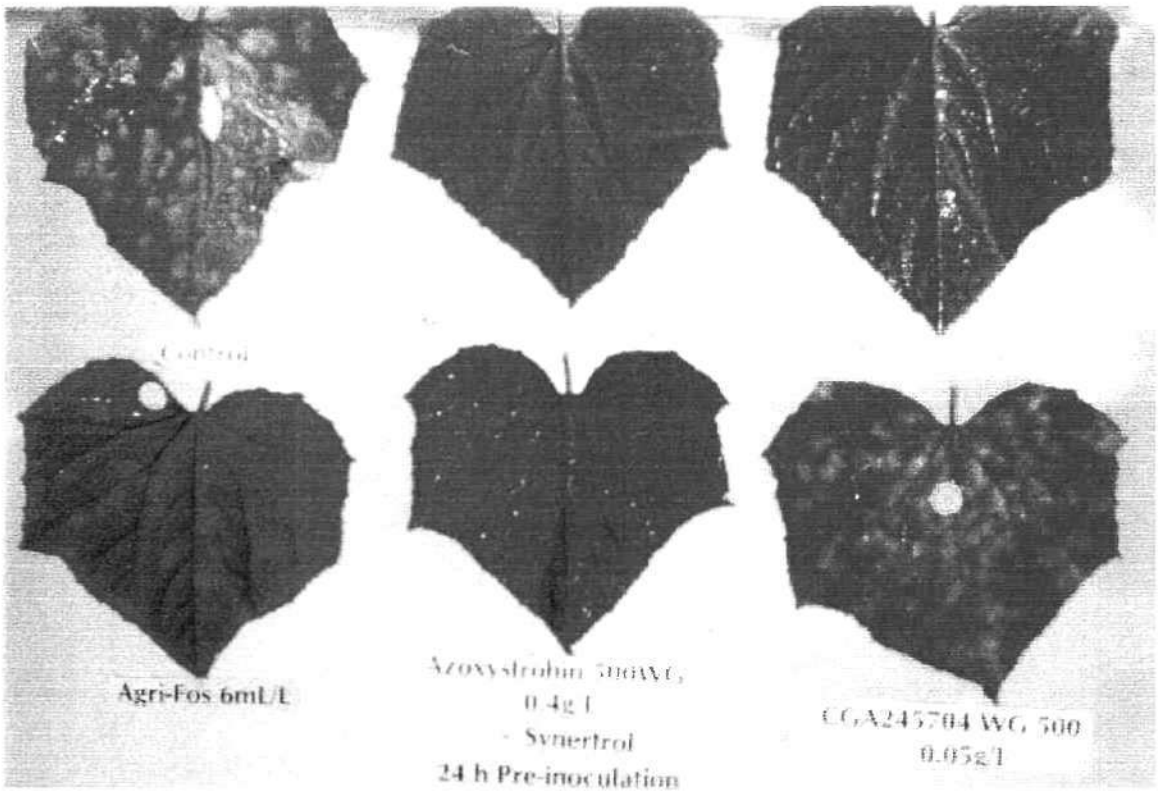

Plate 3. Downy mildew symptom severity on cucumber leaves treated with foliar fungicide applications prior to inoculation with the phenylamide-sensitive isolate 4906.

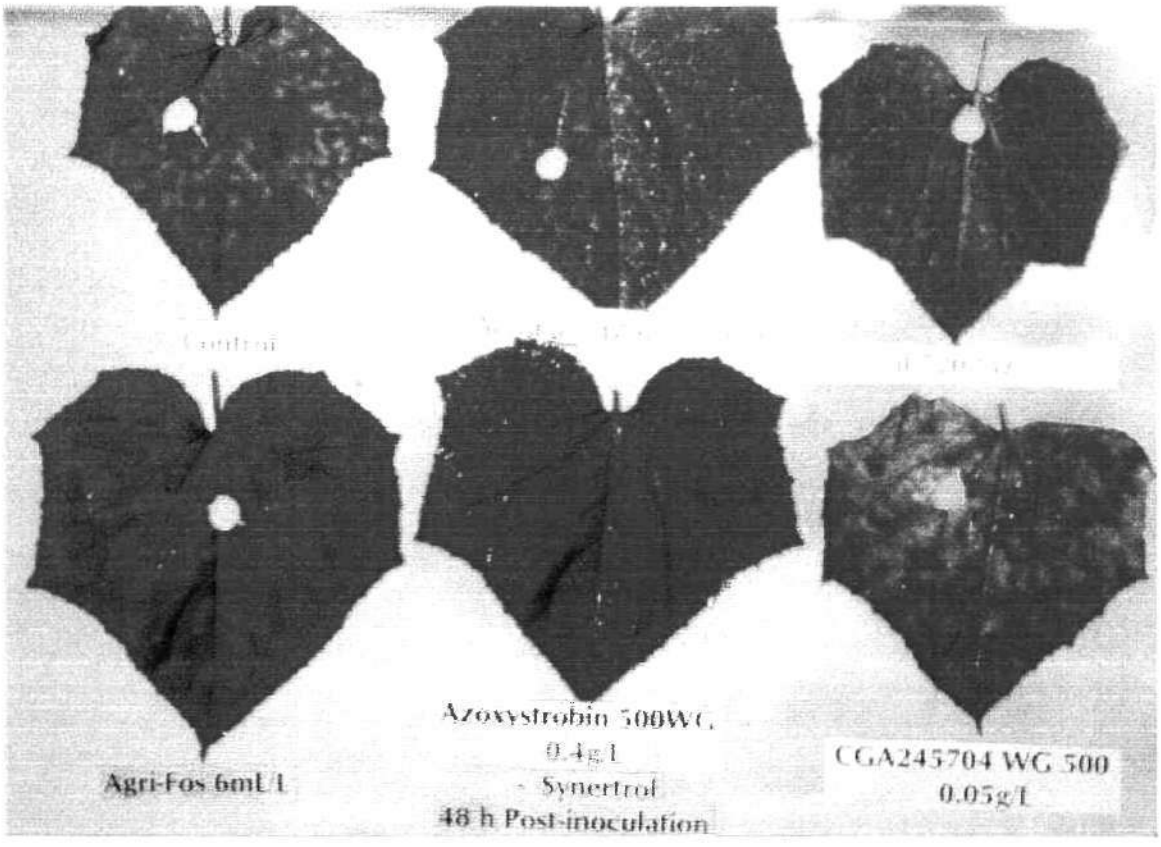

Plate 4. Downy mildew severity on cucumber leaves treated with foliar fungicide applications after inoculation with the phenylamide-sensitive isolate 4906

Table 7: Mean disease severity on cucumber leaves treated after inoculation with *Pseudoperonospora cubensis* isolate 4906

Treatment	Mean Disease Severity (% Leaf Area Affected) (0-6)*
H_2O Control	4.92**e**
Acrobat®MZ	1.46**b**
Ridomil®MZ	1.58**b**
Manzate®DF	1.92**bc**
Azoxystrobin WG	0.29**a**
Previcur®	2.17**c**
Bravo®SC	5.21**e**
Agri-Fos®	2.83**d**
Aliette®WG	3.04**d**
CGA245704	5.25**e**
LSD (P<0.05)	0.52

* Treatments followed by the same letters are not significantly different at the 5% level.

Bravo®SC and CGA245704 showed the poorest systemic activity and gave no significant reduction in either disease severity or sporulation when applied as post-inoculation treatments (Table 5). Agri-Fos® also displayed relatively poor systemic activity, effectively inhibiting sporulation when applied pre-inoculation but causing only limited reductions in severity and sporulation when applied as a post-inoculation treatment (data not presented).

The addition of Synertrol Oil® caused disease severity to be significantly (P<0.05) reduced in post-inoculation treatments, however it tended to cause phytotoxicity symptoms when applied in combination with Azoxystrobin WG, Previcur® or Bravo® SC (data not presented).

4.2.2.4 Discussion

Routine chemical spraying is currently the primary tactic adopted by cucurbit growers for downy mildew control. Effective chemical control requires knowledge of the relative efficacies of a range of fungicides when applied either for their protective or curative properties.

With the recent development of resistance to metalaxyl (the systemic component of Ridomil®MZ) in populations of *P. cubensis*, new chemicals with systemic activity must be found as replacements. In this experiment Acrobat®MZ, a recently registered fungicide, provided post-infectional control levels of a metalaxyl-sensitive downy mildew isolate equivalent to those achieved by Ridomil®MZ, and offers an effective alternative systemic treatment. The experimental compound Azoxystrobin WG surpassed both Ridomil®MZ and Acrobat®MZ as a curative treatment, however, showing the best systemic activity of any of the fungicides tested. The relatively poor systemic activity offered by Agri-Fos® indicates that this chemical may be better applied as a protectant.

Results from this trial support evidence from a previous trial (5.1) that Synertrol Oil® may significantly increase the therapeutic activity of fungicides applied as post-infectional treatments.

4.2.3 Glasshouse evaluation of the systemic capacity of fungicides for *P. cubensis* control

4.2.3.1 Introduction

A previous trial (5.2) indicated that Azoxystrobin WG, when applied as a post-inoculation treatment, was more effective than either Acrobat®MZ or Ridomil®MZ for control of the metalaxyl-sensitive *P. cubensis* isolate 4906. This experiment was designed to determine the duration of control of *P. cubensis* offered by single applications of a range of systemic fungicide formulations.

4.2.3.2 Materials and Methods

Seed of cucumber cv. Crystal Salad was germinated, two seeds per cell, in peat vermiculite mix (1:2) in speedling trays. Seedlings were thinned out, one per cell, and when the first true leaf was emerging they were transplanted, one per pot, into five inch pots containing sterile UC mix. The plants were arranged on benches in a glasshouse and were watered via overhead irrigation, twice daily for two minutes. Temperatures in the glasshouse ranged between 20 and 28°C. At three weeks of age the plants were staked, and when the fourth true leaves were emerging, treatments were applied at recommended rates until runoff using a gas-powered sprayer. Twenty pots were treated with each of the following:

1. H_2O Control
2. Ridomil®MZ 720 @ 2.5g/L
3. Acrobat®MZ 690 @ 2.0g/L
4. Agri-Fos® 200 @ 12mL/L
5. Azoxystrobin WG @ 0.4g/L
6. Galben®M @ 2.5g/L
7. CGA245704 @ 0.05g/L

After treatment the plants were placed in their treatment groups on glasshouse benches. One day after treatment, four replicate plants from each treatment group were misted with a sporangial suspension (1.0×10^4 sporangia/mL) *P. cubensis* isolate 120. This isolate was collected from unsprayed rockmelon plants at DPI Ayr Research Station on 12/5/98. Inoculum was prepared following the method of O'Brien and Weinert (1995). Each pot was enclosed in a moist plastic bag and incubated overnight at 22°C. After incubation the plants were removed from the bags and placed on benches in a glasshouse. This process was repeated with groups of plants four days, eight days and eleven days after treatment with the fungicides.

Seven days after inoculation, the plants were again enclosed overnight in moist plastic bags to induce sporulation. The following day, the three oldest leaves on each plant were rated for disease severity using a 0-6 scale for % leaf area affected:

0 - nil disease

1- few chlorotic spots, < 1% leaf area affected
2 - 1-10%
3 - >10-25%
4 - >25-50%
5 - >50-75%
6 - >75%

In addition, the adaxial surface of each leaf was examined under a stereo-microscope and rated for sporulation intensity on a 0-3 scale:

0 - nil sporulation
1 – sparse sporulation
2 – moderate sporulation
3 – intense sporulation

4.2.3.3 Results

Azoxystrobin WG and Acrobat ®MZ offered the best control of infections that occurred soon after the fungicide applications. Both treatments completely inhibited disease lesion development and fungal sporulation one day after application (Figure 3, 4). After four days Azoxystrobin WG continued to offer complete control of lesion development and sporulation and Acrobat®MZ restricted severity and sporulation to levels which were not significantly (P>0.05) greater than those plants treated with Azoxystrobin WG (Table 9, Figure 4). Ridomil®MZ was also effective in restricting lesion development from infections one and four days after application, however it was not as inhibitory to sporulation as either Azoxystrobin WG or Acrobat®MZ at these two times (Table 9, Figure 4). Azoxystrobin WG and Acrobat®MZ also gave the best control of lesion development eight days after application. At this time Axoxystrobin WG was also the best inhibitor of sporulation, whereas Acrobat®MZ was unable to limit sporulation to levels which were significantly (P>0.05) different to those in untreated control plants (Figure 4).

CGA245704 was poor for control of early infections. One day after application, CGA245704 failed to cause significant (P>0.05) reductions in either disease severity or sporulation. At four and eight days however, CGA245704 reduced both severity and sporulation to levels equivalent to those achieved by Azoxystrobin WG, the best fungicide treatment at these times, and was significantly (P<0.05) better than all other treatments in limiting severity and sporulation eleven days after application (Figure 3, 4).

Galben®M and Agri-Fos® caused significant (P<0.05) reductions in both disease severity and sporulation of early infections (when compared to untreated controls). In all cases however, these products were significantly (P<0.05) inferior to Azoxystrobin WG, Acrobat®MZ and Ridomil®MZ for control of early infections and to CGA245704 for control of infections which occurred eight or eleven days after treatment application. Agri-Fos® was particularly poor at eight and eleven days and did not cause reductions in disease severity or sporulation at either time which were significantly (P<0.05) less than levels in the control plants (Figure 3, 4). A summary of the results is given in Tables 8 and 9.

TABLE 8: Mean disease severity (% Leaf Area Affected) (0-6) on cucumber leaves inoculated with *Pseudoperonospora cubensis* isolate 120 after fungicide application

Treatment	Time after Treatment Application (days)			
	1	4	8	11
Acrobat®MZ	0.000a*	0.167a	2.583ab	4.333bc
Azoxystrobin	0.000a	0.000a	1.750a	3.917bc
Ridomil®MZ	1.000a	0.167a	4.500c	3.583b
Galben®M	2.417b	1.167bc	3.083b	4.583cd
Agri-Fos®	3.167bc	1.667c	5.083c	5.500de
CGA245704	4.500cd	0.750ab	2.667ab	1.583a
Control	5.417d	4.750d	5.443c	5.833e
LSD (P<0.05)	1.384	0.775	1.135	0.963

*Treatments followed by the same letters are not significantly different at the 5% level

TABLE 9: Mean sporulation intensity (0-3) on cucumber leaves inoculated with *Pseudoperonospora cubensis* isolate 120 after fungicide application

Treatment	Time after Treatment Application (days)			
	1	4	8	11
Acrobat®MZ	0.000a*	0.083a	2.833c	2.833b
Azoxystrobin	0.000a	0.000a	2.000ab	2.417b
Ridomil®MZ	1.167b	0.167a	2.917c	2.500b
Galben®M	1.375b	1.750b	2.667bc	2.917b
Agri-Fos®	1.083b	1.500b	2.458bc	2.917b
CGA245704	2.750c	0.500a	1.417a	1.500a
Control	2.750c	2.833c	3.000c	3.000b
LSD (P<0.05)	0.689	0.689	0.823	0.795

*Treatments followed by the same letters are not significantly different at the 5% level

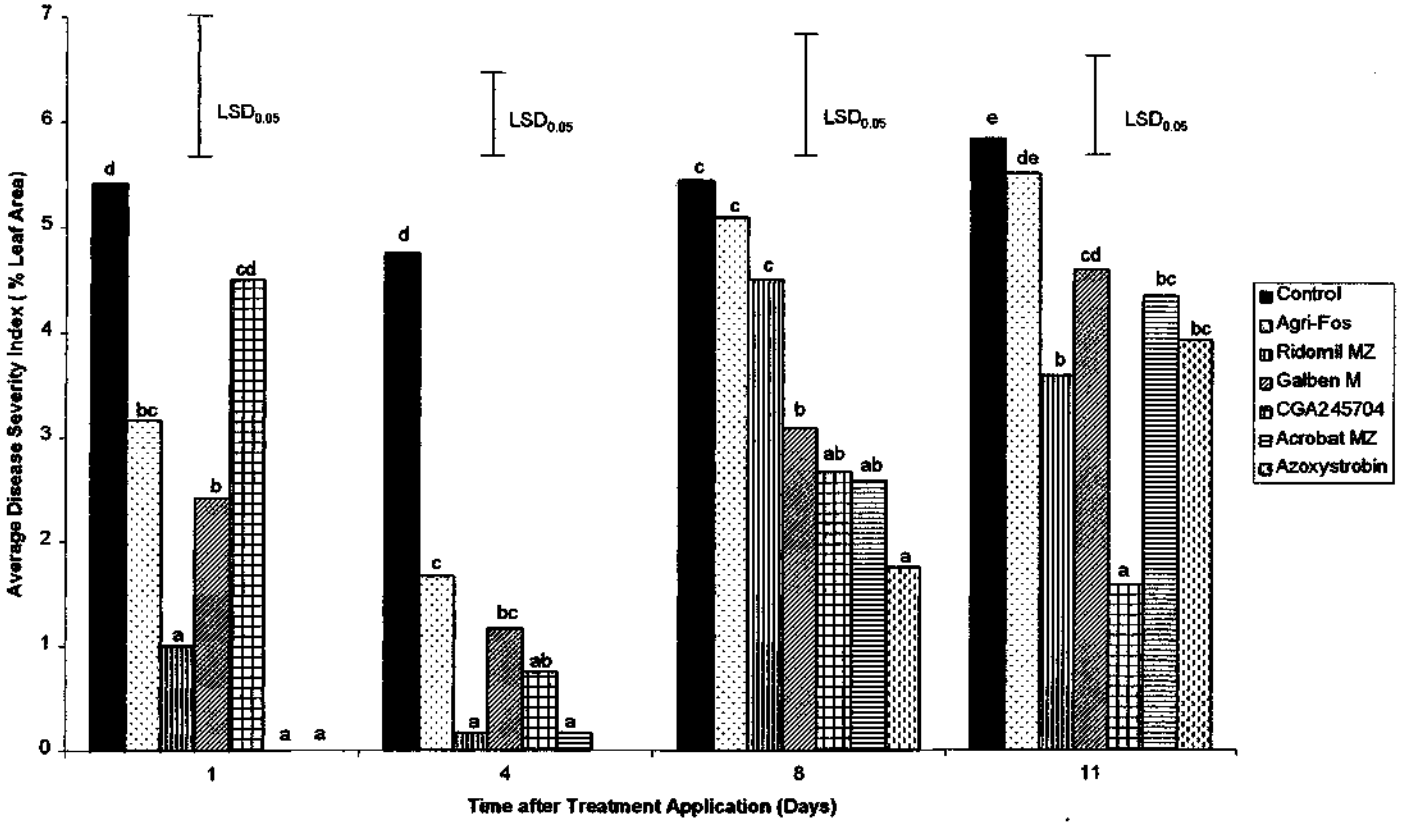

Figure 3: Fungicide efficacy for control of cucurbit downy mildew (isolate 196). Vertical bars represent l.s.d. ($P < 0.05$) within times after treatment. Different letters show significant difference at $P<0.05$

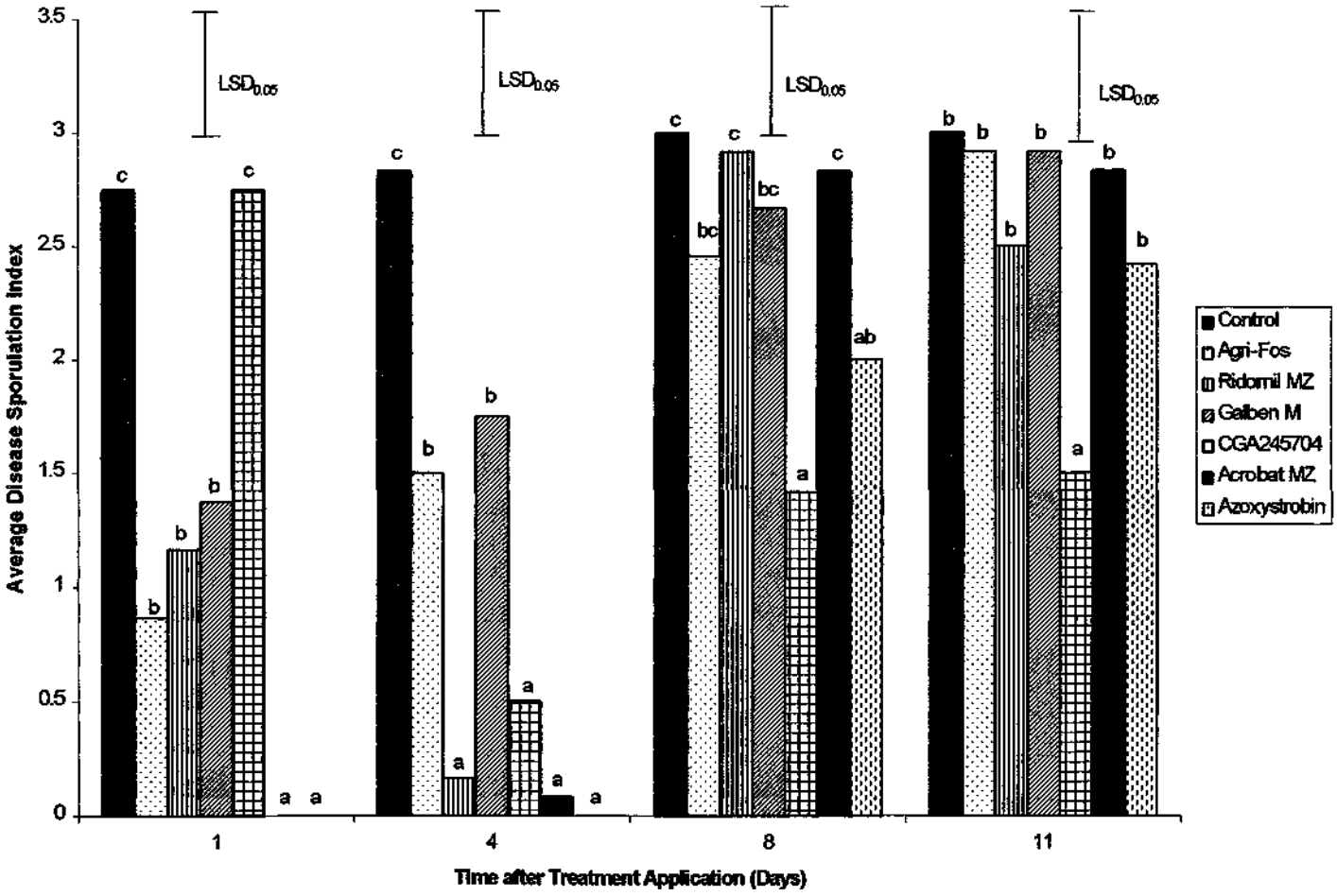

Figure 4: Fungicide efficacy for control of cucurbit downy mildew sporulation (isolate 196). Vertical bars represent l.s.d. ($P<0.05$) within times after treatment. Different letters show significant difference at $P<0.05$

4.2.3.4 Discussion

In this trial, the experimental compound Azoxystrobin WG was superior to Ridomil®MZ for control of *P. cubensis* infections which occurred up to 8 days after an application of the fungicide. The systemic activity of Acrobat®MZ, a recently registered fungicide, was also sufficient to control disease lesion development for up to eight days after application. This result indicates that the recommended spray interval of 7-10 days, on the label of Acrobat®MZ is appropriate to ensure adequate disease control. In comparison, Ridomil®MZ was only successful in controlling infections which occurred within four days of spraying.

The experimental product CGA245704 is a systemic acquired resistance compound which acts by triggering the plants natural defence response, thereby inducing resistance to a range of pathogens. This mode of action helps to explain why this compound was relatively poor in providing immediate control of downy mildew infection directly after spraying but controlled infections which occurred up to 11 days after the product was applied. This long term systemic activity was unrivalled by any of the other fungicides tested in this experiment. CGA245704 may offer more residual protection in the field and may be of particular benefit to growers if it is applied to protect crops during periods of wet weather. During wet weather periods the short-term curative activity offered by other systemic fungicides may be too short to prevent epidemics from developing.

The relatively poor systemic activity which Agri-Fos® displayed in this experiment confirms the results of earlier trials. Of interest, however, is the conservative levels of control achieved by Agri-Fos® only one day after the product was applied (Figure 3, Table 1). This result indicates that Agri-Fos® may also offer only moderate control when used as a protectant chemical.

4.2.4 Field evaluation of systemic and protectant fungicides for *Pseudoperonospora cubensis* control

4.2.4.1 Introduction

Previous glasshouse trials identified Azoxystrobin WG, Acrobat®MZ and Ridomil®MZ as effective eradicant treatments for control of a phenylamide-sensitive *P. cubensis* isolate. Two field trials were conducted to assess the efficacies of a range of chemicals for controlling a downy mildew population known to contain strains highly resistant to phenylamide fungicides (Isolate 120).

4.2.4.2 Materials and Methods

Field experiments were planted at DPI Ayr Research Station on 16 April 1998 (experiment 1) and 24 June 1998 (experiment 2). Seedlings of rockmelon cv. Eastern Star (experiment 1) and rockmelon cv. Eldarado (experiment 2) were raised in plastic speedling trays and transplanted at 0.5m spacings on ten (1m x 60m) trickle irrigated beds mulched with black plastic. Beds were spaced one metre apart. The experiment was a randomised block design (10 treatments x 4 blocks). Within each block the treatments were applied to plots 1 bed x 12m with 2m guards of untreated plants at each end. The following 10 spray treatments were applied to each block:

1. Untreated control
2. Ridomil®MZ 720 @ 2.5kg/ha
3. Acrobat®MZ 690 @ 2.0kg/ha
4. Galben®M @ 2.5kg/ha
5. Azoxystrobin WG @ 0.4kg/ha
6. CGA245704 @ 0.05kg/ha
7. Agri-Fos®200 @ 12L/ha (foliar application)
8. Agri-Fos®200 @ 10-40L/ha (trickle application) (depending on plant growth stage)
9. Manzate®DF @ 2.0kg/ha
10. Rover®500 @ 3.0L/ha

All treatments were applied using a portable misting unit with a single nozzle. Spray volumes were increased from 1000L/ha to 1450L/ha as the plants grew.

4.2.4.2.1 Experiment 1

The protectant fungicides (Manzate® (mancozeb) and Rover®500 (chlorothalonil)) were applied on six occasions at weekly intervals, and the remaining fungicides were applied three times at 12 day intervals. Spraying commenced 14 days after the seedlings were transplanted into the field. The plants were inspected every seven days for the presence of downy mildew symptoms. Downy mildew was first observed in the unsprayed plots about two weeks after the plants were transplanted. Every seven days, four leaves were collected from four randomly selected tendrils from each plot. The sixth youngest leaf from each selected tendril was excised after counting back the number of leaves from the tendril tips. The leaves were enclosed in plastic bags overnight in order to induce sporulation. Disease severity was assessed by rating each leaf using a 0-6 scale for % leaf area affected:

0 – nil disease
1 – few chlorotic spots, < 1% leaf area affected
2 - 1-10%
3 - >10-25%
4 - >25%-50%
5 - >50%-75%
6 - >75%

In addition, the adaxial surface of each leaf was examined under a stereo-microscope and rated for sporulation intensity on a 0-3 scale:

0 – nil sporulation
1 – sparse sporulation
2 – moderate sporulation
3 – intense sporulation.

The number of plants in each plot were counted and the fruit were harvested 81 days after transplant. The fruit were weighed using an electronic balance and the average fruit weights/plant (kg) were determined. The disease severity and fruit weights were analysed using analysis of variance (ANOVA) to detect the effect of fungicide treatment. Genstat for Windows (3.2) was used for all ANOVA procedures.

4.2.4.2.2 Experiment 2

The protectant fungicides (mancozeb and chlorothalonil) were applied on seven occasions at weekly intervals, and the remaining fungicides were applied four times at 12-14 day intervals. Spraying commenced 14 days after the seedlings were transplanted. The plants were inspected every seven days for disease symptoms and downy mildew was first observed in the unsprayed plots 15 days after the plants were planted out. Fruit were harvested and weighed 70 days after transplant. Severity, sporulation and fruit weight assessments were conducted following the method used in experiment 1(5.4.2.1). In addition the foliar wet weights of plants were also determined. The foliar wet weights and fruit weights were analysed using analysis of variance (ANOVA) to detect the effect of fungicide treatment. Genstat for Windows (3.2) was used for all ANOVA procedures.

4.2.4.3 Results

4.2.4.3.1 Experiment 1

Downy mildew was first observed in untreated control plots approximately 14 days after the speedlings were planted out. After 22 days, there were no significant ($P<0.05$) differences in disease severity between any of the treatments. At 32 days, all of the treatments except CGA245704 had limited disease severity significantly, compared to the untreated control blocks (Table 10).

Acrobat®MZ contained disease levels to the lowest of any of the treatments, however the levels of control achieved by Acrobat®MZ at this time were not significantly different to those from either Manzate®DF or Rover®. The lowest levels of disease after 42 days, occurred in the plots sprayed with Rover®. The control achieved by Rover® was significantly ($P<0.05$) better than that provided by Manzate®, the second best treatment. All the other treatments provided levels of control that were not significantly ($P<0.05$) different from untreated control plots. Average fruit weights were greatest in plots sprayed with Rover®, however there were no significant differences ($P<0.05$) between the weight of fruit from Rover® treated plots or plots sprayed with Manzate®DF or Acrobat®MZ (Table 10).

Treatment with Ridomil®MZ and Azoxystrobin WG also significantly improved average fruit weights compared to weights in control plots ($P<0.05$), however these two chemicals were significantly inferior to Rover®, Manzate®DF or Acrobat®MZ in increasing fruit weights. All other treatments did not significantly improve fruit weights compared to fruit from untreated plots (Table 11).

TABLE 10: Field trial 1: Effect of fungicide spray treatments on severity of cucurbit downy mildew (% leaf area affected) (0-6)

Treatment	Days after transplant		
	22	32	42
Acrobat®MZ	0.000**a**	0.350 **a**	5.750**c**
Manzate®DF	0.000**a**	0.850 **ab**	5.250**b**
Rover®500	0.000**a**	1.100 **abc**	4.100**a**
Azoxystrobin WG	0.000 **a**	1.500**bcd**	5.550**bc**
Ridomil®MZ 720	0.000 **a**	2.200**cde**	5.900**c**
Agri-Fos®200 (foliar)	0.000 **a**	2.300**de**	5.800**c**
Agri-Fos®200 (trickle)	0.100 **a**	2.650**ef**	5.700**bc**
Galben®M	0.000 **a**	2.850**ef**	5.900**c**
CGA245704	0.000 **a**	3.700**fg**	5.900**c**
Control	0.150 **a**	4.000**g**	6.000**c**
LSD (P<0.05)	-	1.110	0.495

*Treatments followed by the same letters are not significantly different at the 5% level

TABLE 11: Field trial 1: Effect of fungicide spray treatments on mean fruit weight/plant (kg) at harvest (81 days after transplant)

Treatment	Mean fruit weight/plant (kg)
Acrobat®MZ	0.983**de**
Manzate®DF	0.993**de**
Rover®500	1.223**e**
Azoxystrobin WG	0.783**bcd**
Ridomil®MZ 720	0.818**cd**
Agri-Fos®200 (foliar)	0.625**abc**
Agri-Fos®200 (trickle)	0.470**a**
Galben®M	0.590**abc**
CGA245704	0.550**ab**
Control	0.488**a**
LSD (P<0.05)	0.249

*Treatments followed by the same letters are not significantly different at the 5% level

4.2.4.3.2 Experiment 2

Downy mildew was first observed in untreated plots 15 days after transplant. After 26 days, disease severity in plots treated with Azoxystrobin WG, Galben®M and Manzate®DF was significantly (P<0.05) lower than levels in the untreated plots. Acrobat®MZ also restricted disease symptom severity to levels which weren't significantly (P<0.05) different to Azoxystrobin WG, Galben®M or Manzate®DF.

Acrobat®MZ had limited disease development more effectively than any other treatments after 43 days, however control by Acrobat®MZ was not significantly ($P>0.05$) different to levels of control from either Rover®, Manzate®DF, Agri-Fos applied as a foliar spray or Galben®M. Azoxystrobin WG and Ridomil®MZ also caused significant severity reductions, however, these two chemicals were inferior to Acrobat®MZ, Rover® or Manzate®DF. CGA245704 and Agri-Fos® applied through the trickle tape did not reduce disease severity compared to the unsprayed plots.

At 50 days, plots treated with Acrobat®MZ, CGA245704, Galben®M, Ridomil®MZ, Manzate®DF, Rover® and Agri-Fos® (foliar spray) all contained comparable levels of disease. Agri-Fos® through the trickle, was the only treatment that did not supply a significant level of control from the untreated plots ($P>0.05$).

After 60 days, Rover® and Acrobat®MZ were the best treatments, however they provided levels of control that weren't significantly ($P>0.05$) different from Ridomil®MZ, Manzate®DF, Galben®M, Azoxystrobin WG or Agri-Fos® (trickle application).

At harvest, 70 days after transplant, the average foliar wet weights of plants sprayed with Manzate®DF, Rover® and Galben®M were significantly greater than those from any other treatments ($P<0.05$). The average foliar wet weights of plants sprayed with other treatments were not significantly different from untreated plants (Table 12).

Average fruit weights were greatest from plots treated with Manzate®DF, Rover® and Acrobat®MZ. These three treatment types also yielded the greatest percentage of marketable fruit (data not presented). Fruit weights and marketable fruit percentages were lowest in plots treated with Agri-Fos® through the trickle and CGA245704. These two products did not improve fruit size or quality from the control plots. Galben®M, Ridomil®MZ, Azoxystrobin WG and Agri-Fos (foliar spray), did improve fruit weights and the marketable percentage of fruit significantly ($P<0.05$) compared to the controls, however, in all cases, these chemicals were significantly inferior to Manzate®DF, Rover® and Acrobat®MZ (the three best treatments) in improving fruit size and marketability (Table 12).

TABLE 12: Field trial 2: Effect of fungicide spray treatments on foliar wet weights of plants and fruit weights at harvest (70 days after harvest)

Treatment	Average foliar wet weight/plant (kg)	Average fruit weight/plant (kg)
Acrobat®MZ	0.555b*	1.865de
Manzate®DF	0.880c	2.103e
Rover®500	0.773c	2.088e
Azoxystrobin WG	0.580b	1.087b
Ridomil®MZ 720	0.608b	1.372bc
Agri-Fos®200 (foliar)	0.533ab	1.080b
Agri-Fos®200 (trickle)	0.388a	0.327a
Galben®M	0.778c	1.555cd
CGA245704	0.388a	0.482a
Control	0.450ab	0.425a
LSD (P<0.05)	0.163	0.382

* Treatments followed by the same letters are not significantly different at the 5% level

4.2.4.4 Discussion

In both of these trials, the protectant chemicals Rover® and Manzate®DF, when routinely applied, controlled downy mildew as well as Acrobat® MZ, the most effective systemic fungicide. The phenylamide fungicides Ridomil®MZ and Galben®M were inferior to Acrobat®MZ in improving fruit size and marketability. This result was expected given the presence of highly phenylamide-resistant fungal types in this population.

Fungi are generally not as at risk of developing strains resistant to multi-site-of-action protectant fungicides, and therefore spray programs aimed at fungicide resistance management should be based on protectant chemicals. The results of these two field trials support this tactic. The protectant chemicals Rover® and Manzate®DF should be used on a strict calendar-schedule basis, as in these experiments.

The experimental compound CGA245704 produced a phytotoxic response in the plants at this concentration. Symptoms of phytotoxicity included leaf chlorosis and necrosis as well as reductions in leaf size and internode length. Fruit size and quality was reduced in response to the toxicity of this compound.

Acrobat®MZ was the only systemic product that provided levels of control comparable to the protectants. Acrobat®MZ should be used sparingly (not more than 4 sprays per crop), with applications being timed to combat early infections after periods of rain or heavy dews. On the basis of these experiments, the use of phenylamide fungicides, for control of populations containing resistant types, would appear to offer no advantages, and indeed it seems likely that applying phenylamides at sub-lethal rates in the field will result in a further development of phenylamide-resistant strains. For this reason, the use of phenylamides in downy mildew spray programs, is discouraged in this district. In order to prevent the selection of fungal strains resistant to Acrobat®MZ, registrations for additional systemic compounds,

which can be used in rotation with Acrobat®MZ need to be sought. Azoxystrobin WG may be one such alternative.

4.2.5 Glasshouse evaluation of the efficacy and phytotoxicity of CGA245705 for control of downy mildew on rockmelon cv. Eastern Star

4.2.5.1 Introduction

The experimental product CGA245704 is a systemic acquired resistance compound which acts by triggering the plants natural defence response, thereby inducing resistance to a range of pathogens. Previous glasshouse and field trials have indicated that this compound is phytotoxic to rockmelon and cucumber plants when applied as a foliar spray at 0.05g/L. This experiment was conducted to determine the efficacy and phytotoxicty of CGA245704 at various concentrations for control of downy mildew on rockmelon cv. Eastern Star.

4.2.5.2 Materials and Methods

Seed of rockmelon cv. Eastern Star was germinated in peat/vermiculite mix in the glasshouse. After 7 days the seedlings were transplanted, two per pot, into 7.5 inch pots containing peat and sand (1:1). Two weeks after transplanting, the plants were sprayed until runoff with eight concentrations of CGA245704, as follows:

1. 0g/L
2. 0.005g/L
3. 0.0125g/L
4. 0.025g/L
5. 0.05g/L
6. 0.1g/L
7. 0.15g/L
8. 0.25g/L

The treatments were applied twice, 7 days apart. Half the plants were inoculated with an isolate of *P. cubensis* (1.0×10^4 sporangia/mL) in distilled water and the remainder were not inoculated. There were 4 replicates per treatment. All plants were incubated overnight at high humidity (22°C), then kept in a glasshouse for 7 days and returned to high humidity for a further 24h. The plants were rated for phytotoxicity using the following 0-6 scale:

0 – no visible phytotoxicity
1 – mild symptoms on < 1 leaf/plant
2 – mild symptoms on < 25% leaves/plant
3 - > 25% of leaves showing moderate symptoms
4 – severe symptoms on > 25 – 50% of leaves
5 – severe symptoms on 50-75% of leaves
6 – severe symptoms on >75% of leaves

In addition, counts of leaf numbers per plant were determined, and each plant was cut from the pot at ground-level and weighed. The three youngest leaves on each inoculated plant which showed disease symptoms were also rated for disease severity using a 0-6 scale for % leaf area affected, and a 0-3 rating for sporulation intensity:

% Leaf Area Affected

0 - nil
1 - few chlorotic spots, <1% leaf area affected
2 - 1-10%
3 - >10-25%
4 - >25-50%
5 - >50-75%
6 - >75%

Sporulation Intensity

0 - nil
1 - sparse
2 - moderate
3 - intense

Disease severity and sporulation were analysed using analysis of variance to detect the effects of CGA concentration. Foliar wet weights were analysed using analysis of variance to detect the effects of CGA245704 concentration and ± inoculation with downy mildew and their interaction. The means produced from the analysis of variance were used in an exponential regression of foliar wet weight versus CGA245704 concentration. Phytotoxicity ratings were analysed using analysis of variance to determine differences between the treatments. Means from the analysis of variance were used in a regression of phytotoxicity versus CGA245704 concentration.

4.2.5.3 Results

CGA245704 significantly (P<0.05) reduced sporulation of *P. cubensis* on the inoculated plants at concentrations >0.1g/L. Significant (P<0.05) reductions in disease symptom severity (% leaf area affected) were only observed at concentrations ≥0.15g/L. Foliar wet weights of plants were significantly (P<0.05) reduced compared to untreated plants at concentrations ≥0.025g/L (Table 13).

TABLE 13: Effect of CGA245704 concentration on severity and sporulation of cucurbit downy mildew

CGA245704 Concentration (g/L)	Mean Disease severity	Mean Sporulation	Foliar wet weight (g)
0	5.293**c**	2.876**d**	17.10**e**
0.005	4.791**c**	2.460**bcd**	15.65**e**
0.0125	5.251**c**	2.583**cd**	13.63**de**
0.025	4.729**c**	2.438**bcd**	9.89**c**
0.05	4.916**c**	2.230**bcd**	11.48**cd**
0.1	4.980**c**	2.084**bc**	8.14**bc**
0.15	3.646**b**	1.750**b**	4.87**ab**
0.25	1.812**a**	1.000**a**	3.59**a**
LSD (P<0.05)	1.075	0.727	3.479

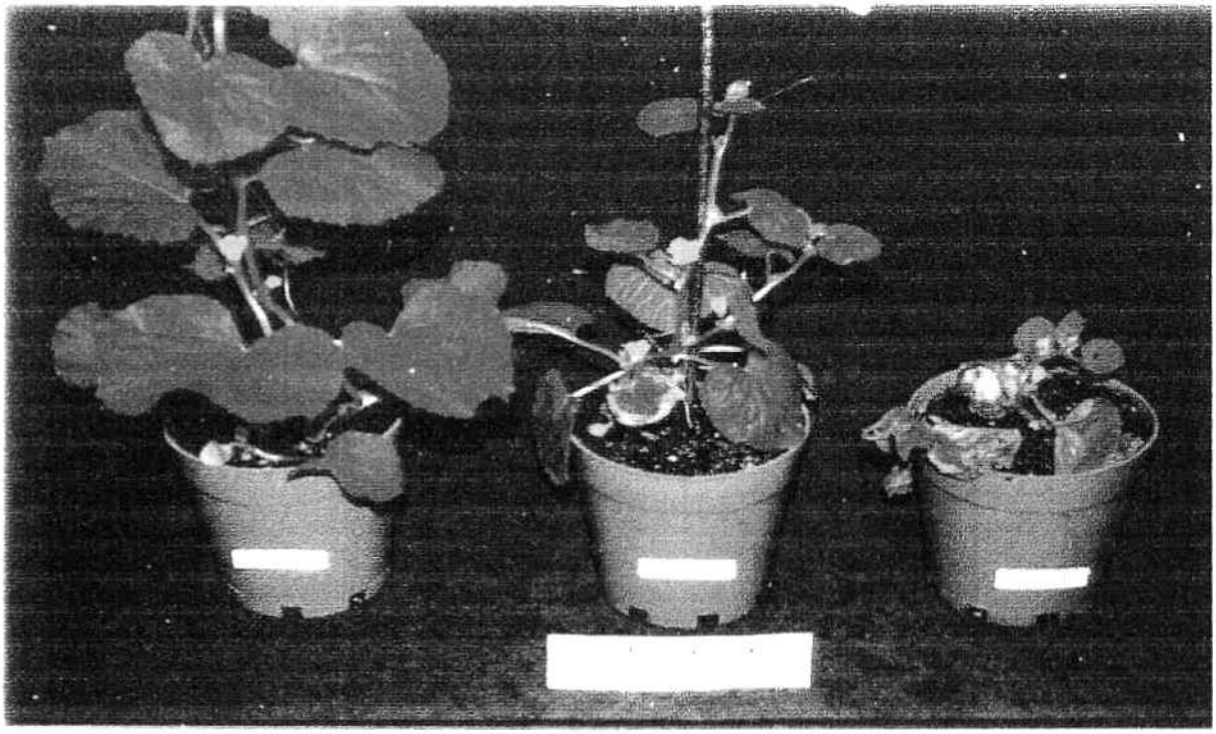

Plate 5. Rockmelon plants (cv. Eastern Star) treated with foliar sprays of CGA245704. Untreated control (left), 0.025g/L CGA245704 (centre), 0.25g/L CGA245704 (right).

This compound caused a phytotoxic response in rockmelon cv. Eastern Star which was strongly dependent on the concentration applied. Symptoms of phytotoxicity included leaf chlorosis and necrosis as well as reductions in leaf size and internode length (Plate 5). In an exponential regression of foliar wet weights versus CGA245704 concentration, the effect of separate linear parameters (± downy mildew x CGA245704 concentration) was almost significant ($P<0.05$). The effect of separate intercepts (± downy mildew) was highly significant ($P<0.001$). The equation for predicting wet weight is:

$$\text{Wet weight} = A + B*R^{(\text{CGA concentration})}$$

The parameters for the equation for both inoculated and uninoculated plants, with the same curvature but different intercepts are presented (Table 14).

TABLE 14: Equation parameters for predicting foliar wet weights of plants treated with CGA2 of plants treated with CGA245704

Parameter	Estimate	S.E
R	0.000000037	0.000000171
B	10.03	
A (uninoculated plants)	5.432	
A (inoculated plants)	1.055	

In a regression of phytotoxicity versus CGA245704 concentration the effects of all separate parameters and separate linear parameters (± downy mildew x CGA245704 concentration) were not significant ($P>0.05$). The curvature of the equation for predicting phytotoxicity is therefore the same, regardless of whether or not the plants were inoculated. The effects of separate intercepts (± downy mildew) was not significant ($P<0.431$). Hence the same curve is used for both inoculated and uninoculated plants. Phytotoxicity is predicted by the following equation:

$$\text{Phytotxicity} = A + B*R^{(\text{CGA concentration})}$$

The parameters for the equation for predicting phytotoxicity are given (Table 15).

TABLE 15: Equation parameters for predicting phytotoxicity to plants treated with CGA245704

Parameter	Estimate	S.E.
R	1.608	0.000000171
B	11.19	1.08
A	-0.516	0.338

4.2.5.4 Discussion

CGA245704 was highly phytotoxic to rockmelon cv. Eastern Star at concentrations that afforded disease control. In the analysis of foliar wet weight data, the insignificant interaction term (± downy mildew x CGA245704 concentration) indicated that the rate of reduction in foliar wet weight for increasing CGA245704 concentration was the same for inoculated and uninoculated plants. The rate of increase of phytotoxicity severity symptoms with increasing CGA245704

concentration was also the same for both inoculated and uninoculated plants. These results indicate that CGA245704 offers fairly poor control of cucurbit downy mildew when used as a sole chemical treatment. Future trials should focus on the effects of CGA245704 when applied in combination with other fungicides.

4.2.6 Protectant and systemic fungicide mixtures for control of cucurbit downy mildew on rockmelon cv. Eastern Star – An evaluation

4.2.6.1 Introduction

Synergistic interactions between fungicides for control of a range of pathogens from the order Peronosporales, have been reported. Mancozeb mixed with either cymoxanil or oxadixyl was far more effective than the individual components alone in controlling metalaxyl-sensitive and insensitive isolates of *Pseudoperonospora cubensis* on cucumber plants in growth chambers (Samoucha and Cohen, 1988). Similarly, a three-way mixture of cymoxanil, oxadixyl and mancozeb was more effective against sensitive and phenylamide-resistant strains of *Phytophthora infestans* on potatoes and tomatoes and *Plasmopara viticola* on grapevines than the individual components alone (Samoucha and Gisi, 1987).

A previous trial (5.5) indicated that the systemic acquired resistance compound CGA245704 is highly phytotoxic to rockmelon plants (cv. Eastern Star) at concentrations that afforded control of downy mildew. Possible synergistic interactions between this compound and other protectant and systemic fungicides should be investigated. This experiment was conducted to test for synergism between registered and experimental fungicides for control of cucurbit downy mildew on rockmelon cv. Eastern Star.

4.2.6.2 Materials and Methods

Seed of rockmelon cv. Eastern Star was germinated in peat/vermiculite mix in the glasshouse. After 14 days the seedlings were transplanted, one per pot, into 5 inch pots containing peat and sand (1:1). Thirteen different treatments were applied to each of four replicate plants as follows:

1. Untreated control
2. Acrobat®MZ @ 2.0g/L
3. Azoxystrobin WG @ 0.4g/L
4. Rover®@ 3.0mL/L
5. Manzate®DF @ 2.0g/L
6. CGA245704 @ 0.025g/L
7. Manzate®DF @ 2.0g/L + CGA245704 @ 0.025g/L
8. Rover® @ 3.0mL/L + CGA245704 @ 0.025g/L
9. Acrobat®MZ @ 2.0g/L + CGA245704 @ 0.025g/L
10. Azoxystrobin WG @ 0.4g/L + CGA245704 @ 0.025g/L
11. Azoxystrobin WG @ 0.4g/L + Manzate®DF @ 2.0g/L
12. Azoxystrobin WG @ 0.4g/L + Rover® @ 3.0mL/L
13. Acrobat®MZ @ 2.0g/L + Rover® @ 3.0mL/L

CGA245704 was applied twice. Two weeks after transplanting, 20 of the plants were sprayed until runoff with CGA245704 (0.025g/L). One week later, all 52 pots were inoculated with an isolate of *P. cubensis* (1.0×10^4 sporangia/mL) in distilled water. The plants were incubated overnight at high humidity (22°C), then sprayed until runoff with the fungicide treatments using a gas-powered sprayer. The plants were again incubated overnight, kept in a glasshouse for 7 days and then returned to high humidity for a further 24h. The two most severely affected leaves of each plant were rated for disease severity using a 0-6 scale and disease severity on the cotyledons was rated using a 0-3 scale for % leaf area affected. A 0-3 rating scale for sporulation intensity was used for both cotyledons and true leaves:

% Leaf Area Affected (true leaves)
0 - nil
1 - few chlorotic spots, <1% leaf area affected
2 - 1-10%
3 - >10-25%
4 - >25-50%
5 - >50-75%
6 - >75%

% Leaf Area Affected (cotyledons)
0 - nil
1- <10%
2- 10-50%
3- >50%

Sporulation Index

0 = nil sporulation
1 = sparse/low
2 = moderate
3 = intense

Mean disease ratings and sporulation ratings were analysed using one-way analysis of variance.

4.2.6.3 Results

Results for the one-way analysis of variance of mean disease severity and sporulation intensity are given (Table 14).

TABLE 16: Efficacy of systemic and protectant fungicides applied alone and in combination for control of cucurbit downy mildew

Treatment	Mean Disease Severity	Mean Disease Sporulation
Control	4.000	2.625
Acrobat®MZ 690	2.250	0.750
Azoxystrobin WG	2.750	1.625
Rover®500	4.875	3.000
Manzate®DF	3.125	1.875
CGA245704	2.000	1.500
Acrobat®MZ 690 + Rover®500	2.750	1.000
Azoxystrobin WG + Rover®500	2.625	2.125
Azoxystrobin WG + Manzate® DF	2.875	1.875
Manzate® DF + CGA245704	2.750	1.375
Rover®500 + CGA245704	2.375	1.500
Acrobat®MZ 690 + CGA245704	2.000	0.000
Azoxystrobin WG + CGA245704	1.000	0.250
LSD (P<0.001)	1.243	0.8297

The residual errors from the one-way ANOVAs of all 13 treatments were used in the analysis of selected treatments with complete factorial structures (Tables 15-18).

TABLE 17: Analysis of variance of mean disease severity values for treatments containing Rover®

Systemic Fungicide	Protectant Fungicide		
	None	Rover®500	*Mean*
None	4.00	4.87	**4.44**
Acrobat®MZ 690	2.25	2.75	**2.50**
Azoxystrobin WG	2.75	2.62	**2.69**
CGA245704	2.00	2.37	**2.19**
Mean	**2.75**	**3.16**	

The interaction of systemic fungicide x protectant fungicide was not significant (P>0.05) for the mean disease severity rating. The main effect of protectant fungicide was not significant (P>0.05), indicating that the addition of Rover® did not improve the efficacy of any of the systemic fungicides. The main effect of systemic fungicide was significant (P<0.001). There were no differences between the mean ratings for Acrobat®MZ, Azoxystrobin WG or CGA245704, but all three systemics gave lower mean disease ratings than if no systemic fungicide was used.

TABLE 18: Analysis of variance of mean sporulation index values for treatments containing Rover®

Systemic Fungicide	Protectant Fungicide		
	None	Rover®500	*Mean*
None	2.62	3.00	**2.81**
Acrobat®MZ 690	0.75	1.00	**0.88**
Azoxystrobin WG	1.62	2.12	**1.87**
CGA245704	1.50	1.50	**1.50**
Mean	**1.62**	**1.91**	

The interaction of systemic fungicide x protectant fungicide was not significant ($P>0.05$) for the mean sporulation index. The main effect of protectant fungicide was not significant ($P>0.05$), indicating that the addition of Rover® did not improve the efficacy of any of the systemic fungicides. The main effect of systemic fungicide was significant ($P<0.001$). There were no differences between the mean sporulation indices for Acrobat®MZ, Azoxystrobin WG or CGA245704, but all three systemics gave lower mean sporulation indices than if no systemic fungicide was used.

TABLE 19: Analysis of variance of mean disease severity values for treatments containing Rover®, Manzate®DF, Azoxystrobin WG and Acrobat®MZ

Systemic Fungicide	Protectant Fungicide			
	None	Rover®	Manzate®DF	*Mean*
None	4.00	4.87	3.12	**4.00**
Azoxystrobin WG	2.75	2.62	2.87	**2.75**
CGA245704	2.00	2.37	2.75	**2.37**
Mean	**2.92**	**3.29**	**2.92**	

The interaction of systemic fungicide x protectant fungicide was not significant ($P>0.05$) for the mean disease severity rating. The main effect of protectant fungicide was not significant ($P>0.05$), indicating that the addition of Rover® or Manzate®DF did not improve the efficacy of any of the systemic fungicides. The main effect of systemic fungicide was significant ($P<0.001$). There were no differences between the mean ratings for Azoxystrobin WG or CGA245704, but both of these systemics gave lower mean disease ratings than if no systemic fungicide was used.

TABLE 20: Analysis of variance of mean sporulation index values for treatments containing Rover®, Manzate®DF, Azoxystrobin WG and Acrobat®MZ

Systemic Fungicide	Protectant Fungicide			
	None	Rover®	Manzate®DF	*Mean*
None	2.62	3.00	1.87	**2.50**
Azoxystrobin WG	1.62	2.12	1.87	**1.87**
CGA245704	1.50	1.50	1.37	**1.46**
Mean	**1.92**	**2.21**	**1.71**	

The interaction of systemic fungicide x protectant fungicide was not significant ($P>0.05$) for the mean sporulation indices. The main effect of protectant fungicide was not significant ($P>0.05$), indicating that the addition of Rover® or Manzate®DF did not improve the efficacy of any of the systemic fungicides. The main effect of systemic fungicide was significant ($P<0.001$). Plants treated with Azoxystrobin WG or CGA245704 produced lower mean sporulation indices than if no systemic fungicide was used.

4.2.6.4 Discussion

The addition of the protectant fungicide Rover® to post-inoculation foliar sprays of three systemic fungicides Acrobat®MZ, Azoxystrobin WG and CGA245704, did not improve the efficacy of the systemics in this experiment. Mixtures of the systemics with Rover® were no more effective than the systemic components alone for limiting disease severity (% leaf area affected) and sporulation intensity. Similarly, the addition of Manzate®DF to the systemic fungicides Azoxystrobin WG and CGA245704 did not limit disease severity or sporulation intensity more than applications of the systemic components alone.

These results indicate that there were no synergistic interactions between the protectant and systemic fungicides, when treatments were applied as eradicants. In all cases significant reductions in disease severity and sporulation intensity were caused by the systemic fungicides only.

4.3. GENERAL DISCUSSION

The downy mildew component of this project sought to achieve the following outcomes:

1. Provide information on the fungicide-sensitivity status of cucurbit downy mildew in the Burdekin-Bowen district.

2. Identify cross-resistance within and between fungicide groups in downy mildew isolates.

3. Evaluate fungicides for efficacy in control of cucurbit downy mildew both in glasshouse and in field trials.

4. Develop an anti-resistance strategy for management of cucurbit downy mildew.

The fungicide resistance screening of downy mildew isolates during the course of this project indicated that resistance to phenylamide fungicides is widespread in the downy mildew populations of the Burdekin/Bowen district. This study represents a continuation of an initial isolate screening study which was conducted by O'Brien and Weinert (1995). In the majority of cases the phenylamide fungicides (Ridomil®MZ 720, Galben®M, Recoil® and Fongarid®) were ineffective for control of isolates collected from these populations. In several instances isolates of intermediate sensitivity to phenylamides were identified. It is probable that the populations from which these isolates were derived are in a transitionary stage and that further selection of more highly resistant strains will occur in these populations if phenylamides continue to be applied at sub-lethal rates in the field. Staub (1994), concluded that phenylamide resistance in populations of *Phytophthora infestans* (late blight of potatoes) and *Plasmopara viticola* (grape downy mildew) tends to decrease in the absence of selection pressure, possibly due to decreased fitness of resistant strains compared to the wild type populations from which they developed. If this is also true of cucurbit downy mildew, a reduction in the proportion of resistant types may occur over time if phenylamide use is discontinued.

Glasshouse trials confirmed that a metalaxyl-insensitive isolate was also resistant to other members of the phenylamide fungicide group (oxadixyl, benalaxyl, furalaxyl). This cross-resistance was confined to the phenylamides and there was no evidence of resistance to either of the alternative systemic compounds, dimethomorph or azoxystrobin.

Glasshouse efficacy trials identified Azoxystrobin WG and Acrobat®MZ 690 as highly effective alternative systemic fungicides to Ridomil®MZ for control of phenylamide-sensitive and insensitive downy mildew isolates. Azoxystrobin WG reduced disease severity more effectively than any of the other fungicides and provided systemic control of infections that occurred up to 8 days after fungicide application. In addition, Synertrol® Oil as a spray-tank adjuvant enhanced the therapeutic activity of dimethomorph by delaying sporulation of the pathogen on glasshouse grown plants. In the field, the protectant fungicides, Rover® (chlorothalonil) and Manzate®DF (mancozeb), when routinely applied, controlled

downy mildew as well as Acrobat®MZ the most effective systemic fungicide. Agri-Fos® performed relatively poorly, both in the glasshouse and in the field.

The experimental compound CGA245704 was generally highly phytotoxic at concentrations that afforded disease control. In glasshouse trials symptoms of phytotoxicity were evident at concentrations ≥0.025g/L. In the field, severe phytotoxicity symptoms were produced on plants treated with a 0.05g/L foliar spray. This compound did however exhibit longer term systemic activity against downy mildew than any other fungicide in a glasshouse evaluation. The duration of systemic control offered by very low non-phytotoxic concentrations (≤0.025g/L) of CGA245704 warrants investigation in future trials. Provided the phytotoxicity constraints of this product can be addressed via application at reduced concentrations, the long-term residual protection offered by CGA245704 may be of particular benefit if applied to protect crops during periods of wet weather.

Fungal pathogens are generally not as at risk of developing resistance to multi-site of action protectant fungicides, and therefore spray programs aimed at fungicide resistance management should be based on protectant chemicals. The results of field trials in this project support this tactic. Achieving sufficient plant coverage with protectant chemicals is a limitation to downy mildew control in most field situations due to equipment constraints and difficulty in penetrating leaf canopies. Incorporation of systemic fungicides into spray programs will help to address efficacy constraints due to poor plant coverage. Acrobat®MZ is the only systemic product currently registered that provides levels of control comparable to regular protectant fungicide applications. Acrobat®MZ should be used sparingly (not more than 4 sprays per crop), with applications being timed to combat early infections after periods of rain or heavy dews. Azoxystrobin WG is another chemical which showed considerable promise as an effective alternative systemic to Acrobat®MZ in these experiments. Once registration procedures are complete, this chemical should be rotated with Acrobat®MZ in protectant based spray programs.

4.4. RECOMMENDATIONS

- Phenylamide fungicide (Ridomil®MZ, Galben®M, Recoil®, Fruvit®) use should be discontinued in the Burdekin/Bowen district for control of cucurbit downy mildew.

- Phenylamide resistance should continue to be monitored in this district, to determine if/when phenylamides should be re-introduced into spray programs.

- Protectant fungicides (mancozeb, chlorothalonil) should form the basis of spray programs (application at 7 day intervals). Systemic fungicides (Acrobat®MZ and Azoxystrobin WG (pending registration)) should be used sparingly and timed to combat early infections following periods of rain or heavy dew.

- The systemic activity of low concentrations of CGA245704 warrants further investigation. The ability of Synertrol® Oil to enhance the therapeutic activity of dimethomorph should also be examined further in field trials.

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5. GUMMY STEM BLIGHT SECTION

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5.1 INTRODUCTION

Melon production is an important horticultural industry in Queensland. Gummy stem blight (GSB) caused by the fungus *Didymella bryoniae* is an important disease affecting rockmelon, honey-dew (*Cucumis melo.*), and watermelon (*Citrullus lanatus*). The disease causes leaf spots, hypocotyl and stem cankers and fruit rot (Schenck 1968; Persley *et al* 1989). Yield losses of 30% or more have been encountered following prolonged showery weather conditions conducive to the disease.

Control of GSB in field-grown melons is presently based on regular applications of protectant dithiocarbamate and phthalimide fungicides. However, results are often unsatisfactory when disease pressure is high (Fletcher and Preece 1966), suggesting more effective chemicals need to be found. This report describes 3 field experiments which examined the efficacy of a range of fungicides from different chemical groups and the strategic use of one of these chemicals in the control of gummy stem blight of watermelon.

5.2 FUNGICIDE SCREENING TRIALS

MATERIALS AND METHODS

Fungicide screening experiments
Field experiments were planted at the Delta Horticultural Research Station at Bowen in April 1997 (experiment 1) and at the Centre for Wet Tropics Agriculture South Johnstone in September 1997 (experiments 2 and 3). In experiment 1, rockmelon cv. Eastern Star and in experiments 2 and 3 watermelon cv. Warpaint were grown on beds 1m wide on plastic mulch and watered with trickle irrigation. Each plot consisted of a 15m section of a single row 1m wide, separated from neighbouring plots by a 1.5m guard area of the same cultivar. Melon vines were regularly 'trained' to keep them within the confines of each plot. Treatments were arranged in a randomised complete block design with 4 replications. Fungicides were applied by a shoulder-mounted misting unit. Fungicides used were taken from different chemical groups (Table 1) and included azoxystrobin (Amistar, 500g/kg w.g), procymidone (Sumisclex, 500g/L e.c.), benomyl (Benlate, 500g/kg w.p.), chlorothalonil (Bravo, 500g/L flowable), metalaxyl plus mancozeb (Ridomil, 80g/kg + Dithane, 640g/kg w.p.), metiram (Polyram, 800g/kg w.p.), cyproconazole (Alto 100g/L e.c.). An adjuvant consisting of synthetic latex and surfactant (Bond, 450g/L + 100g/L) was included with each spray treatment.

Downy mildew (DM) severity was assessed on 5 randomly selected laterals from each plot using the following scale: 0, no mildew; 1, no leaves dead, mildew present as scattered lesions; 2, some <1/3 of leaves dead and scattered lesions on remainder; 3, some 1/3 of leaves dead and concentrated lesion development on remainder; 4, >1/3 but <2/3 of leaves dead; 5, >2/3 of leaves dead. GSB severity was assessed using the following scale: 1, no gummy stem blight symptoms; 2, scattered leaf spots; 3, leaf and petiole lesions, death of some leaves; 4, <25% of older leaves dead with hypocotyl

and/or stem lesions; 5, 25-50% of leaves dead with hypocotyl and/or stem lesions; 6, >50% of leaves dead with severe hypocotyl and/or stem lesions. Fruit were assessed as marketable if they were firm and free of rots and blemishes.

5.2.1 Experiment 1

The treatments (Table 2) were applied on 8 occasions at weekly intervals commencing 19 days after the rockmelons were transplanted into the field. Spray volumes increased from 228 to 889 L/ha as the plants grew. Assessments of severity of downy mildew and gummy stem blight were made 43 and 77 days after transplanting. Fruit were harvested over 2 weeks, with yields per plot (number and weight of marketable fruit) being assessed. Fruit were assessed as marketable if they were firm and free of rots and blemishes.

5.2.2 Experiment 2

Treatments were the same as in experiment 1 except for the fungicide cyproconazole being replaced by the spray adjuvant (synthetic latex plus surfactant) used alone. Treatments were applied on 8 occasions at weekly intervals commencing 15 days after the seedlings were transplanted into the field. Spray volumes increased from 228 to 889 L/ha as the plants grew. Three fruit harvests were made over 9 days with yields per plot (weight and number of marketable fruit) being assessed. Gummy stem blight severity was assessed 75 days after transplanting by rating disease severity on 10 randomly selected laterals from each plot using the scale previously mentioned.

5.2.3 Experiment 3

The treatments (Table 4) consisted of weekly or fortnightly applications of 2 rates of azoxystrobin (Amistar, 500g/kg w.g) used alone or in alternating schedules or mixtures with chlorothalonil (Bravo, 500g/L flowable).. Ten applications of the weekly treatments and 6 applications of the fortnightly treatments were made and these were commenced 14 days after the watermelons were transplanted into the field.. Spray volumes increased from 228 to 889 L/ha as the plants grew. An assessment of disease severity was made after the final spray application. A single fruit harvest was conducted with yields per plot (weight of marketable fruit) being assessed.

Trial site infestation

Field plantings were inoculated with spores of *D. bryoniae* 2 days after the fourth fungicide application (experiment 1) 6 days after the fifth fungicide application (experiment 2) and 3 days after the fourth fungicide application (experiment 3) using the technique devised by Vawdrey (1994). In experiments 1 and 2, an inoculum concentration of 1.5×10^6 conidia/mL was prepared, while in experiment 3 a concentration of 5×10^5 conidia/mL was used. The inoculum was applied at a rate of 2.0 mL/m of row. In experiment 1 just before inoculation, overhead sprinkler irrigation was applied for 15 min to wet the foliage. For the next 3 days, similar irrigations were applied in the early evening, providing at least 12 h of leaf wetness. In experiments 2 and 3, the field inoculation followed days of intermittent showers and overcast conditions.

5.3 RESULTS

Fungicide screening experiments

5.3.1 Experiment 1.

Plants in the trial grew poorly as a result of poor land preparation and cool growing conditions. Although plants in the experiment were inoculated with *D. bryoniae*, gummy stem blight failed to develop due to prolonged dry conditions and a lack of sufficient foliage to create a favourable microclimate for the disease. However an outbreak of downy mildew occurred in the experiment causing severe defoliation and yield loss in some treatments. Azoxystrobin gave the best overall control of downy mildew, however the level of disease control achieved with this treatment was not significantly different from chlorothalonil or metalaxyl plus mancozeb (Table 2). Cyproconazole and benomyl were ineffective in reducing the incidence of downy mildew compared to the unsprayed treatment. At day 77, metiram was superior to cyproconazole, procymidone, benomyl and the unsprayed treatment. All chemicals except cyproconazole and benomyl produced a significant increase in the number and weight of marketable fruit and the average weight of fruit (Table 2). Cyproconazole was phytotoxic, causing a necrosis of leaf margins in young leaves. and was therefore replaced in experiment 2 with the adjuvant synthetic latex plus surfactant used alone.

5.3.2 Experiment 2.

Symptoms of gummy stem blight were apparent within 14 days of inoculation and the disease developed slowly as a result of fairly dry weather conditions. All chemicals significantly reduced the disease and azoxystrobin gave the best overall control of gummy stem blight (Table 3). Azoxystrobin was superior to all treatments except procymidone. Azoxystrobin produced a significant increase in the weight of marketable fruit compared with all other treatments except benomyl. Gummy stem blight had no significant effect on the number of marketable fruit (Table 3). The average weight of fruit was signicantly greater in all chemical treatments except benomyl, chlorothalonil and synthetic latex plus surfactant.

5.2.3 Experiment 3

Symptoms of gummy stem blight were apparent in untreated plots within 14 days of inoculation and the disease developed into a severe epiphytotic. The total of 1113mm of rainfall was recorded at South Johnstone during the experiment. All fungicide treatments showed significantly less disease than the unsprayed plants(Table 4). Under severe disease pressure, weekly applications of azoxystrobin (300g a.i./ha) significantly reduced the disease and gave the best overall control of gummy stem blight. Differences in disease control led to differences in yield. Weekly applicatons of azoxystrobin (300g a.i./ha) and azoxystrobin (300g a.i./ha) alternated with chlorothalonil produced a significant increase in the weight of marketable fruit compared with the other treatments.

5.4 GENERAL DISCUSSION

5.4.1 Although gummy stem blight failed to develop in experiment 1 at Bowen HRS, the damaging effects of downy mildew were shown in a lower yield of marketable fruit. Cyproconazole, the triazole fungicide used in this experiment was phytotoxic and therefore omitted from the experiment at South Johnstone RS. Other triazole fungicides used in previous experiments involving cucurbits (Vawdrey 1994) showed signs of phytotoxicity or were ineffective in controlling gummy stem blight. The level of downy mildew control achieved with azoxystrobin was superior to all treatments except chlorothalonil and metalaxyl plus mancozeb. In recent times, growers have raised concerns regarding resistance to the downy mildew fungicide metalaxyl plus mancozeb. This loss in sensitivity to the chemical was not evident in this early season melon crop possibly a result of resistant strains of downy mildew being at low levels in the total mildew population.

5.4.2 In experiment 2, gummy stem blight developed late in the crop and although the disease severity was low, it still managed to reduce the weight of marketable fruit. All chemical treatments reduced the severity of the disease, and azoxystrobin and procymidone were superior to the registered products metalaxyl plus mancozeb and chlorothalonil.

5.4.3 Experiment 3 showed that gummy stem blight can be a most severe disease which can cause major yield loss due to extensive defoliation followed by premature ripening, sunburn and fruit breakdown. The heavy rainfall (8 times the recorded rainfall for the same period the previous year) not only enhanced the disease severity but also caused fruit to split making them unmarketable.

All treatments reduced the severity of disease and weekly applications of azoxystrobin (300g a.i./ha) alone was superior to all other treatments. It was disappointing none of the other spray strategies performed as well as weekly azoxystrobin (300g a.i./ha) alone. This is likely a result of the severe disease pressure experienced. Under such severe disease pressure, azoxystrobin may need to be applied preventively.

The superior efficacy of azoxystrobin in controlling downy mildew, and gummy stem blight in these experiments and powdery mildew in other recently conducted experiments (H.Townley 'Crop Care Australasia' personal communication) is a promising result for future disease control in cucurbits. The translaminar systemic activity of azoxystrobin (Anon 1996) will be of most benefit during periods of severe disease pressure, especially when the dense growth of vines makes good fungicidal cover with protectant chemicals difficult to achieve. However, the overuse of a single systemic fungicide may lead to fungicide resistance problems, as reported by Van Steekelenberg (1987) with benzimidazole fungicides. If loss of sensitivity to azoxystrobin is to be delayed or prevented, the number of sequential applications should be kept to a minimum. One recommendation (Anon 1998) is that there should be no more than 3 sequential applications after which it should be alternated with at least 2 applications of an effective fungicide with a different mode of action. The use of azoxystrobin in conjunction with another fungicide such as chlorothalonil will do

much to ensure effective disease control and reduce the occurrence of fungicide-resistant strains.

5.5 RECOMMENDATIONS

This project has demonstrated the improved efficacy of azoxystrobin in the control of downy mildew and gummy stem blight of melons. Crop Care Australasia, the company distributing this product have indicated registration for use on melons should be in place late in 1999. Other chemicals in the strobilurin group are currently being assessed for the control of diseases in other crops eg. leaf spot in bananas. It is highly likely they will also prove effective in the control of foliar diseases of melons.

5.6 ACKNOWLEDGEMENTS

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Table 1. Fungicide treatments used in experiments 1and 2 and their various chemical groups

Chemical group	Active constituent	Trade name
Strobilurin	azoxystrobin	Amistar
Dicarboximide	procymidone	Sumisclex
Benzimidazole	benomyl	Benlate
Phthalimide	chlorothalonil	Bravo
Phenylamide	metalaxyl	Ridomil
Dithiocarbamate	metiram	Polyram
Triazole	cyproconazole	Alto

Table 2. Experiment 1. Downy mildew severity at 43 and 77 days from transplanting, total weight and number of marketable fruit following different fungicide applications to control downy mildew and gummy stem blight of rockmelon cv. Eastern Star.

Downy mildew severity assessed on 5 terminals/plot: 0, nil disease; 5, >2/3 of leaves dead

Treatment	Rate (g a.i./ha)	Downy mildew assessment		Number of marketable fruit per plot	Weight of marketable fruit (t/ha)	Average weight of fruit (kg)
		Day 43	Day 77			
Azoxystrobin	300	0.25 a	1.60 a	42.25 c	19.14 a	0.99 a
Chlorothalonil	1500	0.35 a	1.95 ab	44.00 c	18.18 a	0.93 a
Metalaxyl plus Mancozeb	200+1600	0.45 a	2.10 ab	45.75 c	19.43 a	0.97 a
Metiram	160	0.65 ab	2.50 b	41.75 c	18.90 a	1.02 a
Cyproconazole	60	1.20 bc	5.00 d	3.00 a	1.41 c	0.52 b
Procymidone	500	0.65 ab	3.60 c	23.75 b	10.47 b	1.01 a
Benomyl	500	1.45 c	4.95 d	1.75 a	0.77 c	0.26 b
Unsprayed		1.60 c	5.00 d	1.25 a	0.42 c	0.39 b
l.s.d. ($P = 0.05$)		0.60	0.79	10.57	4.41	0.46

Treatments with the same letters are not significantly different (P=0.05)

Table 3. Experiment 2. Effect of fungicide spray treatments on the severity of gummy stem blight, the total weight of marketable fruit and the average weight per fruit of watermelon cv.Warpaint.

Gummy stem blight severity assessed on 10 terminals/plot: 1, nil disease; 6, >50% of leaves dead with severe hypocotyl and/or stem lesions

Treatment	Rate (g a.i./ha)	Disease severity	Number of marketable fruit per plot	Weight of marketable fruit (t/ha)	Average weight of fruit (kg)
Azoxystrobin	300	1.28 a	35.00	111.86 a	7.19 a
Procymidone	500	1.83 b	29.02	92.00 bc	7.10 a
Benomyl	500	2.28 c	34.50	101.39 ab	6.63 abc
Chlorothalonil	1500	2.38 c	30.12	90.84 bc	6.86 ab
Synthetic latex plus surfactant	450 + 100	2.40 c	35.17	92.10 bc	5.93 c
Metiram	160	2.58 c	28.75	89.61 bc	7.05 a
Metalaxyl plus mancozeb	200 + 1600	2.58 c	29.25	91.31 bc	7.02 a
Unsprayed		3.15 d	27.75	76.63 c	6.23 bc
l.s.d. ($P = 0.05$)		0.37	n.s	16.65	0.79

Treatments with the same letters are not significantly different (P=0.05)

Table 4. Effect of the strategic use of azoxystrobin on the severity of gummy stemblight and the total weight of marketable fruit of watermelon cv. Warpaint

Gummy stem blight severity assessed on 10 terminals/plot; 1, nil disease; 6, >50% of leaves dead with severe hypocotyl and/or stem lesions.

Treatment	Rate (g a.i./ha)	Disease severity	Weight of marketable fruit (t/ha)
Azoxystrobin applied weekly	300	3.31 a	28.07 a
Azoxystrobin alternated with chlorothalonil	300 1500	3.78 b	23.28 ab
Azoxystrobin applied weekly	150	3.90 bc	16.85 c
Azoxystrobin + chlorothalonil weekly	150 1500	4.23 cd	17.09 c
Azoxystrobin applied fortnightly	300	4.30 d	18.72 bc
Azoxystrobin + chlorothalonil (fortnightly)	150 1500	4.80 e	16.70 c
Chlorothalonil applied weekly	1500	5.08 e	10.70 d
Untreated		6.00 f	6.20 e
l.s.d. (P=0.05)		0.42	5.18

Treatments with the same letters are not significantly different (P=0.05)

6. FRUIT CHEWING INSECTS SECTION

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6.1 INTRODUCTION

Cucumber moth (*Diaphania indica* (Saunders) Pyralidae, and Heliothis *Helicoverpa armigera* (Hubner) and *H. punctigera* (Wallengren) Noctuidae all within the Order Lepidoptera continue to cause damage to curcubit crops. In melons, damage to growing vines is caused by Cucumber Moth while flowers are damaged by Heliothis but the majority of the damage caused by all three of these pests is to the fruit. The Cucumber Moth feed on the surface of the skin and Heliothis chew holes into the flesh of the fruit and this contributes to fruit quality problems. One of the main problems is that the immature stages (larvae) of the cucumber moth tend to shelter under the fruit at ground level chewing on the rind of the fruit undetected. It is not until the fruit is picked that the damage becomes obvious and the fruit has to be discarded or down-graded. Rarely does this insect burrow into the flesh of the fruit whereas the Heliothis will feed on the fruit surface and at times penetrate the fruit to feed on the flesh. In both of these cases the control of the insects can be difficult due to poor pesticide coverage in these areas. If the fruit has been penetrated then it has to be rejected.

In the major melon production area based on the Burdekin district, growers rely on insecticide applications to control these pests. The timing of applications and when they are needed has not been based on presence or absence of these insects but applied as a precautionary measure. The reason for this has been that the information on the ecology of these pests in melon crops is lacking. Before developing good control methods for these insects more knowledge needs to be gained so that maximum benefits can be achieved in controlling these pests. In contributing to this knowledge the following results have been obtained.

6.2 INSECTS ASSOCIATED WITH MELON CROPS

6.2.1 INTRODUCTION

No previous studies have tried to identify the diversity of insect species that can be found in melon crops. Before sound management practices can be formulated it is important that this diversity be known. The reason for this is that this information needs to be collected before an understanding of the relationships between the different groups and how they might be impacting on each other can be studied ie parasite/host.

6.2.2 MATERIALS and METHODS

Most of the collections have been obtained by using a mobile vacuum machine, collecting the insects from the leaf surface and from within the canopy. The samples from within the canopy also include some of the insects that are found on the surface of the soil. Other sampling has involved collecting immature stages from the field and breeding them in the laboratory to determine the incidence of parasites.

These samples were taken to get some estimate of the number and species of Arthropods that could be collected from melon crops. These were then categorised as beneficial or pests. An example of the diversity of insects that can be collected from melons at three different sites on the same date is given in table 1.

6.2.3 RESULTS.

Table 1. Number of insects collected from three sites on the same date from melon crops grown in the Burdekin area.

Order	**Family**	**Genus/species**	**SITE**		
			1	**2**	**3**
Araneida	Argiopidae	Arcys sp.		2	
	Oxyopidae	Oxyopes sp.		1	1
	Thomisidae	Diaea sp.		5	
Odonata	unknown				1
Orthoptera	Acarididae	unknown			1
	Tettigoniidae	Homeoxipha sp.			5
		unknown	1		
Hemiptera	Aleryodidae	Bermisa tabaci		16	
	Aphididae	Myzus persicae			3
	Cicadellidae	species 1	2		
		Species 2	1		
	Colobathristidae	Phaenacantha australiae		1	
	Lygaeidae	Oxycarenus luctuosus		7	
	Miridae	Taylorilygus pallidulus		2	1
Thysanoptera	Thripidae	Thrips sp.			1
Neuroptera	Hemerobiidae	Micromus spp.			1
Coleoptera	Bruchidae			1	

	Coccinellidae	Coelophora inaequalis		2	
		Harmonia octomaculata			2
		Micraspis sp.			1
		Orcus spp		2	
	Chrysomelidae	Aulacophora abdominalis	1		
		Galerucinae			4
		Paropsis spp.			1
	Corixidae	unknown			1
	Euolpinae	unknown		1	
	Histeridae	unknown		1	
	Lampyridae	unknown		2	
	Nitulidae	unknown		1	
	Staphylinidae	Paederus sp.	1	1	1
Diptera	Culicidae	unknown		9	
	Lonchaeidae	Lamprolonchaea brouniana		1	7
	Muscidae	Atherigona sp.	2		
	unknown	species 1		12	
	unknown	species 2		41	
		Species 3		1	
		Species 4		2	
		Species 5		1	
		Species 6		2	
Lepidoptera	Arctiidae	Utetheisa pulchelloides			1
	Noctuidae	Helicoverpa armigera	1	4	4
	Plutellidae	Plutella xylostella		1	
	unknown (immature)			1	2
Hymenoptera	Apidae	Apis mellifera		2	2
	Brachonidae	unknown		1	
	Chalcidae	unknown		1	
	Formicidae	Iridomyrex spp.			2
		unknown			2
	Ichneumonidae	unknown		1	
	unknown	unknown		1	
		unknown		1	

From this type of sampling the following insects were identified as being pests or beneficials. The insects that have been identified as melon pests are all from the Order Lepidoptera and belong to two families, Noctuidae and Pyralidae. These are *Helicoverpa armigera* (Hubner) and *Helicoverpa punctigera* (Wallengren) both from the family Noctuidae and *Diaphania indica* (Saunders) from the family Pyralidae. The beneficials recorded for these fruit chewing insects pests are;

ARANEIDA - spiders.

A large number of spiders have been collected from over 5 different families with the majority of these belonging to the family Thomisidae. These spiders will be affecting both the populations of beneficials as well as the pest species and these spiders are sensitive to chemical sprays. In melon crops it is difficult to measure the affect they are

having on these melon pests as most of the spiders are too small to snare the adult moths but they will feed on very small larvae.

ODONATA - dragonflies.
A few individual species have been collected but these are having very little affect on these fruit chewing pests although they do feed on the adult moths if intercepted in flight. Because of their mobility, sprays have little affect on their populations.

MANTODEA - praying mantids.
Again only a few specimens have been collected and they also would be having little affect on the pest populations. The low numbers recorded for this order of insects show that they are probably affected by spray frequency.

ORTHOPTERA - grasshoppers/crickets.
A number of species from the family Tettigoniidae have been collected from melon crops and some of these species are known to be predacious on other insects especially eggs or young larvae but again they are having little affect on these pest species of melons. Spraying does affect these populations.

HEMIPTERA - bugs.
Two families of bugs that have been collected and can influence the populations of the fruit chewing pests. These are *Taylorilygus sp.* from the family Miridae and *Pristhesancus plagipennis* Walker from the family Reduviidae. These bugs have been recorded feeding on immature stages of other insects especially eggs and small larvae. The latter insect also feeds on bees. The numbers of these two bugs collected is again not high enough to be seen as a major benefit. The populations are affect by the sprays applied.

THYSANOPTERA - thrips.
These insects have been collected in all of the crops sampled and it is difficult to evaluate their importance as most are pests in their own right feeding on plant sap and pollen. Some of the thrips collected have been recorded as feeding on eggs of other insects and this would apply to the fruit pest in this crop. These populations are not affected by sprays as much as some of the other insect groups.

NEUROPTERA - lacewings.
Both adults and nymphs of this insect have been recorded and the nymphs do feed on the eggs and the very immature larvae of these melon pests. The main species collected are from the family Chrysopidae and are mainly aphid feeders. Sprays do affect these populations.

COLEOPTERA - beetles.
As with the Hemiptera there has also been a large number of beetles collected from these melon crops. A number of these beetles are predatory and are feeding on the eggs of these melon insect pests. The family Coccinellidae is well represented with *Orcus sp.*, *Micraspis sp.* and *Coelophora inaequalis* (Fab.). Another beetle found regularly is the rove beetle *Paederus sp.* from the family Staphylinidae but it has not been determined if they are feeding on the immature stages of these melon pest. It has been recorded that these beetles are predacious on other insects. Other predatory beetles that have been collected are Carabids. The three types collected in these crops are ground dwellers and the extent of their activity is around the fruit lying on the ground. These

beetles do feed on the small larval stages around these fruit and this would include larva from the order, Diptera (flies). Some of these beetles are more affected by sprays than others and the amount of vine or age of the crop does have an affect on the population numbers.

DIPTERA - flies.
To date no parasitic flies have been bred from these melon pests even though there are a number of species recorded from Heliothis in other crops within this area.

HYMENOPTERA - wasps.
Only one larval wasp parasites has been bred from *Diaphania indica* and this is the Two-Toned Caterpillar Parasite *Heteropelma scaposum* (Morley). These parasites have also been bred from Heliothis larvae. Other species bred from Heliothis larvae include, Orange Caterpillar Parasite *Netelia producta* (Brulle) Ichneumonidae, *Microplitis sp.* and species from the family Chalcididae. There are a number of egg parasites that have been bred from Heliothis and they are;
Trichogrammatoidea spp. - the most abundant.
Trichogrammatoidea bactrae - small numbers.
Trichogramma spp. - small numbers.
It is not conclusive if the populations of these parasites are affected by sprays or by the abundance of their hosts. The numbers do fluctuate at different times of the year.

Table 2 shows the average percent parasatism of Heliothis eggs at different sites in cucurbit crops.

Table 2. Percent parasitism of Heliothis eggs at five different sites.

	Gumlu	**Home Hill**	**Ayr**	**Ayr R.Stn**	**Brandon**
Range low	0	29	1	12	0
High	50	51	3	29	26
Average	21	41	1.8	20.5	13

6.2.4 CONCLUSION.

Sampling of melon crops throughout the Dry Tropics has revealed that a large number of insects from many families within a number of Orders can be found in melon crops. Differences in the types and number of insects collected in me on crops is not influenced by melon varieties to the same extent as to whether and how often the crop is sprayed.

From these collections it has revealed that there are no predators or parasites that are causing a major control of these melon pests other than the egg parasites which can have up to 51% parasitism of *Helicoverpa spp.* eggs. Collections of insects do vary between sprayed and unsprayed crops with more insects and a greater diversity being collected from the unsprayed crops. The combination of all of these groups that do feed on these melon pests could be having an overall affect but it is too difficult to measure. Independent measurements of the different insect groups will need to be made under different spraying regimes and using different pesticides to measure the affect of these sprays in managing these insect populations. It has been noted that in crops that are not sprayed frequently, the population of spiders is high and these spiders are feeding on the adult whitefly populations that are beginning to infest melon crops and are becoming a major pest in this area.

6.3 INSECTICIDE CONTROL TRIALS

6.3.1 INTRODUCTION

In evaluating chemicals for their efficacy against the fruit-chewing insects only those chemicals that have shown efficacy against Heliothis in other crops were considered. The reason for this is that this insect has shown tolerance to a number of pesticides whereas the Cucumber moth has not recorded this same level of tolerance. Further reduction in the number of chemicals was based on how they might be developed into an IPM system for this crop considering the appearance of Silverleaf Whitefly.

6.3.2 MATERIALS and METHODS

Treatments			Rate
A	MPV with	10g/L Delta endotoxin	2L/ha
	D-C-Tron plus with	839g/L Petroleum oil	0.16% conc.
	Daisyvite	Protien supplement for calfs	2kg/ha
B	Gemstar with	2 thousand million/ml of Obs	750g/ha
	D-C-Tron plus	839g/L Petroleum oil	0.16% conc.
C	Orthene	750g/kg Acephate	130g/100L
D	Talstar	100g/100L Bifenthrin	60mls/100L
E	Control	Nil spray	

The trial design was a latin square with four chemical treatments and a nil sprayed treatment. Each plot was 12 metres long and comprised of two rows with a plant spacing of 50cm. The application method was by a motorised knapsack sprayer and the volume of water used was at a rate of 833L/ha. This rate was sufficient to give coverage of the leaves to runoff.
Treatment efficacy was evaluated by recording the number of larvae on five plants per plot. These plants were randomly selected at each count. Counts were taken at pre-treatment, 4 day post-treatment and 7 day post-treatment. A second application was applied after the 7 day count and a 4 day post-treatment count after this application was undertaken. No Heliothis were present in this trial.

6.3.3 RESULTS

The number of larvae recorded showed that there was an average of 4.4 larvae per plot at the pre-treatment count, 3.84 larvae at the 4 day post-treatment count and 2.24 larvae at the 7 day post-treatment count.

Table 3. ANOV of the data for the different counts is shown in the following table.

Treatment	Pre-treat. Count	4 day post-treatment count	7 day post-treatment count	4 day post-treatment count x 2 application.
A	7.6	2.80[a]	2.20	7.00[a]
B	5.2	7.60[b]	4.20	14.80[b]
C	3.6	0.80[a]	0.00	0.60[a]
D	2.4	0.20[a]	0.20	0.80[a]
E	3.2	7.80[b]	4.60	7.00[a]
Prob.	0.051	<0.001	0.051	0.007

Numbers followed by the same are not significantly different.

There was not difference between the treatments at the pre-treatment and seven day post-treatment counts.

At the 4 day post-treatment count, the nil spray treatment and the Gemstar with D C Tron plus treatment had significantly higher populations than the other treatments. This difference was not significant at the 7 day count but the trend followed that of the 4 day count.

Following the second application all treatments were significantly better than the Gemstar with D C Tron plus treatment.

6.3.4 CONCLUSION

From these results it can be seen that some of the insecticides tested are effective against Cucumber moth. As these insecticides are also known to be effective against Heliothis in other crops it can be assumed that the if both pests were present then an application of these chemicals should have given control. Of interest is that the biological insecticide Gemstar did not perform as well as the formulation of Bt, another biological insecticide, with similar additives. Also of interest is that Bifenthrin which gave good control of Cucumber moth and is known to control Heliothis has also shown to be effective against Silverleaf Withefly in another study. This will give added support for this chemical to be registered in melon crops.

6.4 SAMPLING METHODS to MONITOR CROPS for PESTS

6.4.1 INTRODUCTION

Monitor insect populations in a crops is a management tool that growers are always looking for. This gives the grower a time frame that is required to spend in each crop and at the same time offering some degree of certainty as to what damage that population will cause. It also helps in deciding if pesticide applications are needed to control these pests which can be a saving on expenditure and a reduction in pesticide residue in their produce.

6.4.2 METHODS

Observations carried out in the field and in nurseries that supply seedlings to growers, showed that insect infestations occur on melon plants in both of these situations. The main pest that has been encountered is the Cucumber Moth {*Diaphania indica* (Saunders)}. The larva of this insect has been identified as a pest of seedlings, field plants as well as the fruit on mature crops. The same does not apply to Heliothis (*Helicoverpa spp.)* as this insect has been identified as a pest of melons from around flowering until harvest with most damage occurring to the fruit. Occasionally they may occur as a pest of growing plants when the numbers are high and then they may cause some economic damage at this stage.

6.4.3 RESULTS

6.4.3.1 Nursery situation

Examination of speedling trays in commercial nurseries and on farm nurseries revealed that Cucumber Moth do attacked these young plants and it is at this stage that severe damage can occur. From these observations it is essential that all trays be inspected daily to note presence or absence of this pests larval stage or evidence by chewed leaves. If control is needed then manual removal of the insects is possible but generally a spray should be applied if one Cucumber Moth larvae per tray is detected. The reason for choosing larvae is that the eggs of this insect are very difficult to see. If one larva is present then it is more than likely that there are other eggs still to emerge as well it is easy to miss the young larvae as they are hard to detect because of their mottled green colour, which camouflages them within the leaf canopy. Young seedlings can be completely destroyed by larvae feeding at this stage.

6.4.3.2 Transplant to two weeks.

In the field, monitoring of crops at least twice per week from planting out of the seedlings until the plants are approximately two weeks old should be undertaken. The main pest at this stage is the cucumber moth larva and as well as determining larval numbers the percentage of leaf damaged should be noted. The percentage should be based on intervals of 25%. Inspection sites should cover the crop edges as well as throughout the crop. A minimum of twenty, randomly selected sites per crop should be inspected though more sites will give a better estimate of the numbers of insects and percentage of the crop damaged. At each site five plants should be inspected. Inspections should concentrate on looking for webbing of the leaves, parts of the leaf material missing (chewed) and especially in the growing point of the plant for larvae. The larvae, green in colour, tend to shelter in the growing point and also under the leaves. The dome shaped eggs, laid singly, greenish in colour are difficult to detect on

the canopy of the plants and this makes egg counts unsatisfactory as to determining levels when controls need to be employed.

6.4.3.3 Two weeks until flowering
Inspections can be reduced to once per week, using the same method as described previous, until the plants start to flower. The reason for this is that if the plants are attacked at this stage little damage occurs. This has been based on results of field trials presented under the section on economic threshold levels.

6.4.3.4 Flowering
As the plants start to flower monitoring needs to include checking around the flowering sites. At this stage inspections should be mainly looking for Heliothis. Heliothis eggs are laid around the young developing fruit, flowers, along the stem and also on the leaves. Therefore these are the main areas to check though only the underside of the young leaves near the growing point need be checked. Control options should be employed when an average of two healthy eggs or 1 larva per 5 plant site is exceeded using the method describe previously. Eggs showing a black colour should not be considered healthy as they are probably parasitised. It has been shown that egg parasitism in Heliothis can reach over 51% in melon crops and up to 80% in other types of crops in this area. With larval counts there is very little tolerance to fruit damage so control options will need to be used when this larval density is reached. Growers will need to consider the effect of these pesticides on bee populations needed for pollination during this period on an individual bases.

6.4.3.5 Fruiting
As the plants grow and the canopy becomes dense it is very difficult to check individual plants and this makes it impractical to get reliable counts. At this stage the scouting method for insect levels should be directed at the fruit. The sample size needs to be changed from five plants at each site to checking all fruit within a radius of two metres at each site. Both of the fruit-chewing insects should be looked for during this period. It is important at this time to check on the underside of the fruit as this is where cucumber moth larvae shelter and feed. At this stage the economic level for insects is dependent on the cost of the control to the expected return. The percent damage can be calculated from the counts undertaken as each fruit recorded with insects present can be considered lost through damage.

6.4.4 CONCLUSION

Random monitoring of crops can be time consuming with uncertain results but with this sampling method for the different growth stages the time involved is measurable and offers a high degree of certainty to the growers that the results from the inspections will improve their management of insect pests. If control is required during any of these stages then a number of insecticides have proven successful in trials including the present recommendation of Endosulfan. Use of other pesticides that have shown good control will be dependent on registration of these by the chemical companies with the NRA.

Growers will also need to consider the effect of pesticide applications if required during the flowering period on the bee populations.

6.5 ECONOMIC THRESHOLDS

6.5.1 INTRODUCTION

Melon plants tend to be very vigorous following transplanting and start to develop runners within a three to four week period. With this rapid plant growth in the early stages it warranted investigation into how much production would be lost if the leaf material was removed during this period. As Cucumber Moth larvae are very active during this period and loss of leaf material is highest at this time, this research investigated removal of different percentages of leaf material on production. Also with this information it would contribute towards the value of the scouting method in the field on making decisions as to when control measures need to be applied.

6.5.2 MATERIALS and METHODS

All leaves on a selected number of plants per plot were manipulated by removing different percentages of leaf material. These percentages varied from 0% to 100% in degrees of 25%. In the 25% removal of leaf, each leaf was cut down the centre along the mid-rib to a point at 90° cut half way down the length of the leaf between the tip and base of the leaf to the mid-rib. Removal of 50% was obtained by cutting along the mid-rib from the tip to the base of the leaf and removing half of that leaf. Removal of 75% following that method outlined in the 50% removal and then removing half of the remaining leaf from the tip end. In all cases the mid-rib of the leaf was left on the remaining part of the leaf. For 100% removal of the leaf the leaf stem was cut at the junction of the leaf stem and its leaf blade.

Trial design. The trial was designed as a Latin square with 5 treatments.

Treatments.	A	Control nil leaf removed
	B	25% of the leaf material removed
	C	50% of the leaf material removed
	D	75% of the leaf material removed
	E	100% of the leaf material removed

The leaves were removed as described above and they were removed on three separate occasions. The first removal of leaf was made when the first true leaves appeared, the second removal of leaf one week later and the third another week after the second. Three plants were selected at random for each of the removal periods.

6.5.3 RESULTS and DISCUSSION

The following results are presented as averages for the number and weight of fruit.

Analyses was performed on the total of the three leaf removal periods for each treatment using average number of fruit and average weight of fruit and the results are presented in table 4. As well, analyses on the total average number of fruit and average weight of fruit was made for the three fruit categories, very green, green and mature, and the results are presented in tables 5 to 7.

Table 4. Average number and weight of total fruit and average number and weight of fruit for each stage of maturity harvested from each treatment totalled for the three leaf removal periods.

	Treatment					
Variable	**A**	**B**	**C**	**D**	**E**	**Probably**
Av. Total fruit	19.20	18.00	17.20	17.40	16.00	0.463
Av. Weight of total fruit	334.2	346.1	338.2	352.6	352.0	0.144
Av. # very green	5.20	5.60	4.40	3.80	3.60	0.424
Av. # green	6.00	5.80	6.20	8.20	10.20	0.056
# mature	8.00^{b}	6.60^{b}	6.60^{b}	5.40^{b}	2.20^{a}	0.010
Av. Weight very green	199	211	199	140	151	0.238
Av. Weight green	278	294	346	375	377	0.158
Av. Weight mature	387^{b}	379^{b}	364^{b}	342^{b}	207^{a}	0.030

Numbers followed by the same letter are not significantly different P = <0.05

The significant differences that showed up between the treatments, when the data is combined for the three leaf removal periods, were for the average number and weight of the mature fruit. This showed that treatment E [all leaf material removed] had significantly lower average number and weight of fruit than all the other treatments.

Table 5. Average number and weight of total fruit and average number and weight of fruit for each stage of maturity harvested from each treatment for the first leaf removal period (first true leaf stage).

	Treatment					
Variable	**A**	**B**	**C**	**D**	**E**	**Probably**
Av. Total fruit	6.00	6.40	6.60	5.00	5.60	0.474
Av. Weight of total fruit	113.5	113.5	105.8	117.3	112.7	0.546
Av. # very green	1.40	2.20	2.00	1.00	2.20	0.515
Av. # green	2.20	2.00	1.80	2.40	2.40	0.898
Av. # mature	2.40^{bc}	2.20^{bc}	2.80^{c}	1.60^{ab}	1.00^{a}	0.039
Av. Weight very green	78.2	62.9	55.7	33.6	70.3	0.333
Av. Weight green	88.8	96.7	115.2	122.4	127.0	0.230
Av. Weight mature	127.4^{b}	136.6^{b}	123.2^{b}	126.4^{b}	73.0^{a}	0.038

Numbers followed by the same letter are not significantly different P = <0.05

The result from the first leaf removal period data show that treatment E [all the leaf material removed] had a significantly lower average number of mature fruit than treatments A [nil leaf material removed], B [25% of the leaf material removed] and C [50% of the leaf material removed]. Treatment D [75% of the leaf material removed] also had significantly less average number of mature fruit than treatment C.

With the average weight of mature fruit, treatment E [all leaf material removed] had significantly lower average weight of fruit than the other treatments.

Table 6. Average number and weight of total fruit and average number and weight of fruit for each stage of maturity harvested from each treatment for the second leaf removal period (one week after first cut).

	Treatment					
Variable	**A**	**B**	**C**	**D**	**E**	**Probably**
Av. Total fruit	7.20^{c}	6.40^{bc}	4.80^{a}	6.00^{abc}	5.20^{ab}	0.011
Av. Weight of total fruit	109.5	113.0	113.9	119.3	115.9	0.221
Av. # very green	2.20	2.00	1.00	1.60	1.20	0.215
Av. # green	2.00	1.80	2.00	3.00	3.00	0.417
Av. # mature	3.00^{c}	2.60^{bc}	1.80^{ab}	1.40^{a}	1.00^{a}	0.014
Av. Weight very green	58.4	77.9	58.3	53.8	62.6	0.527
Av. Weight green	93.7	99.8	100.9	128.2	125.2	0.326
Av. Weight mature	130.6	133.5	103.5	109.1	108.4	0.780

Numbers followed by the same letter are not significantly different P = <0.05

Treatment A [nil leaf material removed] and B [25% of the leaf material removed] had significantly more average total number of fruit than treatment C [50% of the leaf material removed]. Treatment A also had significantly more average total number of fruit than treatment E [all of the leaf material removed].

Treatment A and B had significantly more average number of mature fruit than treatment E and D [75% of the leaf material removed]. Treatment A also had significantly more average number of mature fruit than treatment C.

Table 7. Average number and weight of total fruit and average number and weight of fruit for each stage of maturity harvested from each treatment for the third leaf removal period (two weeks after first cut).

	Treatment					
Variable	**A**	**B**	**C**	**D**	**E**	**Probably**
Av. Total fruit	6.00	5.20	5.80	6.40	5.20	0.456
Av. Weight of total fruit	111.2	119.6	118.5	116.0	123.4	0.202
Av. # very green	1.60	1.40	1.40	1.20	0.20	0.201
Av. # green	1.80^{a}	2.00^{a}	2.40^{a}	2.80^{a}	4.80^{b}	0.024
Av. # mature	2.60	1.80	2.00	2.40	0.20	0.133
Av. Weight very green	61.9^{b}	70.4^{b}	84.7^{b}	52.6^{ab}	17.6^{a}	0.043
Av. Weight green	95.4	97.6	129.9	124.6	124.3	0.451
Av. Weight mature	128.9^{b}	109.3^{b}	137.2^{b}	106.7^{b}	25.4^{a}	0.012

Numbers followed by the same letter are not significantly different P = <0.05

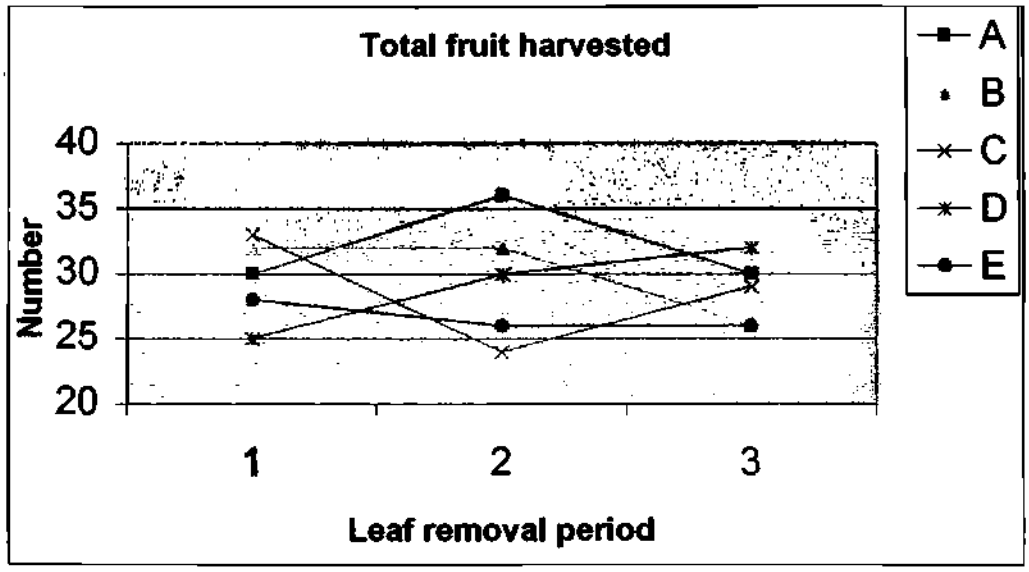
From the third leaf removal period treatment E [all leaf material removed] had significantly more average number of green fruit than all the other treatments.

Treatment E had a significantly lower average weight of very green fruit than treatments C [50% of the leaf material removed], B [25% of the leaf material removed] and A [nil leaf material removed]. Treatment E also had a significantly lower average weight of mature fruit than all the other treatments.

In the following figures the totals of three plants per leaf removal period are used to show the differences between the treatments for the different leaf removal periods.

In figure 1 the comparisons of the total number of fruit harvested for each treatment over the three leaf removal periods can be seen. This shows the non-significant difference between the treatments at the first leaf removal period and at the third leaf removal period while there was a significant difference between the treatments for the second leaf removal period. In this period the difference in the total number of fruit harvested between treatment A [nil leaf removed] and treatments C [50% leaf removed] and E [all leaf removed] can be seen, also treatment B [25% leaf removed] had significantly more fruit than treatment C.

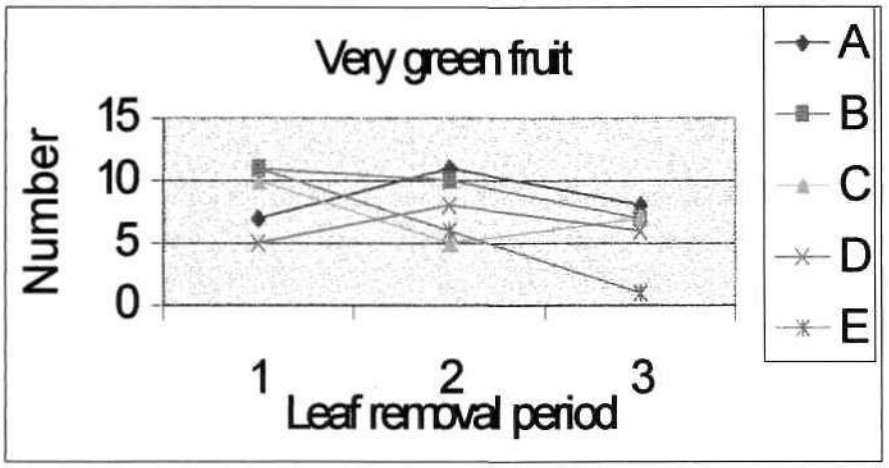
Figure 1. Total number of fruit harvested for each treatment across the three leaf removal periods.



In figures 2 to 4 the total number of fruit harvested has been separated into the three different fruit categories, very green, green and mature.

From figure 2 the difference between the treatments in the average number of fruit harvested for the very green fruit maturity stage is shown. Even though there is no significant difference between the treatments at any of the three leaf removal periods there is a general decrease in some of the treatments as the lateness of the leaf removal period increases.

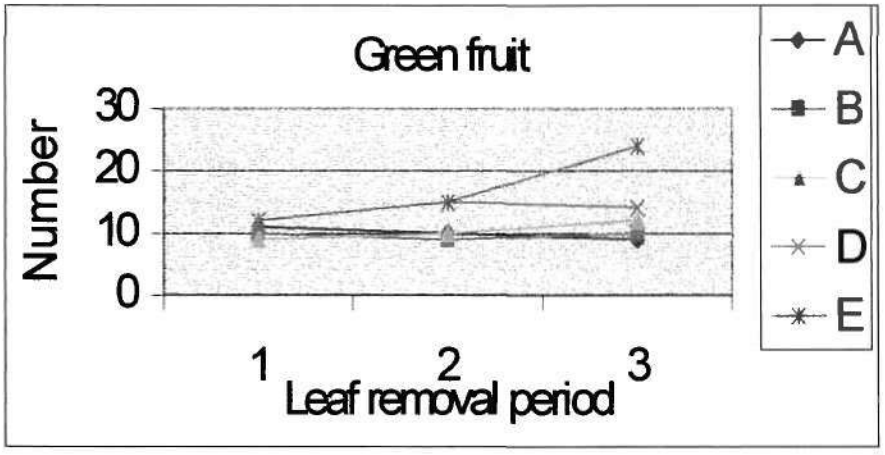
Figure 2. Total number of fruit harvested in the very green maturity stage for each treatment across the three leaf removal periods.



Looking at figure 2 the continual decline in treatment E [all leaf removed] from the first leaf removal period through to the third leaf removal period could indicate that the fruit set occurred during the same period. As the plants matured then there would be a reduction in the number of very green fruit harvested.

Figure 3 shows the total number of green fruit stage of maturity for each treatment over the three leaf removal periods. From this figure it shows that treatment E [all leaf removed] had significantly more green fruit at the third leaf removal period than all the other treatments. This difference could suggest that removal of all of the leaf material from these plants has delayed the maturity of these plants.

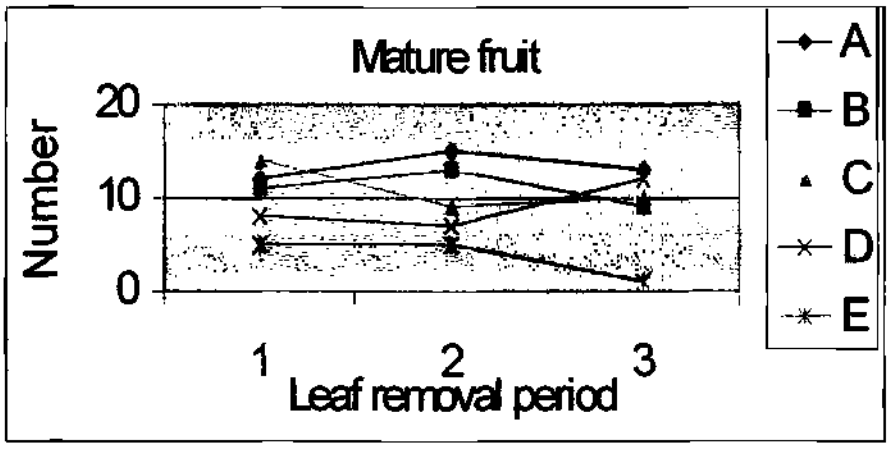
Figure 3. Total number of fruit harvested in the green maturity stage for each treatment across the three leaf removal periods.



In figure 4 it shows the total number of mature fruit harvested for each treatment over the three leaf removal periods. From this figure it shows the significant difference between treatment C [50% leaf removed] had significantly more average number of fruit at the first leaf removal period than treatments D [75% leaf removed] and E [all leaf removed]. Treatments A [nil leaf removed] and B [25% leaf removed] also had significantly more fruit than treatment E. At the second leaf removal period treatment A had significantly more fruit than treatments C, D and E. Treatment B also had

significantly more fruit than treatments D and E. At the third leaf removal period treatment E had very low numbers of fruit but this difference was not significant.

Figure 4. Total number of mature fruit harvested for each treatment across the three leaf removal periods.



In the following sets of data the treatments are compared separately over the three leaf removal periods.

Table 8. Average number and weight of total fruit and average number and weight of fruit for each stage of maturity harvested over the three cutting periods for treatment A.

Variable	Time of cutting: First true leaf stage	1 week later	2 weeks after first cut	Probably
Av. Total fruit	6.00[a]	7.20[b]	6.00[a]	0.026
Av. Weight of total fruit	113.5	109.5	111.2	0.830
Av. # very green	1.40	2.20	1.60	0.66
Av. # green	2.20	2.00	1.80	0.922
Av. # mature	2.40	3.00	2.60	0.801
Av. Weight very green	78.2	58.4	61.9	0.560
Av. Weight green	89	94	95	0.977
Av. Weight mature	127.4	130.6	128.9	0.873

Numbers followed by the same letter are not significantly different P = <0.05

In treatment A [nil leaf removed], the average total number of fruit harvested from the second leaf removal period had significantly more fruit than the other two leaf removal periods.

Figure 5 shows the difference in the number of fruit harvested for total and the three separate fruit ripeness categories at the three leaf removal periods in treatment A.

Figure 5. Number of fruit harvested for total, very green, green and mature stages of fruit maturity for treatment A across the three leaf removal periods.

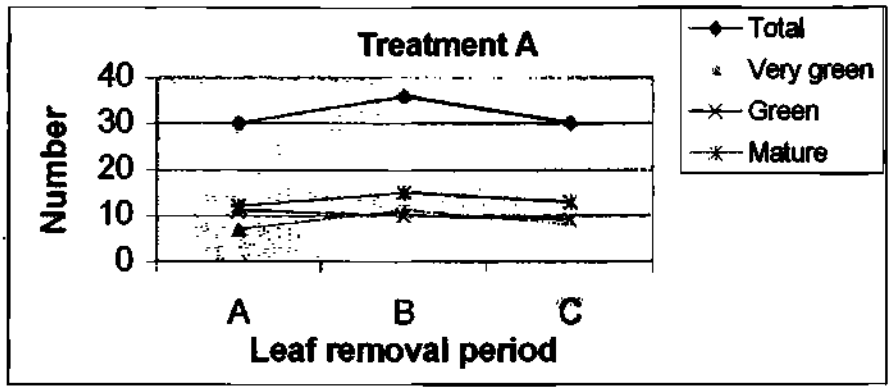


Table 9. Average number and weight of total fruit and average number and weight of fruit for each stage of maturity harvested over the three cutting periods for treatment B.

Variable	Time of cutting: First true leaf stage	1 week later	2 weeks after first cut	Probably
Av. Total fruit	6.40	6.40	5.20	0.073
Av. Weight of total fruit	113.5	113.0	119.6	0.602
Av. # very green	2.20	2.00	1.40	0.492
Av. # green	2.00	1.80	2.00	0.940
Av. # mature	2.20	2.60	1.80	0.471
Av. Weight very green	62.9	77.9	70.4	0.740
Av. Weight green	96.7	99.8	97.6	0.859
Av. Weight mature	136.6	133.5	109.3	0.443

There were no significant differences between the leaf removal periods for any of the variables when the plants had 25% of their leaf material removed.

Figure 6 shows the slight variations between the numbers for total, very green, green and mature stages for treatment B over the three leaf removal periods.

Figure 6. Number of fruit harvested for total, very green, green and mature stages of fruit maturity for treatment B across the three leaf removal periods.

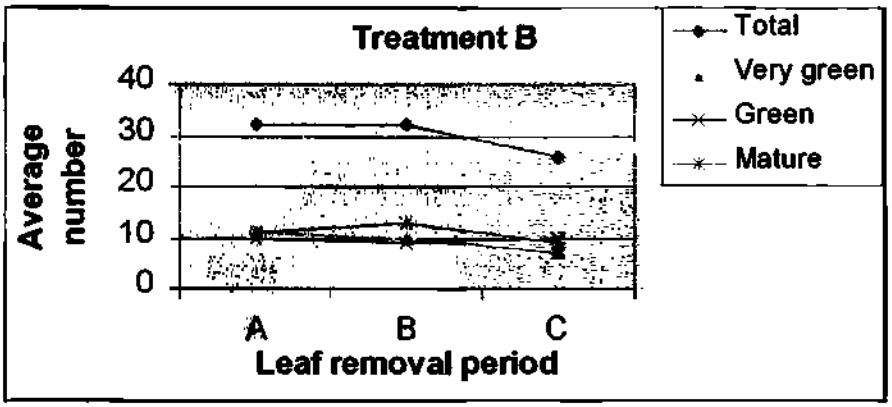


Table 10. Average number and weight of total fruit and average number and weight of fruit for each stage of maturity harvested over the three cutting periods for treatment C.

Variable	Time of cutting: First true leaf stage	1 week later	2 weeks after first cut	Probably
Av. Total fruit	6.60	4.80	5.80	0.090
Av. Weight of total fruit	105.8	113.9	118.5	0.182
Av. # very green	2.00	1.00	1.40	0.251
Av. # green	1.80	2.00	2.40	0.634
Av. # mature	2.80	1.80	2.00	0.296
Av. Weight very green	55.7	58.3	84.7	0.251
Av. Weight green	115.2	100.9	129.9	0.435
Av. Weight mature	123.2	103.5	137.2	0.327

There were no significant differences between the leaf removal periods for any of the variables when the plants had 50% of their leaf material removed.

Figure 7 shows the slight variations between the total, very green, green and mature stages for treatment C over the three leaf removal periods.

Figure 7. Number of fruit harvested for total, very green, green and mature stages of fruit maturity for treatment C across the three leaf removal periods.

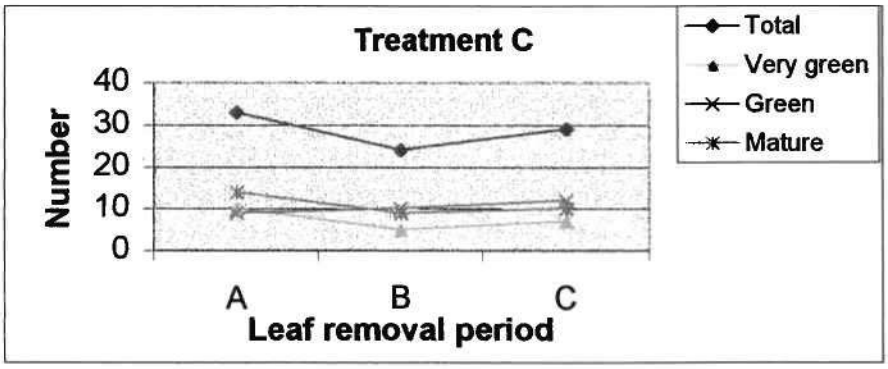


Table 11. Average number and weight of total fruit and average number and weight of fruit for each stage of maturity harvested over the three cutting periods for treatment D.

Variable	Time of cutting: First true leaf stage	1 week later	2 weeks after first cut	Probably
Av. Total fruit	5.00	6.00	6.40	0.174
Av. Weight of total fruit	117.3	119.3	116.0	0.868
Av. # very green	1.00	1.60	1.20	0.748
Av. # green	2.40	3.00	2.80	0.820
Av. # mature	1.60	1.40	2.40	0.240
Av. Weight very green	34	54	53	0.677
Av. Weight green	122.4	128.2	124.6	0.581
Av. Weight mature	126	109	107	0.820

There were no significant differences between the leaf removal periods for any of the variables when the plants had 75% of their leaf material removed.

In figure 8 it shows the variations between the number of fruit for total, very green, green and mature stages for treatment D over the three leaf removal periods.

Figure 8. Number of fruit harvested for total, very green, green and mature stages of fruit maturity for treatment D across the three leaf removal periods.

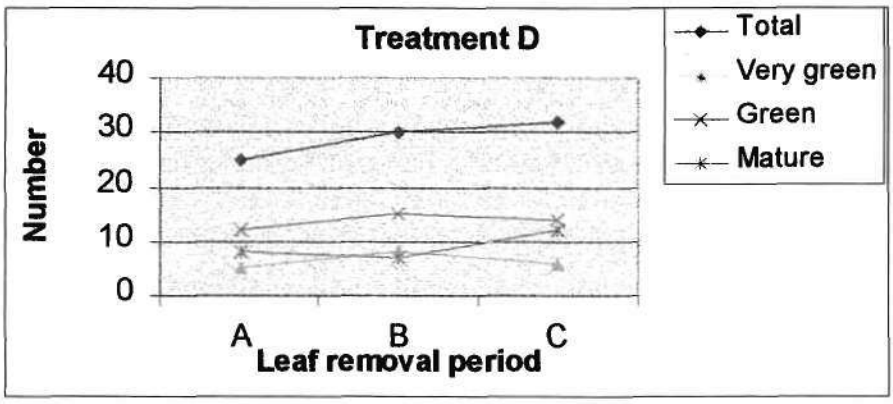


Table 12. Average number and weight of total fruit and average number and weight of fruit for each stage of maturity harvested over the three cutting periods for treatment E.

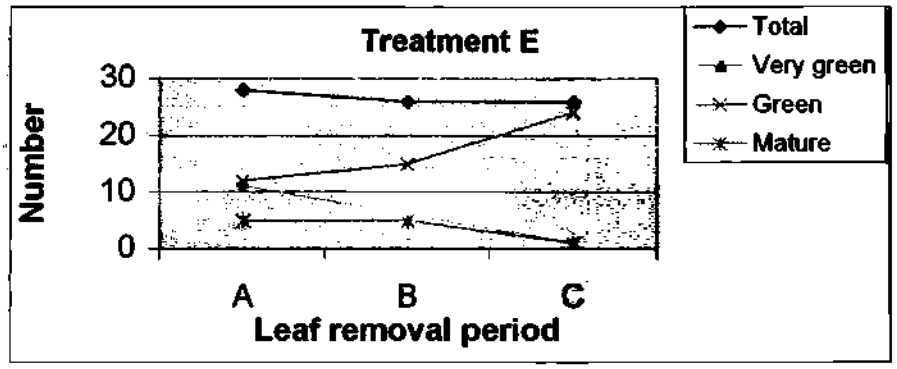
	Time of cutting			
Variable	**First true leaf stage**	**1 week later**	**2 weeks after first cut**	**Probably**
Av. Total fruit	5.60	5.20	5.20	0.834
Av. Weight of total fruit	112.7	115.9	123.4	0.129
Av. # very green	2.20	1.20	0.20	0.080
Av. # green	2.40[a]	3.00[a]	4.80[b]	0.007
Av. # mature	1.00	1.00	0.20	0.214
Av. Weight very green	70.3	62.6	17.6	0.105
Av. Weight green	127.00	125.20	124.30	0.513
Av. Weight mature	73	108	25	0.143

Numbers followed by the same letter are not significantly different P = <0.05

In treatment E [all of the leaf material removed], the average total number of green fruit harvested from the third leaf removal period had significantly more fruit than the other two leaf removal periods.

In figure 9 it shows the variations between the number of fruit for total, very green, green and mature stages for treatment E over the three leaf removal periods.

Figure 9. Number of fruit harvested for total, very green, green and mature stages of fruit maturity for treatment E across the three leaf removal periods.



6.5.4 CONCLUSION

From the results in this trial it is not clear-cut that removal of leaf material early in plant growth has an affect on production. In the nil leaf remove treatment (A) where the plants in the three leaf removal periods are of the same age, there was a significant difference in the total number of fruit harvested at the second leaf removal period. Also from the results there was no significant difference between the treatments in the average total number of fruit harvested. In this trial the average total number of fruit harvested ranged from 19.2 in the nil leaf removed treatment to 16.0 in the treatment with all leaf removed.

The results do show that the time of plant manipulation had no affect other than in treatment E [all leaf removed] where the average number of green fruit harvested was significantly higher in the third leaf removal period. As mentioned earlier the control treatment did show a significant difference between the leaf removal periods.

A trend that can be seen in the results, is that the removal of all of the leaf (treatment E) did cause a significant reduction in the number of mature fruit harvested compared to the other treatments. This also showed up in the lower weight of these fruit. This suggests that removal of leaf material from the plants can cause a delay in fruit maturity and size. If harvesting in this trial was delayed then this fruit may have developed to maturity with no difference from the nil leaf removed plants (treatment A) in the number of mature fruit. A problem with having a delay is that the longer the plants are in the field the more exposure they are subjected to by pests, especially diseases.

Plate 1. Trial area showing age of plants at the third leaf removal period.

Note how much growth has occurred within a two - three week period after transplanting.

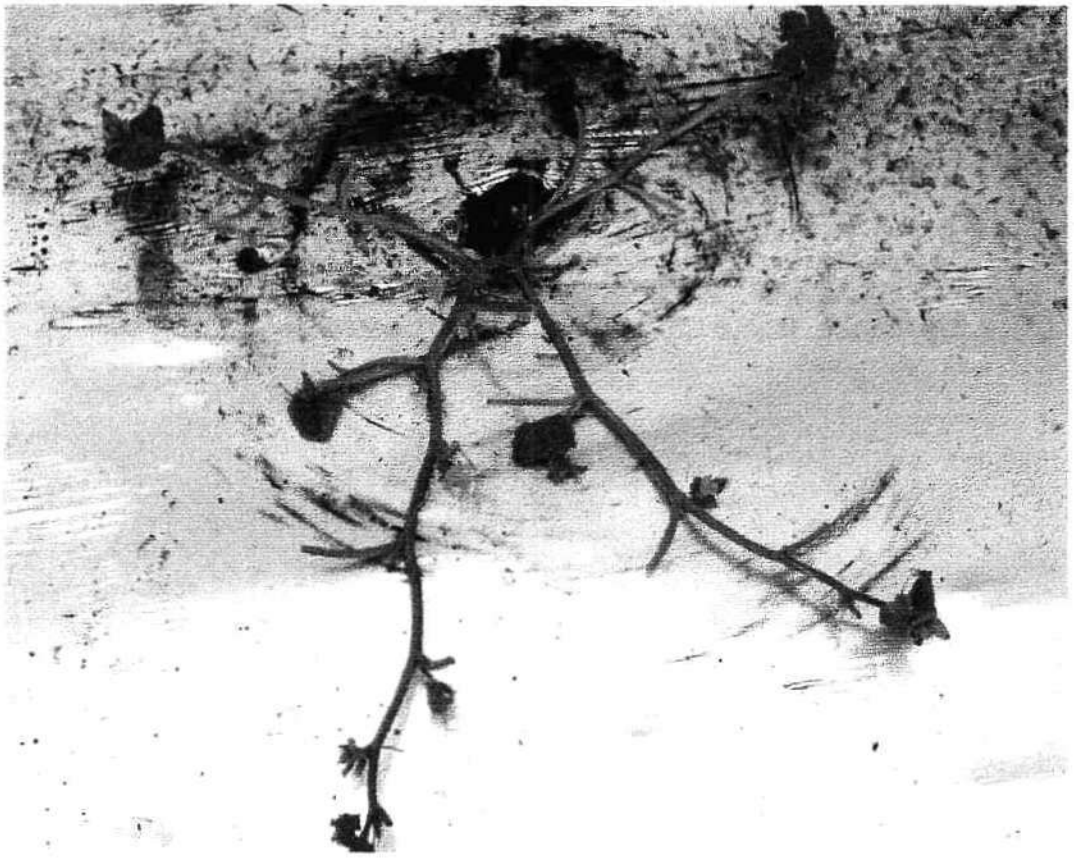
Plate 2. Plants at the third leaf removal period showing extent of leaf removed with 0% leaf removed, Treatment A.

Note all leaves are still intact and plant growth healthy.

Plate 3. Plants at the third leaf removal period showing extent of leaf removed with 50% leaf removed, Treatment C.

Note that all of the leaves were manipulated except those still developing at the growing points. The leaf material was removed so that the midrib of the leaf was still intact.

Plate 4. Plants at the third leaf removal period showing extent of leaf removal with 100% leaf removed, Treatment E.



Note only the growing tips were not removed in this treatment.

6.6 RECOMMENDATIONS

The following activities are recommended:

1. The registration of the following pesticides Orthene, Bifenthrin and MPV is warranted to replace the present ineffective pesticides.. The oil, DC Tron plus, already has minor use approval to use in these crops and no registration is required for the milk supplement.

2. Further studies should be carried out to determine if loss of leaf at a later stage in the plant growth cycle causes a reduction in production. From the present results it could indicate that there is an over use of pesticides in controlling Cucumber Moth in the plant's vegetative stage. Evaluation of disease pressure as a result of delaying maturity should be considered in any future studies.

3. The use of the scouting system should be tested in other cucurbit crops as the present model has only been evaluated in rockmelons. The model also needs to be evaluated to incorporate other insect pests mainly Silverleaf Whitefly and Aphids. The possibility of using this model in monitoring diseases at the same time should be evaluated.

6.7 ACKNOWLEDGEMENTS

The author is grateful for the technical assistance of Mr. A. Horsfield and Mr. S. Boreel also for the assistance of Mrs. D. Galvin and Miss. T. Bettridge with field support and laboratory management. The support provided by Mr. I. Kay and Dr D. Murray is also acknowledged. Thanks is also extended to staff at the Ayr Research Station for crop management of trials.

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7. TECHNOLOGY TRANSFER

1. Information developed from this project was disseminated widely to the QDPI extension officers and crop consultants in the Dry Tropics region and to grower organisations.

2. Grower meetings in Ayr and Bowen were attended regularly and presentations were given outlining the outcomes of the project at that point in time.

3. Registration of the fungicide Amistar (Azoxystrobin) for the control of downy mildew in cucurbits was achieved with the support of the data from this research project.

4. Results were presented in a paper at the 1999 Australasian Plant Pathology Conference held in Canberra.

5. An article on the control of downy mildew was published in the Queensland Country Life. Other results have been distributed on several flyers in the Dry Tropics. These results have been published in "The Plant Path Page" and the "Vegie Patch" both are widely distributed newsletters in the Dry Tropics and Burnett region.

6. Results from the project are being prepared for publication. At least one publication on downy mildew will be written for a refereed journal.

8. RECOMMENDATIONS

7.1 Downy mildew

Future research should include a continuation of the phenylamide resistance monitoring program, to determine if/when phenylamides should be re-incorporated into spray programs in this district. The efficacy and systemic activity of low concentrations of CGA245704 also warrants further investigation. Field evaluations of the synergistic interaction between dimethomorph (Acrobat®MZ) and Synertrol®Oil should also be completed.

The following activities are recommended:

1. Phenylamide fungicide use (Ridomil®MZ, Galben®M, Recoil®, Fruvit®) should be discontinued in the Burdekin/Bowen district for control of *P. cubensis*.

2. A phenylamide-resistance monitoring program of *P. cubensis* populations should be continued in this district, to determine if/when phenylamides should be re-introduced into spray programs.

3. *P. cubensis* isolates from the Burdekin/Bowen district should continue to be collected and maintained in a long-term culture collection as a resource for use in future fungicide resistance screening studies.

4. Protectant fungicides (mancozeb, chlorothalonil) should form the basis of spray programs (application at 7 day intervals). Systemic fungicides should be used sparingly (not more than 4 sprays per crop), in rotation, and timed to combat early infections following periods of rain or heavy dew.

5. The systemic activity of low concentrations (≤0.025 g/L) of CGA245704 warrants further investigation. The synergistic interaction between Synertrol® Oil and dimethomorph should also be evaluated in the field.

7.2 Gummy stem blight

This section of the project has demonstrated the improved efficacy of azoxystrobin in the control of downy mildew and gummy stem blight of melons. Crop Care Australasia, the company distributing this product have indicated registration for use on melons should be in place late in 1999. Other chemicals in the strobilurin group are currently being assessed for the control of diseases in other crops eg. leaf spot in bananas. It is highly likely they will also prove effective in the control of foliar diseases of melons.

7.3 Fruit chewing caterpillars

1. The registration of the following pesticides Orthene, Bifenthrin and MPV is warranted to replace the present ineffective pesticides.. The oil, DC Tron plus, already has minor use approval to use in these crops and no registration is required for the milk supplement.

2. Further studies should be carried out to determine if loss of leaf at a later stage in the plant growth cycle causes a reduction in production. From the present results it could indicate that there is an over use of pesticides in controlling Cucumber Moth in the plant's vegetative stage. Evaluation of disease pressure as a result of delaying maturity should be considered in any future studies.

3. The use of the scouting system should be tested in other cucurbit crops as the present model has only been evaluated in rockmelons. The model also needs to be evaluated to incorporate other insect pests mainly Silverleaf Whitefly and Aphids. The possibility of using this model in monitoring diseases at the same time should be evaluated.

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